Guiding questions for increasing the generation of product ideas to meet changing needs (QuChaNe)

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ABSTRACT

One of the reasons why products are replaced is as a consequence of changes in the users' personal life. Adaptable or upgradable products have the advantage that, to some extent, they counter dissatisfaction in products that still work by improving functionalities or adding new ones. So, to develop adaptable products, designers have to consider the potential changes in the users' personal life during the earlier phases of the design process. This work presents a list of scenario creation-type questions which promote design ideas that consider changing needs (QuChaNe). To check the effectiveness of this list of questions, an experiment with 28 designers was conducted. In the experiment, the designers applied the proposed list of questions to generate ideas for products. The same task was carried out using no prescribed method as a control group for comparison purposes. The results show that the use of the list of scenario creation questions leads to the generation of more ideas for changing needs and with higher quality. This finding implies that designers could use these questions to generate ideas for changing needs as a previous task before applying design for adaptability (DFA) or upgradability (DFU) methods. This would ultimately lead to more adaptable products.

Keywords: scenario creation questions, idea generation, changing needs, creativity

1. Introduction

As users' lives change, certain products are no longer used because they are poorly adapted to new needs. For designers, using methods that allow them to design products considering the future needs of users may result in products' lifetime extension. Although there are different creative methods, in this study we will focus on question-based methods to promote divergent thinking and thus encourage the generation of ideas. The following sections summarise the methods for generating ideas based on questions and explain the relevance of designing for changing needs. Sections 1.3 and 1.4 present existing checklists to identify user and contextual needs and identify research gaps and research questions.

1.1. Question based methods for idea generation

Designing is a problem-solving process that starts with a need and ends with a solution (Asimow 1962). Roozenburg and Eekels (1995) established four stages in this problem-solving design process: analysis, synthesis or idea generation, evaluation and decision-making. The topic of this work is the idea generation stage. During idea generation, designers use their individual background knowledge and experience, sources of inspiration and methods to encourage creativity and come up with ideas. There are different types of inspirational sources that vary from internal to external stimuli. Internal stimuli consist of mental imagery or verbal information in the

person's or design team's working or long-term memory. External stimuli are any kind of visual, verbal, audible or tangible entity in the surroundings (Eastman 2001).

Methods to support designers during idea generation are usually categorised into intuitive, e.g. brainstorming and its variants (Parnes 1992; Van der Lugt 2000; VanGundy 1983; Vehar et al. 1999), the Why method (De Bono 2010), random input (Davis 1999), synectics (Gordon 1961) and logical, e.g. TRIZ (Altshuller 1999), in addition to methods that rely on databases. Another way to classify them is according to whether the stimulation is originated internally or externally (López-Mesa et al. 2011). Examples of methods that promote internal stimulation include Brainstorming and those that use external stimuli would be Direct Analogy (Davis 1999), Random Input (Vehar et al. 1999) or question-based methods such as SCAMPER (Eberle 1971).

This paper is focused on question-based methods for generating ideas. Questions are applied in the design process for different purposes and influence design thinking, particularly during idea generation (Eris 2004). Several design problem analysis and problem-solving methods are based on asking questions. The five W's and an H method, attributed to Aristotle, is a general question asking method in which the questions who, what, where, when, why and how are applied to the problem or situation (VanGundy 1985). Osborn (1953) proposed the "73 Idea-spurring questions" that were later reorganised by Eberle (1971) into the SCAMPER method. In SCAMPER, designers use predefined questions classified into seven categories: Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate and Reverse to stimulate the generation of ideas. The Why Questioning Method of Lateral Thinking (De Bono 2010) successively raises a why question on a given answer. 'What if' is another question-based method that consists in a mental simulation reasoning used when practical experimentation is not possible (Trickett and Trafton 2007). In the design field, the 'what if' reasoning is used during the solution generation stage of any co-evolution episode and to evaluate solution alternatives (Wiltschnig et al. 2013). VanGundy (1985) also proposed the use of a general checklist of questions as a stimulus to generate new problem perspectives. This list includes questions such as "What else could help you deal with this situation and why?" and "How is this situation related to others you have dealt with?" The Quarantee checklist (1992) provides a list of questions that aims to define the design problem by considering all the objectives of the problem and also to generate ideas and to assess them.

Eris (2004) developed a question-driven design thinking model that distinguishes between two types of questions: Low-Level Questions (LLQs) and High-level Questions (HLQs), which comprise Deep Reasoning Questions (DRQs), related to convergent thinking, and Generative Design Questions (GDQs), related to divergent thinking. Low-level questions are used to clarify something or to obtain missing information. For instance: "This part is disassembled with no tools, right?" High-level questions imply higher levels of reasoning. For example, "What would be the ideal way to adapt to the user's height?" is a Generative Design Question (GDQ) and encourages thinking about many ideas and not just accepting the first obvious one. Generative Design Questions are classified into Enablement; Method Generation, Proposal or Negotiation; Scenario Creation and Ideation. In Scenario Creation Questions the questioner wishes to construct scenarios involving the question concept to investigate possible outcomes. In the question "What if the device was used on a child?" the questioner wants to generate as many possible outcomes as possible from the scenario "the device is used by a child" (Eris 2003).

Improving idea generation is important to avoid fixation, a behaviour that describes people's tendency to only conceive a typical use or function for a particular object (Duncker 1945; Maier 1931). In the design field, it is defined as the unconscious tendency to inappropriately reuse parts/principles from previously seen examples during idea generation (Jansson and Smith 1991). Design fixation describes a negative transfer of knowledge between a source and the target (Smith et al. 1993). Thus, creative methods, including question-based methods for divergent thinking, are examples of approaches that encourage people to think more creatively and avoid fixation. There is little empirical evidence about the impact of questions during idea generation. One study identified all the verbal questions raised during the design discourse in a multidisciplinary group of seven students. The results show that the formulation of high-level questions, and especially the generative ones, seems to facilitate sequences of cognitive moves triggered by reflection on dissatisfaction with the current situation. This reflection can act as a resistance to design fixation (Cardoso et al. 2016).

1.2. Designing products for users' changing needs

Users' needs are defined as "problems that hinder users in achieving their goals in a specified context of use" (Kujala 2008). A product may meet a user's needs, but if these needs change over time, the product might not satisfy the new needs or be designed to be upgraded. In this article, a user's need that changes over time is considered a changing need. In fact, Van Nes and Cramer (2006) noted that one of the reasons why products are replaced is the contextual or situational influence which entails changes in the user's personal life. Examples of this could be a user who needs to replace a TV remote control because of impaired vision or replacing a clothes horse because the user has moved to another house and it does not fit in the new place. Pialot et al. (2017) also found that more than 50% of electrical household appliances thrown away were not defective. Throwing away products that still work is not compatible with sustainable development (WBCSD 2000). Consequently, it is important to develop production and consumption models that rationalise and maintain the value of materials (The MacArthur Foundation 2013).

Companies can benefit from designing products that are easily adapted to future requirements (Engel et al. 2017). Upgradable artefacts are defined by Shimomura et al. (1999) as "artefacts that can upgrade their functionality during operation and/or at remanufacturing stage". The concept comprises products "with certain fixed structural characteristics which discontinuously evolve through the integration of functional changes several times during their life" (Pialot et al. 2017). For Linton and Jayaraman (2005), design for upgradability and adaptability consists in "designing the product to continue being useful under changing conditions by improving the quality, value, and effectiveness or performance". Examples of such products would be initiatives like modular smart phones or furniture that adapts to the growth of the children. Upgradable products can then, with certain limitations, be adapted to changes, including new functions and improved performance of existing functions. Upgrading products is a good way to counter dissatisfaction in products that still work, since it improves functionalities or adds new ones. It is also interesting for industry since it implies loyalty. At the same time, it is one of the models with the strongest positive impact on the rationalisation of materials use (Khan et al. 2018; Pialot et al. 2017).

