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Fictionation: development and evaluation of an idea generation tool grounded on design fiction

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Abstract
Idea generation requires the generation of many, various and novel ideas, and has the greatest impact on the quality of the final design solution within the design process. The literature offers numerous design methods and tools available for the use of designers in idea generation, though criticisms include the shortcomings of methods in supporting illogical thinking, as well as the lack of studies that test the effects of these methods on idea generation. This paper presents Fictionation, a card-based idea generation tool that seeks to increase novelty and variety by fostering an environment of creative invention based on design fiction and illogical thinking. The effects of the tool on the novelty and explored variety scores of the design outputs are investigated with an experimental study among undergraduate industrial design students. The results indicate that the Fictionation tool increases the novelty and variety of the ideas, and also has effects on improving academic performance and creating a more homogeneous student group.

Keywords Design methods and tools · Idea generation · Novelty · Variety · Design education

Introduction

Design methods and tools assist designers in managing the complexity of design activities and enhancing the design process outputs (Cross, 2008; Roozenburg & Eekels, 1995; Roy & Warren, 2019; Wallace, 2011). The vast majority of design methods and tools focus on idea generation since it is viewed as the phase of the design process that requires the most creativity. As a response to the design problem at hand, designers are expected to produce

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solution alternatives during the idea generation phase. In order to arrive at a final design output, the alternative solutions are assessed, refined, and developed following this phase. In this respect, idea generation is a critical step of the design process, as subsequent phases and the final product are dependent on it (Corremans, 2011; Murphy et al., 2023; Shroyer et al., 2018).

The common objective of design methods and tools developed for idea generation is to foster creativity and encourage divergent thinking in order to uncover novel outcomes (Fricke, 1996; Liu et al., 2003). However, many of the available methods and tools have been criticized for 1) failing to reveal various and novel ideas and causing fixation (Bruseberg & McDonagh-Philp, 2002; Linsey et al., 2010; Murphy et al., 2023; Sio et al., 2015; Vasconcelos & Crilly, 2016), 2) lacking in illogical thinking, which is the essence of creative thinking (Haritaipan, 2019; Kris, 2000) and 3) lacking in terms of asserting measurable results regarding their effects on the outcomes of the design activity (Corremans, 2011; Haritaipan, 2019; Murphy et al., 2023; Shah et al., 2000). This article introduces Fictionation, a card-based idea generation tool based on design fiction and illogical thinking, that attempts to boost the novelty and variety of generated ideas, increase academic performance as well as an experimental study measuring its effects on design outcomes.

Overview of design methods and tools

Design methods are procedures and action plans that assist designers in solving complicated design problems and enhancing the results of the design process (Cross, 2008; Haritaipan, 2019; Roy & Warren, 2019; Wallace, 2011). Although fundamental design activities such as drawing and sketching can be considered as design methods since they support design activity with their means and techniques (Cross, 2008; Tovey et al., 2003), the literature treats design methods as formalized procedures that are not only inherent to the design activities, but also gathered from other disciplines, to support design processes (Baxter, 1995; Cross, 2008; Wright, 1998), particularly in terms of understanding the design problem, generating design concepts, and evaluating alternative solutions (Cross, 2008; Pahl, et al., 2007; Roozenburg & Eekels, 1995; Wright, 1998). Design tools, on the other hand, are equipment that are used during the implementation of the method, enhancing the effects of the method usage, becoming part of the activity and documenting the outcomes (Cross, 2008; Gericke et al., 2017. These may be in the form of objects or media, such as props, hardware, software and instruments for exploration and representation (Blessing & Chakrabarti, 2009; Dalsgaard, 2017).

Classification of design methods

Various design methods aid design activity a) by focusing on different phases of the design process to explore a design problem, generate ideas or evaluate, b) by targeting individuals or groups, c) through silent or verbal acting and d) through logical or intuitive thinking (Cross, 2008; Jones, 1980; Shah, 1998; VanGundy, 1988). The different approaches of the available design methods have led to the need for their classification to better understand them. In terms of their nature, Jones (1980) grouped design methods considering their purposes within the divergence-transformation-convergence framework, VanGundy (1988) considering their target audience, medium and procedure, Shah (1998) based on whether they contain intuitive or logical procedures, Pahl et al. (2007) as solution-finding methods and selection and evaluation methods, and Cross (2008) as creativity methods and rationality methods. Building on the analysis-synthesis-evaluation paradigm of Jones (1980, 1984), in terms of their function, Roozenburg and Eekels (1995) categorise design methods with analysis as converting a design problem into design specifications, synthesis as devising a provisional design, simulating (testing) as predicting the properties of a design, and evaluation as decision making for selecting the best design. Pahl et al. (2007) distribute methods under the categories of product planning and task clarification, conceptual design, and embodiment design. While product planning and task clarification refers to a set of activities towards problem definition, methods for conceptual design and embodiment design comprise activities related to divergence through solution finding, and convergence through selection and evaluation (