There is an extensive field of research concerning the study and development of design methods for adaptable products. To mention some of them and the different designations employed, there are design for adaptability (DFA) methods, as in Engel et al. (2017); design for upgradability methods (DFU) (Xing and Belusko 2008), modular design methods, as in Gershenson et al. (2004); product platform and family design methods, as in Simpson et al. (2001); and mass customised design, as in Siddique and Boddu (2004). The usual inputs for these methods include modules, interactions, design constraints and plan of changes.

1.3 Checklist to identify users' needs

As said, changes in the user's personal life are a cause of product replacement. User needs can be identified through user-centred and participatory design approaches (Land 1982; Wilkinson et al. 2014). There are a number of checklist-type methods for identifying contextual needs in product design, as in Green et al. (2006). This checklist uses the question format, allowing the designer to identify the needs. The authors classify the contextual needs into different categories, namely, how (usage application), where (usage environment) and who (customer characteristics). Each of these categories is divided into different contextual factors. For example, in the category *usage environment*, in the section referring to the context factor Weather/climate, one of the questions is "What weather/climate will the product be exposed to? We also find two questions in the category *customer characteristics*. The first one is "Does the user have any physical condition that may cause difficulty performing the task? (Strength, control, range-of-motions, vision)", which belongs to the factor Physical ability. The second one is "Are there any cultural practices or expectations related to this product?", which belongs to the factor Relevant customs and practice. If we analyse these questions, we can see that, while they help to detect a need that may affect the design, the questions do not centre attention on the possibility that these needs will change over time. For example, they do not focus on the designer thinking about whether a change (either temporary or permanent) in the user's physical capabilities might affect the use of the product.

Telenko et al. (2009) and Telenko and Seepersad (2010, 2014) propose a checklist to help increase the durability of the products and reduce their energy consumption based on user needs and experiences. This checklist is divided into user factors such as number of users; replacement and maintenance programmes; situational factors like

altitude, temperature, humidity, precipitation, wind, and solar insolation, and product factors related to functionality, such as upgradeability. The method consists in applying brainstorming sessions about each item (number of users, temperatures, etc.) on this checklist to stimulate ideas on environmental design questions and on customer needs. This method helps to analyse the context of use and emphasises environmental aspects of the phase of use. However, none of the elements on this checklist focus on the possibility that the needs could change over time.

1.4 Need to encourage ideas for changing needs

So**,** although there are methods for identifying the contextual needs of a design, there are no specific question-based methods to aid designers to think about future changes in the user's personal life. However, identifying these needs in the earlier stages of the design process could lead to upgradable products with a higher value. This work focuses on scenario creation questions, as these questions help to promote future ideas and suggestions that have still not been considered. Although the design-thinking patterns that lie behind the use of generative questions during the design process are still being studied, this research has been driven by existing findings. Therefore, the aim of the present work is to help designers come up with ideas that take changing needs into account, by using a predefined list of scenario creation questions. The key characteristic of ideas for changing needs is that they comprise a representation of a concept that can overcome the reason for replacing the product. For instance, a children's bed with a structure that can be extended to adapt to the growth of the user is an idea for a changing need. Hence the following research questions will be addressed:

RQ1: Does applying a list of predefined scenario creation questions lead to the generation of more ideas that consider changing needs?

RQ2: Are the ideation effectiveness of the process (quantity and variety) and the creativity of the final selected concept (novelty and quality) when the predefined scenario creation questions are applied similar to when no prescribed method is applied?

2. Formulating questions to generate ideas for changing needs

To address the research objective, the first step was to draw up a list of questions that would help to obtain ideas about changing needs. These questions have been generated through personal reflection by the authors about contextual needs that may change over time. These questions are classified considering the contextual needs categories used in the literature. Accordingly, these guidelines were considered to generate the list:

- They should be high-level, generative questions, specifically of the scenario creation type defined by Eris (2004).
- They should refer to possible future changes in the user's lifestyle indicated by Van Ness and Cramer (2006) and to functional upgradability as defined by Shimomura et al. (1999).
- They should refer to categories that are related to the user (who), the environment (where) and the functionality (how) (Green et al. 2006; Telenko et al. 2009; Telenko and Seepersad 2010, 2014).

Considering these premises, four topics or categories have been identified to which the questions would refer: number and size of the user (S) and user capacities (C), technological updates and changes (U) and, finally, the product environment (E). For instance, in a pushchair for kids the product could be used to carry one or two children, for example, a 4-month-old baby or one aged 12 months. The person who pushes it might suffer a disability in his/her hand. Maybe the user needs to use the pushchair on an uneven terrain or perhaps a broken part needs to be replaced (Royo 2016).

Table 1 shows the list of scenario creation questions proposed to encourage thinking about ideas for changing needs, hereafter identified as QuChaNe. The questions are arranged according to the four categories with a coding scheme. Thus, this list of questions differs from that of Telenko et al. (2009) and Telenko and Seepersad (2010, 2014) in that it uses scenario creation questions (Eris 2004) to stimulate thinking about changes that may occur during use. For example, regarding the number of users, the question is: "Could the number of people using the

product simultaneously increase or decrease?" The questions proposed in Table 1 make the designer think about possible changes in use that may occur in the future and not only in the knowledge of the design context, as occurs with the questions of Green et al. (2006). To apply them, the designer should generate possible outcomes for each of them in relation to the design problem at hand. These questions are intended to cover most of the changing needs with a relatively small number of questions. They are not intended to replace the initial function and requirement formulation of a design brief, but are proposed as a complementary method to help think about new changing needs and to encourage the generation of ideas for changing needs.

Table 1. Scenario creation questions to help designers to identify changing needs during idea generation (QuChaNe)

CATEGORY	**Code**	**Scenario creation questions** (QuChaNe)
Number and size of users	S1	*Could the number of people using the product simultaneously increase or decrease?*
	S2	*Could the product adapt to a change in the size of the user?*
PERCEPTUAL capacities	C1	*Could the product be used properly even though users' hearing/touch/visual capacities diminish?*
PHYSICAL capacities	C2	*Could the product be used properly even though users have problems with their motor functions?*
	C3	*Could the product be used properly even though users' physical capacities can improve/worsen with age?*
	C4	*Could the product be used properly even though users have different physical strengths?*
Cognitive functions (memory, attention, reasoning, etc.)	C5	*Could the product be used properly even though users' cognitive functions can improve/worsen with age?*
	C6	*Could the product be used properly even though users' cognitive functions diminish?*
UPDATES, TECHNOLOGICAL CHANGES	U1	*Could there be technological innovations to be included in the product?*
	U2	*Does the product have components that are easy to change if they break down?*
	U3	*Could new functions be added to the product?*
ENVIRONMENT	E1	*Would the product need to be ready to come into contact with different kinds of surfaces?*
	E2	*Would the product prove functional in different climates and weather conditions?*
	E3	*Would the product prove functional in different habitats or places?*
	E4	*Would the product be understood and well accepted by different cultures?*

3. Experimental procedure

This section describes the experiment conducted to answer the two research questions.

3.1. Organisation, material and survey

The experiment was carried out with 28 final-year students of the Bachelor's Degree in Industrial Design and Product Development Engineering of the Universitat Jaume I of Castellón (Spain). Participants consisted of 8 males and 20 females aged between 21 and 39, with a mean age of 24 years. A design task was defined, which involved the participant designers individually solving two design problems in two different ways: the first by applying no prescribed method (NM) and the second by applying QuChaNe shown in Table 1. The approach adopted involves comparing the design outcomes achieved when a particular method is applied with the outcomes obtained when no method is prescribed. This strategy has been used in previous research when the influence of a design method is analysed, such as in Chulvi et al. (2012). The experiment was conducted in a single day. The participants met at the same time in a room furnished with tables and chairs and with drawing materials where the experiment was scheduled to take place (Figure 1).

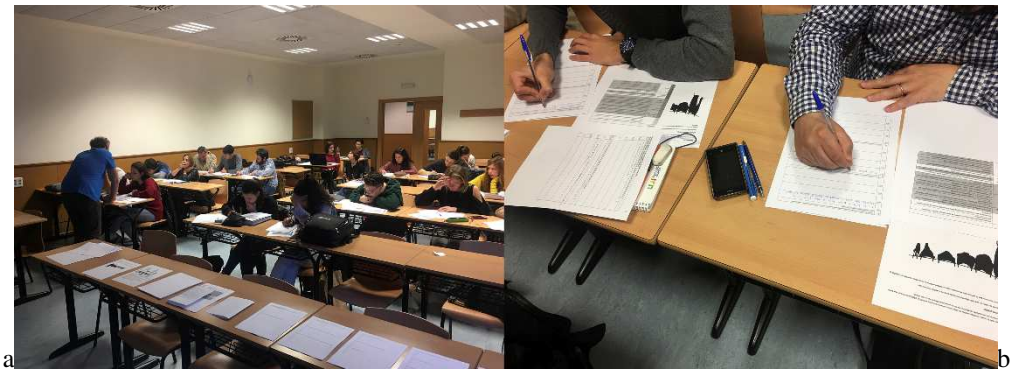
a  b

Figure 1. a) Room with the participants in the experiment; b) Material provided

First of all, the objective of the experiment was explained to them and they were randomly divided into two groups of the same size (groups 1 and 2) without leaving the room. Then, all of them worked individually on two different problems that consisted in coming up with as many ideas as possible about two different products that should adapt to changing needs. Problem A was a domestic washing machine and Problem B was a clothes horse (Figure 2).

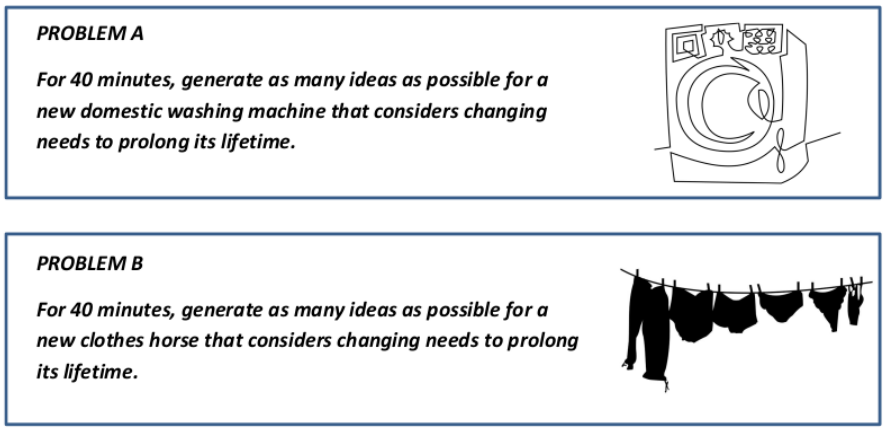


Figure 2. Definitions of the design problems

Figure 3 depicts the stages of the experiment. In the first part, after reading the problem definition, the participants should work individually to generate as many ideas as possible without using any prescribed method for idea generation. Group 1 worked with the washing machine and group 2 worked with the clothes horse. They should express each idea on a separate sheet of paper by means of explanations and drawings. Finally, they selected the final proposal according to these criteria: adaptation to changing needs and novelty. This task lasted 40 minutes. The final proposal could be either one of the ideas or a combination of several of the ideas generated, and they provided details about it with additional drawings and descriptions on how the proposal fulfilled the criteria. This was followed by a 10-minute rest period for participants.

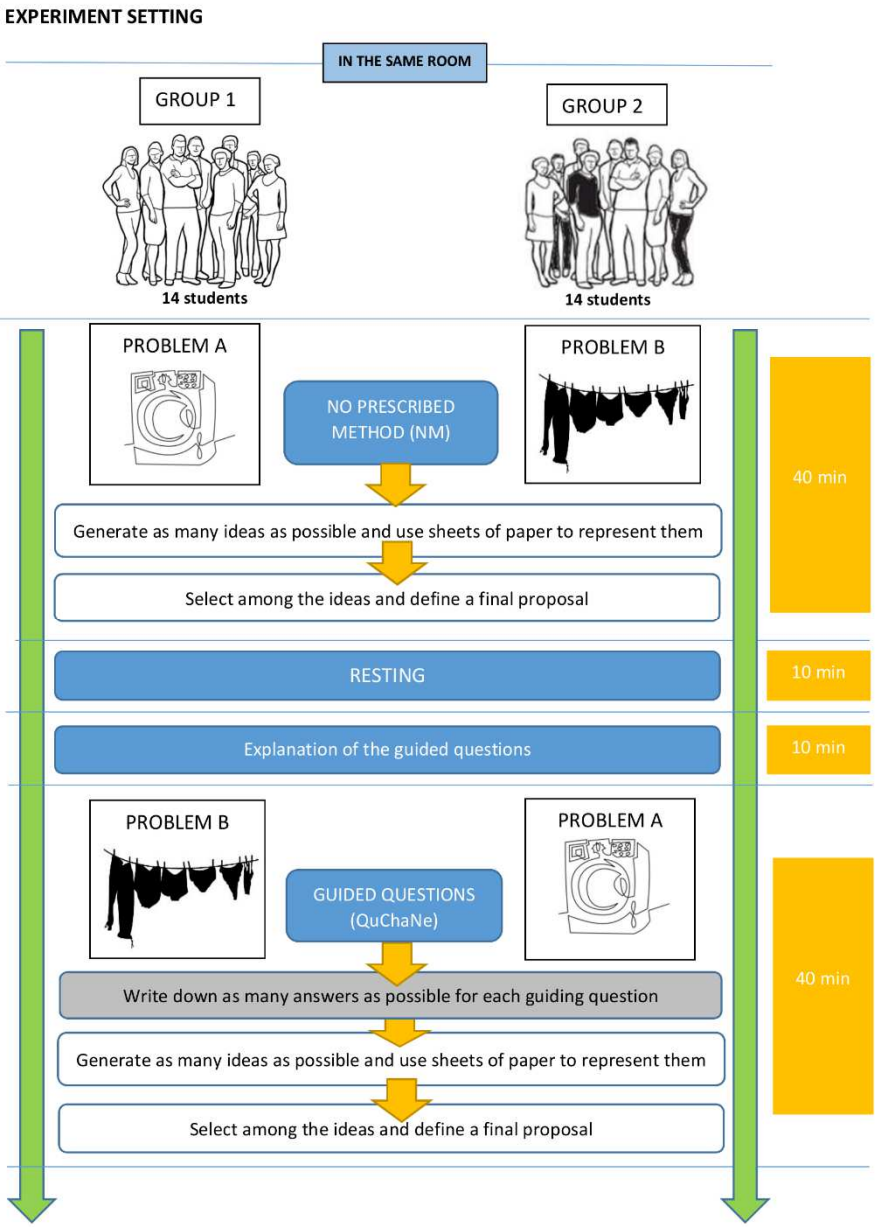


Figure 3. Stages of the experiment

In the next stage of the experiment, the same participants were asked to think up ideas for the other problem. So, group 1 now worked with Problem B, new concepts for clothes horses, and group 2 worked with the washing machines (Problem A). On this occasion they were provided with the predefined list of scenario creation questions QuChaNe (Table 1). First, a 10-minute presentation was given explaining the questions and how they would be applied to an example, in this case a pushchair. Then, they had 40 minutes to come up with ideas and present a final proposal. To this end, they were provided with a template for each scenario creation question in which they read the question and wrote down an answer on a different line (Figure 4). They had to answer all the questions with as many answers as they could think of. They could change the order and come back to an earlier question if they wanted to. They were also allowed to add more lines if they had more answers or to leave some empty. After answering the questions, they started thinking about ideas for the design problem, and could look at the answers to the questions as often as they wanted. Again, every idea had to be expressed on a different sheet using text and drawings. The final step is identical to that of the previous problem: they selected and detailed the final proposal

according to the same criteria. Figure 5 shows two final proposals for the clothes horse obtained from the experiment.

Make a note of all the answers you think are related to the proposed product

Briefly answer all the questions	
S1	*Could the number of people simultaneously using the product increase or decrease?*
S1.1	
S1.2	
S1.3	
S1.4	
S1.5	

Figure 4. Template for answering the guiding questions for changing needs QuChaNe

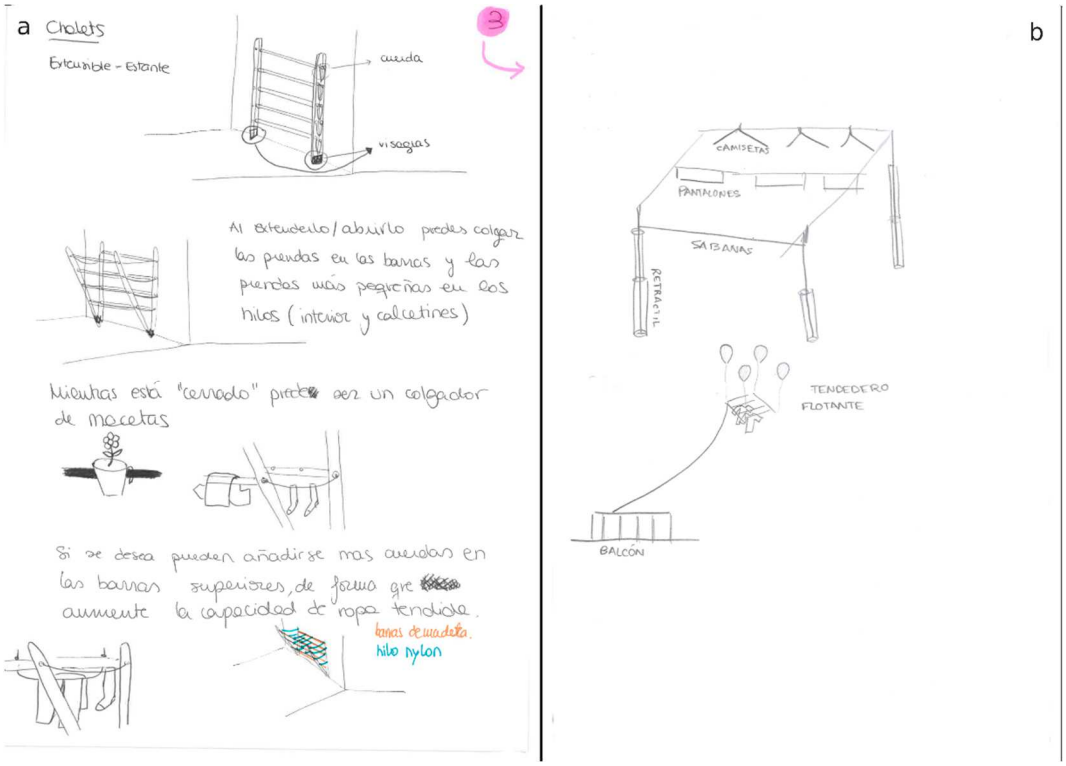


Figure 5. Example of experiment outcomes: a) NM, b) QuChaNe

3.2. Identifying ideas that meet changing needs

To answer the first research question (RQ1) the number of ideas that consider changing needs have to be assessed. We adopted the definition of an idea as the representation of a concept at a certain level of abstraction (Linsey 2007; Shah et al. 2000). And an idea that considers a changing need is an idea identified in a concept that refers to future changes in the user's personal life (Table 2). For each design proposal generated during the experiment, 28 with no prescribed method and 28 using the scenario creation questions, the following criteria were used to identify the ideas for changing needs:

- They must meet changing needs according to one of the four defined categories: user changes (S); their capabilities (C); technological changes or updates (U) and the environment (E). If an idea belongs to several categories, it is classified in only one of them.

- The idea has to be able to overcome a reason for replacing the product. Those needs that might provide value but do not overcome the inconvenience caused by a change are not considered. For example, a drum that increases in size according to the number of people who need to use the washing machine is an idea for a changing need. But the possibility of having a self-supplying washing detergent dispenser to avoid users having to put detergent in each wash or a door delay system are not considered in the accountability of ideas for changing needs.

- It has to be novel, that is, not existent on the market. For instance, a washer-dryer machine that takes up less space and fits in smaller spaces is not considered because it already exists. However, if the idea implies an innovation that improves the adaptability of existing products, it is considered. An example could be a washer-dryer machine with a new drying technology that reduces the space required to wash the same amount of clothes.

- It must not entail purchasing the equivalent to two single products. For instance, a twin washing machine to adapt to an increasing number of people using it would not be considered.

Table 2. Definition and criteria to identify ideas that meet changing needs.

Metric	Definition	Criteria
Number of ideas that consider changing needs	Amount of ideas identified in a concept that refers to future changes in the user's personal life.	It implies a change in the number and size of users, user capacities, technological updates or in the product environment. It must be able to overcome a reason for replacing the product. It has to be different from convectional solutions and it must not entail purchasing the equivalent to two single products. It must be able to overcome a reason for replacing the product. It has to be different from convectional solutions and it must not entail purchasing the equivalent to two single products.

In addition to these guidelines, when analysing the design outcomes, there have been some particular situations that have been solved as follows: in some cases, the annotated sketches proposed an idea that could solve changing needs belonging to more than one subcategory. For example, if a voice control system has been developed for the washing machine, this idea can help elderly people (subcategory: physical capacities/ageing) or people with vision problems (subcategory: perceptual capacities). In these cases, firstly, all the documentation generated during the experiment has been reviewed in case additional information was indicated at earlier stages. If it was not indicated in the previous documentation, we have chosen one of the possible subcategories.

The identification of ideas for changing needs in two of the final proposals obtained from the experiment is depicted in Figure 6. Hereafter, a final proposal is the idea or combination of ideas that each designer decides to present as the problem solution (Figures 6.a and 6.b). Each proposal is examined to identify ideas for changing needs according to the four criteria. For instance, the proposal depicted in Figure 6.b has one idea for a changing need: "Illustrations on screens to help understanding by elderly people and people with learning difficulties".

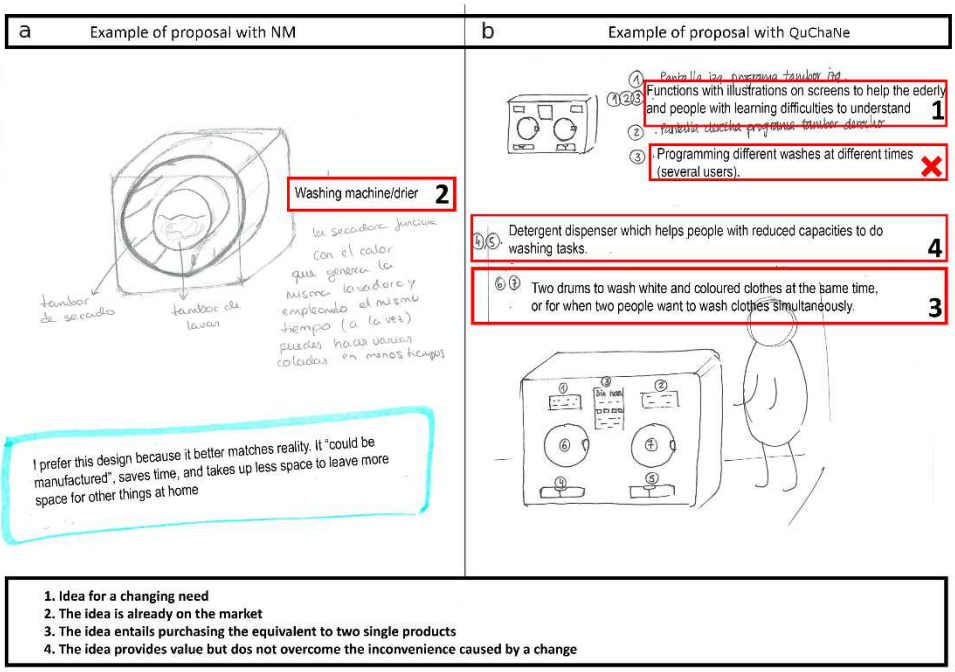


Figure 6. Example of identification of ideas for changing needs in two final proposals: a) with no prescribed method (NM), b) with guiding questions (QuChaNe)

3.3. Ideation effectiveness measurement and creativity concept assessment

To address the second research question (RQ2), a review of the literature was performed to assess quantity, variety, quality and novelty. The metrics proposed by Shah et al. (2003) have been extensively applied to assess the effectiveness of the ideation process ever since their publication (Jagtap et al. 2015; Oman et al. 2013).

According to Shah et al. (2003), quantity is the total number of ideas obtained during the time devoted to idea generation. Variety is a measure of the solution space explored during the idea generation process. It measures how different concepts are from each other. It is assessed by defining a tree of four levels of abstraction, physical principles, working principles, embodiment and detail, and taking into account how many ideas differ at each abstraction level. The variety score is then established as the total sum of the products for the number of different ideas at each level of abstraction multiplied by a coefficient according to that level. Several refinements for variety have been published since then (Linsey 2007; Nelson et al. 2009; Oman and Turner 2009, 2010; Peeters et al. 2010; Verhaegen et al. 2013). In this study variety is assessed using the refinement proposed by Nelson et al. (2009), since it allows a value to be assigned to differentiate between designs at higher hierarchical levels.

Novelty is the measure of how unusual or unexpected the final idea is. In order to assess it, the problem is broken down into key functions or characteristics, which are weighted according to their importance. The idea obtained is rated on a scale from 1 to 10, depending on the degree of 'rarity' in each function obtained. More recently some refinements have been published to assess novelty (Peeters et al. 2010; Verhaegen et al. 2013; Sluiss-Thiescheffer et al. 2016; Jagtap 2019; Fiorineschi et al. 2020). These studies provide refined assessments of the novelty of the idea generation process considering all the ideas and assessing the novelty of a single idea as established in the original metric. Since the present research only assesses the novelty of the final concept, the original metric for novelty published in Shah et al. (2003) is suitable for use. Table 3 shows the two functions with their weights and the reference values, for assessing novelty. The novelty scores and function weights have been judged by the authors.

Table 3. Functions and scores for novelty assessment with Shah et al.'s (2003) metric

	Functions		Weight	Novelty scores for each function		
				3	7	10
Washing machine	F1	Capacity regulation	0.6	Modular	Extendible	Others
	F2	Washing clothes	0.4	Water	Steam/pulverised	Others
Clothes horse	F1	Capacity regulation	0.6	Modular	Extendible	Others
	F2	Placement	0.4	Floor	Ceiling/wall	Others

Lastly, quality measures how the final concept selected fulfils the design requirements at a purely functional level. Functional requirements are weighted with the same proportion as that used for novelty. Each of them is scored by the authors on a scale from 0 to 10, where 0 indicates that the solution is unable to comply with the desired function, 5 denotes that it fulfils the function at an acceptable level, and 10 indicates that the function is performed in the best possible way (Table 4). The assessment for quality of the selected idea is the weighted sum of the ratings of each of the functions associated with the design specifications considered, weighting them according to the importance of that function in the product (Nelson et al. 2009; Oman et al. 2013; Sha et al. 2003). Nelson et al. (2009) and Oman et al. (2013) contribute with an improved assessment of the quality for the set of ideas. Nonetheless, the assessment of the quality of a single idea remains the same respect to Shah's et al. Table 5 summarises the meaning of these metrics.

Table 4. Functions and scores for quality assessment with Shah et al.'s (2003) metric

Product	Functional requirement	Weight	Quality scores										
			0	1	2	3	4	5	6	7	8	9	10
Washing machine	Capacity regulation	0.6	It is not extended					Doubles space easily					Considerably more than doubles washing space. Automatic
	Washing	0.4	It does not wash clothes					Conventional way to wash					Far more efficient way to wash than the conventional method
Clothes horse	Capacity regulation	0.6	It is not extended					Doubles space in one phase					Considerably more than doubles. In many phases
	Easy to place in different ways	0.4	Not stable					Stable on floor. Handling it is normal					Very stable. Many positions. Versatile. All stable

Table 5. Definition and measures to evaluate effectiveness of the process (quantity and variety) and the creativity of the final selected concept (novelty and quality).

Metric	Definition	Measures	Source
Quantity	Amount of solutions considered	It is the total number of ideas obtained during the time devoted to idea generation.	Shah et al. (2003)
Variety	Diversity of solutions considered.	It is a measure of the solution space explored during the idea generation process. Variety is measured by examining how each of the functions are performed in each of the proposals and they are divided according to the level of abstraction into which they are differentiated.	Nelson et al. (2009)
Quality	Fulfilment of the design requirements at a purely functional level by the selected concept.	It is a measure of the feasibility of an idea and how close it comes to meet the design specifications. Is the weighted sum of the ratings of how each of the functions associated with the design specifications is fulfilled, weighting them according to the importance of that function in the product.	Shah et al. (2003)

Novelty	Unusualness or unexpectedness of the final idea regarding to other ideas.	It is a measure of the originality of an idea. Is the weighted sum of the ratings of the way in which each function has been solved regarding to how different it is within the design space, weighting them according to the importance of that function in the product.	Shah et al. (2003)

4. Results

In this section the design outcomes obtained in the experiment are analysed to answer the research questions.

4.1. Number of ideas for changing needs applying QuChaNe

The analysis described in section 3.2 is performed with the 56 final design proposals obtained, 28 for the washing machine and 28 for the clothes horse. Table 6 shows the number of ideas obtained for changing needs at each one of the 56 final proposals. As can be seen in the table, some of them do not present any ideas for changing needs that meet the four criteria outlined in section 3.2, some present just one idea for a changing need and a few of them present more than one. Each idea is classified according to the four categories shown in Table 1. The table also shows the number of ideas for changing needs that already exist on the market.

Table 6. Number of ideas for changing needs in the final proposal for each participant and problem

Student	NM								No. of changing needs obtained		QuChaNe								No. of changing needs obtained	
	Washing machine				Clothes horse				TOTAL VALID IDEAS	Ideas discarded because they exist in the market	Washing machine				Clothes horse				TOTAL VALID IDEAS	Ideas discarded because they exist in the market
	CATEGORIES										CATEGORIES									
	S	C	U	E	S	C	U	E			S	C	U	E	S	C	U	E		
5									0	-						●			1	-
6									0	-					●		●		2	-
7									0	-						●		●	2	-
8	●	●							2	-					●	●			2	-
9	●								1	-					●				1	-
14			●						1	-					●				1	-
15	●	●							2	-						●●		●	3	-
16	●								1	-						●			1	-
17		●●							2	-									0	1
20									0	-						●			1	-
21									0	1						●			1	-
22			●						1	2						●			1	1
24	●								1	-									0	-
25	●	●●●							4	-						●		●	2	-
1					●				1	-		●							1	1
2					●				1	1		●●●							3	-
3									0	-		●●●	●						4	-
4					●				1	-		●							1	1
10					●				1	-	●								1	-
11					●				1	-		●							1	-
12								●	1	-		●							1	1
13									0	1									0	-
18						●			1	1		●●●							3	-
19									0	-		●●●							3	-
23									0	-	●	●●							3	1
26									0	1		●●●							3	-
27						●			1	-									0	-
28									0	1		●							1	-
TOTAL	15				8				23	8	25				18				43	6
AVERAGE	1.07				0.57				0.82	1.14	1.78				1.28				1.53	1

CATEGORY	S	Size and quantity of users	C	Capabilities	U	Upgradability	E	Environment
● Represents one changing needs idea								

The ideas for changing needs were identified individually by the first and the fourth authors. The assessment has a percentage agreement of 94.0% and a linearly weighted Cohen's Kappa coefficient of 0.845, indicating an almost perfect agreement between evaluators (Landis and Koch 1977).

The results show that when applying QuChaNe the mean value of ideas for changing needs is higher than when using NM for the two problems. More ideas were obtained for the washing machine problem than for the clothes horse problem. When analysing each student's progress between using NM and QuChaNe, we see that 13 of the 28 designers obtained more ideas for changing needs when they used GQs, 4 of them obtained fewer ideas and 11 continued with the same number of ideas (Figure 7).

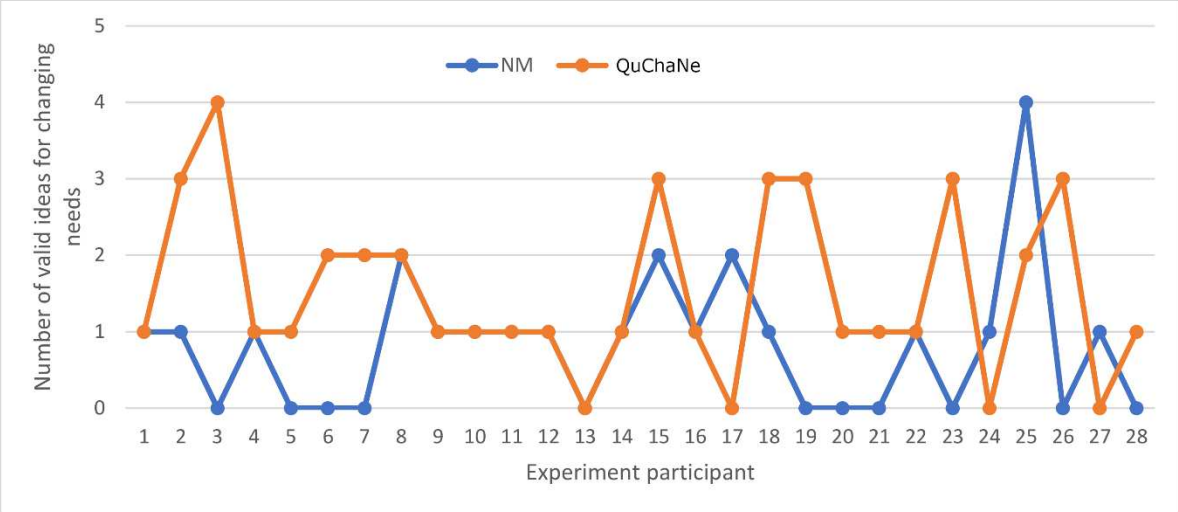


Figure 7. Comparison of the number of valid ideas for changing needs when no prescribed method is applied (NM) and using the predefined list of questions (QuChaNe)

The category with more ideas for changing needs is capabilities in both problems. Of the 23 ideas obtained via NM, 11 ideas (47%) correspond to category S (size and quantity) and 9 to the capability category. The categories that obtained fewer ideas were environment and upgradability. Of all the valid ideas for changing needs using GQs, 74% corresponded to category C (capabilities). As when no method is applied, the categories with fewer ideas are upgradability and environment. Table 7 shows the means and standard deviations and Figure 8 shows the box and whisker plots of the medians and quartile ranges of the number of valid ideas (Figure 8a) and the number of valid ideas plus those that already exist on the market (Figure 8b). The results indicate that by applying GQs more ideas for changing needs are obtained in the final proposal.

Table 7. Means and standard deviations of the number of ideas for changing needs

	No prescribed method (NM)	Scenario creation questions (QuChaNe)
No. of valid ideas for changing needs	M = 0.82, SD = 0.90	M = 1.54, SD = 1.10
No. of valid ideas for changing needs plus those existing on the market	M = 1.14, SD = 0.93	M = 1.75, SD = 1.11

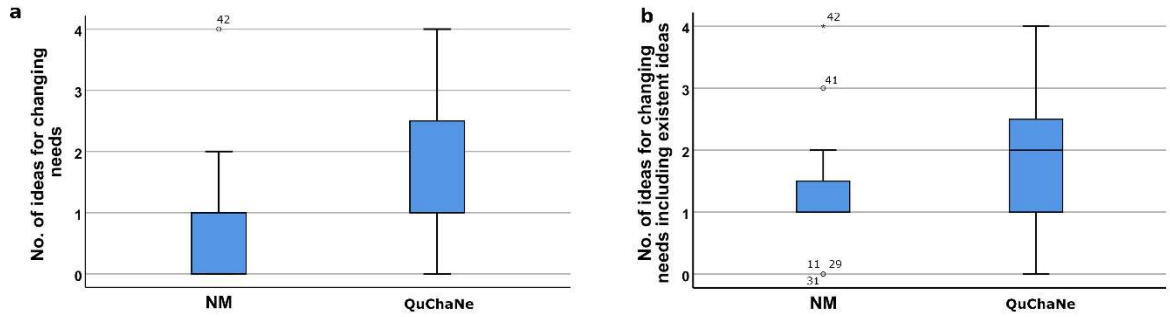


Figure 8. Box and whisker plots for the results: a) number of ideas that meet changing needs; b) number of ideas that meet changing needs, including ideas that already exist

The Kolmogorov-Smirnoff and Shapiro-Wilkinson tests indicate that the data are not normal. In this case, and as the data to be compared are related because the same user generates ideas for a problem using QuChaNe and NM for a different problem, the Wilcoxon test was run with a sample size of N=56 and with a 5% estimation error (α=0.05) for the two dependent variables. If using QuChaNe had no influence, the medians of the differences in the number of ideas generated for changing needs would have to be zero or come very close to zero. When this occurs, the p significance level is higher than the estimation error (0.05). So, the following null hypotheses (H_0) are tested:

- "The number of ideas for changing needs does not depend on applying the predefined list of guiding questions QuChaNe."
- "The number of ideas for changing needs, including those already existing on the market, does not depend on applying the predefined list of guiding questions QuChaNe."

These null hypotheses are the equivalent to checking whether the differences in the measured variables in both ways, that is, using QuChaNe or not, can be considered null, i.e. if the p-value is higher than 0.05. Table 8 shows the test results and Table 9 shows the effect size index for the Wilcoxon test. As can be seen in Table 10, the answer to research question RQ1 is affirmative: more design ideas for changing needs are generated when scenario creation-type questions are used compared to when no prescribed method is applied. Moreover, the effect size is large, so applying the predefined list of scenario creation questions has a large effect, increasing the number of ideas for changing needs in the final outcome.

Table 8. Wilcoxon signed ranks for idea generation with and without guiding questions QuChaNe

		N	Mean rank	Sum of ranks
Number of ideas for changing needs	Negative ranks Positive ranks Ties	28 4 24	17.29 11.00	484.00 44.00
Number of ideas for changing needs, including those that exist on the market	Negative ranks Positive ranks Ties	37 3 16	21.07 13.50	779.50 40.50

Table 9. Index to estimate the effect size

Wilcoxon index for effect size $\left\lvert Z/\sqrt{N}\right\rvert$	**Effect size**
≤0.1	Null effect
$0.1<\left\lvert Z/\sqrt{N}\right\rvert \leq 0.3$	Small effect
$0.3<\left\lvert Z/\sqrt{N}\right\rvert \leq 0.5$	Medium effect
$\left\lvert Z/\sqrt{N}\right\rvert > 0.5$	Large effect

Table 10. Wilcoxon test results for H_0. (p= significance level; Z= standard score (z-score); effect size=$\left| Z/\sqrt{N} \right|$)

Null hypothesis H_0	Wilcoxon signed-rank test	Conclusion	Effect size (N=56)
Number of ideas for changing needs does not depend on whether students use QuChaNe or not	Z= -4.272 p<0.000	Reject H_0	0.56
Number of ideas for changing needs, even including those that already exist on the market, does not depend on whether students use QuChaNe or not	Z= -5.150 p<0.000	Reject H_0	0.68

4.2. Ideation effectiveness applying guiding questions (QuChaNe)

The second research question asks whether the variety and quantity of the ideation process and the novelty and quality of the final concept change when QuChaNe are applied. Table 11 shows the results of the assessment for the four metrics: quantity, variety, novelty and quality. As explained in section 3.3, the assessment of quantity and variety implies considering all the ideas generated by each designer, whereas quality and novelty are assessed considering the final proposal. Hence, the total number of ideas produced during the ideation is not related at all with the number of ideas for changing needs contained in the final proposal. It is worth noting that when QuChaNe are applied many participants have generated only one idea, just the final one that is proposed. This could be due to two reasons: one is that the time available for the experiment is perhaps too short to answer the guiding questions (QuChaNe) and then start generating ideas; the other is that answering the questions is in some way a generation of ideas, although at a higher level of abstraction than when representing the ideas with drawings. Approximately half of the time was spent on generating changing needs and the other half on generating ideas. So, even though the number of drawings presented on independent sheets is very low when QuChaNe is applied, they have probably generated some ideas in their minds but in the end have not drawn them. This reality is also reflected in the variety, since if there is only one idea generated, the equation to assess the variety provides a value of zero.

Table 11. Quantity and variety of the ideation process and quality and novelty of the final concept

	Of all the ideas obtained				Of the final proposal			
	QUANTITY		VARIETY		QUALITY		NOVELTY	
	Washing machine	Clothes horse	Washing machine	Clothes horse	Washing machine	Clothes horse	Washing machine	Clothes horse
NM	4.00	6.00	1.80	1.88	6.20	5.20	1.20	4.60
	2.00	4.00	1.67	1.40	1.60	5.80	3.00	5.40
	2.00	5.00	2.33	1.92	4.60	5.80	2.80	7.00
	4.00	3.00	1.13	0.84	5.60	6.40	3.00	5.40
	2.00	3.00	1.13	0.72	4.40	5.20	5.40	7.00
	2.00	3.00	0.20	0.64	2.00	2.80	3.00	5.40
	3.00	3.00	2.33	0.72	2.00	2.80	3.00	7.00
	3.00	4.00	1.33	1.56	3.60	1.60	4.60	2.80
	4.00	4.00	0.00	0.84	2.00	2.80	1.20	2.80
	3.00	5.00	1.00	1.28	2.00	2.80	1.20	1.20
	3.00	4.00	2.13	1.84	2.00	2.80	3.00	7.00
	3.00	3.00	0.40	0.96	2.00	2.40	1.20	2.80
	3.00	6.00	0.13	1.48	2.00	2.40	3.00	1.20
	4.00	3.00	1.53	0.60	6.20	2.40	3.00	2.80
Qu Cha Ne	1.00	3.00	0.00	0.84	5.00	2.80	1.20	1.20
	1.00	2.00	0.00	1.00	2.00	4.60	1.20	3.00
	3.00	2.00	1.13	0.80	2.00	3.60	1.20	5.80
	4.00	3.00	1.33	1.00	5.00	8.40	3.00	5.40
	2.00	2.00	1.67	0.68	7.40	5.00	5.40	5.40
	1.00	3.00	0.00	1.28	5.00	7.40	3.00	5.40
	1.00	2.00	0.00	1.00	2.00	6.20	1.23	4.60
	1.00	1.00	0.00	0.00	2.00	4.40	1.20	3.00
	1.00	1.00	0.00	0.00	2.00	2.40	1.20	2.80
	1.00	2.00	0.00	1.00	2.00	3.20	1.20	7.00
	1.00	3.00	0.00	0.72	5.00	3.20	5.40	2.80

	1.00	1.00	0.00	0.00	2.00	5.80	3.00	1.20
	2.00	1.00	0.33	0.00	6.20	2.00	3.00	3.00
	1.00	3.00	0.00	0.64	2.00	3.20	1.20	1.20

Table 12 shows the means and standard deviations for these metrics. Figure 9 provides the box and whisker plots, which indicate the differences in the medians and distributions of the assessments for novelty, variety, quality and quantity depending on whether NM or GQs are used. As we can see, the quantity, variety and novelty are greater when NM was applied, while GQs led to higher quality.

Table 12. Means and standard deviations for the novelty, variety, quality and quantity metrics using no prescribed method (NM) and the QuChaNe list of questions

	NM	QuChaNe
Novelty	M = 3.61, SD = 1.94	M = 3.01, SD = 1.84
Variety	M = 2.21, SD = 0,65	M = 0.48, SD = 0.54
Quality	M = 3.48, SD = 1.66	M = 3.99, SD = 1.95
Quantity	M = 3.50, SD = 1.07	M = 1.79, SD = 0.92

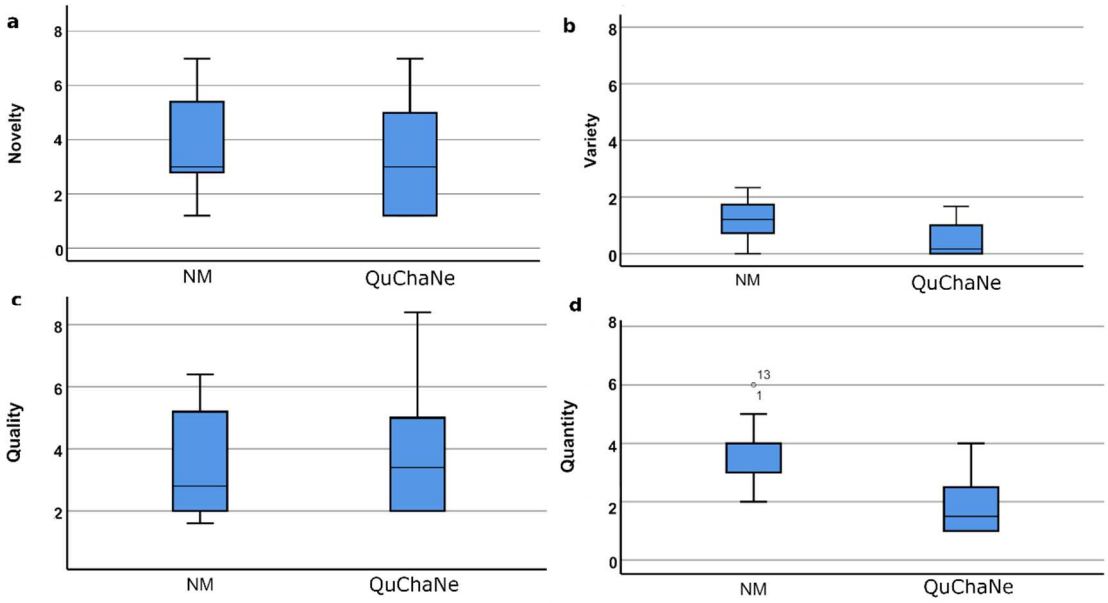


Figure 9. Box and whisker plots for the results of measuring: a) novelty, b) variety, c) quality, and d) quantity according to the method applied using Shah's metrics

Again, both the Kolmogorov-Smirnoff and the Shapiro-Wilkinson tests indicate that data are not normal. The Wilcoxon test was run with a sample size of N=56 and a 5% estimation error (α=0.05) for the four metrics. Table 13 shows the results obtained for the following null hypotheses (H_0):

- "The novelty of the ideas does not depend on applying the guiding questions (QuChaNe)."
- "The variety of the ideas does not depend on applying the guiding questions (QuChaNe)."
- "The quality of the ideas does not depend on applying the guiding questions (QuChaNe)."
- "The quantity of the ideas does not depend on applying the guiding questions (QuChaNe)."

Table 13. Wilcoxon signed ranks for novelty, variety, quality and quantity with and without guiding questions

		N	Mean rank	Sum of ranks
Novelty	Negative ranks Positive ranks Ties	56 0 0	28.50 00.00	1596.00 00.00
Variety	Negative ranks Positive ranks Ties	31 20 5	28.63 21.93	887.50 438.50
Quality	Negative ranks Positive ranks Ties	56 0 0	28.50 00.00	1596.00 00.00
Quantity	Negative ranks Positive ranks Ties	42 0 14	21.50 0.00	903.00 0.00

Table 14 offers the Wilcoxon test results. The answer to the second research question (RQ2) is negative: quantity, variety, novelty and quality are ~~is~~ not similar when the predefined scenario creation questions are applied. Quality increases if GQs are applied, but quantity, variety and novelty are lower in comparison to when no method is applied. In quantity, quality and novelty the size effect is large, that is, there is a big difference in the four metrics when the GQs are applied. As has been pointed out, the fact that the novel designers have spent a significant proportion of time thinking about changing needs means that they have not had enough time to generate ideas when the guided questions were used. This time varies from one participant to another and has not been measured, but it could be approximately half the time (20 minutes). This might have had an effect in the form of decreasing variety and fewer results. Although variety is lower when the guiding questions (QuChaNe) are applied, the effect size is small.

Table 14. The Wilcoxon test results for H_0 (p= significance level; Z= standard score (z-score); effect size=$\left| Z/\sqrt{N} \right|$)

Null hypothesis H_0	Wilcoxon signed-rank test	Conclusion	Effect size (*N*=56)
The novelty of the ideas does not depend on whether students use QuChaNe or not	Z=-6.521 p<0.000	Reject H_0	0.87 large
The variety of the ideas does not depend on whether students use QuChaNe or not	Z=-2.111 p<0.000	Reject H_0	0.28 small
The quality of the ideas does not depend on whether students use QuChaNe or not	Z=-6.516 p<0.000	Reject H_0	0.87 large
The quantity of the ideas does not depend on whether students use QuChaNe or not	Z=-5.683 p<0.000	Reject H_0	0.76 large

5. Discussion

The fact that the guiding questions QuChaNe encourage the generation of more ideas for changing needs might be because these questions helped the participants to understand other points of view they had not spontaneously contemplated. This result falls in line with the conclusion reached by Cardoso et al. (2016); that is, QuChaNe extend the conceptual design space and can reframe the problem at hand. The statistical analysis showed that the QuChaNe strongly affected the number of changing needs ideas. This large effect could be conditioned by the participants' lack of experience in designing products for adapting to changing needs. The fact that the washing machine problem produced more solutions to cover changing needs than the clothes horse problem could be because a clothes horse is a product that interacts less with users and involves less technology.

Having a different number of ideas for changing needs among the four categories could be due to some of these categories being more complex and needing additional more specific questions. With the environment category, this could be due to this category not being as well understood as the others or maybe because the problems might

not have inspired the participants enough. Another possibility is that the decrease of the rate of idea generation decreases over time (Howard and Murray 2003), has resulted in fewer ideas for the last questions of QuChaNe. It could be interesting for future works to check if, balancing the questions from all categories of changing needs over time would help to improve novelty without compromising on quality.

The guiding questions (QuChaNe) helped to obtain better quality ideas than NM, but the novelty, variety and quantity of the solutions were inferior. The lower values in quantity and variety might be due, as mentioned in the previous section, to participants not having enough time to answer the guiding questions (QuChaNe) and to generate drawings or perhaps to the fact that while answering the questions, the designers have generated ideas internally although they have not drawn them. The ratio "time to generate changing-needs/time to generate ideas" might have affected the results. In this experiment, this ratio is approximately 0.5, which could have led to lower variety and quantity when guiding questions are applied. We estimate that for a lower ratio, for instance 0.25 or less, the difference in quantity and variety would decrease.

Regarding the variety and novelty of the final idea, the results pointed to a similar trend to that found in previous studies: the higher the variety is, the higher the individual novelty will be (Jagtap et al. 2015). Previous studies, like that by Chulvi et al. (2012), stated that applying intuitive methods such as brainstorming and when no method is prescribed provides more novel outcomes, whereas applying structured methods such as guiding questions provides the best rated outcomes in terms of usefulness. The study by López-Mesa et al. (2011), which used guiding questions, specifically the SCAMPER method, also found that using guiding questions produced more feasible ideas (feasibility being understood as a measurement of quality) than when visual stimuli were applied.

The results presented is this study show that when the guiding questions (QuChaNe) are applied, the quantity is lower and the quality of the final proposal is higher than when no method is applied. One of the two functional requirements used to assess quality is the capacity to adapt. The higher values in quality when the guiding questions are applied might be due to the fact that these questions have stimulated thinking about changing needs. This is an interesting finding since in real-life design quality is preferred over quantity (Kazakci et al. 2015). To compare this result with previous studies, we have to consider that ideation quality, a property of a set of ideas, is different from idea quality, a property of a single idea. Since this study only assesses the quality of the final proposal, we cannot make a straightforward comparison with the works that analyse the correlation between quality of the ideation and quantity.

Since Osborn (1963) suggested that "the more ideas produced, the more good ideas", several studies have demonstrated a correlation between idea quantity and idea quality, for instance Dylla (1991) and Dennis et al. (1997). However, other studies claim that there are conditions under which this correlation is not true (Connolly et al. 1990; Reinig and Briggs 2008, 2013). Reinig and Briggs (2013) identified six mechanisms that reduce the ratio of good ideas to total ideas. In particular, the use of the guiding questions in this research might have acted as an additional stimulus and activated new parts of the knowledge network, thereby reducing cognitive inertia (Mackay and McKiernan 2006) and leading to ideas that better fulfil the design goal. Results are also in line with those of Cash et al. (2012), who found that teams exposed to additional information about the product in a constrained design task produce fewer ideas than those not exposed to additional information, but with an increased percentage of effective ideas.

The results obtained are limited to the profile and level of experience of the participating sample, in this case, novice designers. It is possible that with engineers and senior designers, the results might be different. Another limitation is that the number of questions in QuChaNe may be too long for the time used in this experiment. Previous studies have shown that creative sessions of 2 hours, in comparison with 50 minutes sessions, can improve novelty without compromising quality (Tsenn et al. 2014). So, it could be interesting to extend this study in order to check whether there is an advantage in having more time. Also, having solved two problems in the same session, and with the number of QuChaNe questions, the participants were a little tired in the second part, precisely the QuChaNe part. Perhaps separating the sessions on different days would have improved the results in favour to QuChaNe.

6. Conclusions

This work presents an outcome-based analysis of the ideas generated for changing needs in an experiment with individual designers applying no prescribed method compared to when a predefined list of questions is applied. It was observed that, even though they spent the same amount of time on idea generation, when designers use a predefined list of scenario creation questions:

- The design outcomes contain more ideas for changing needs than when applying no prescribed method (NM).
- The quality of the final ideas is higher than when applying NM.
- Although the final design presents more ideas for changing needs than when NM is applied, the total number of ideas generated during the ideation process is lower than when NM is applied.
- The novelty and variety of ideas are lower than when NM is applied.

This paper provides a list of scenario creation-type questions which promote design solutions that consider changing needs. At a practical level, designers could apply these questions as a creative task before using design for adaptability (DFA) or upgradability (DFU) methods. In this way, designers would come up with a larger number of ideas for changing needs, which could lead to more adaptable/upgradable products.

Further research should analyse how to improve novelty, quantity and variety using the defined guiding questions QuChaNe. Possible ways to address this could be by increasing the time given to generate ideas; splitting QuChaNe questions in 2 or 3 subgroups and apply each of them in a separate creative session; balancing the questions from all the categories of changing needs over time during the generation of ideas; or by applying QuChaNe in combination with intuitive techniques or in a more flexible way.

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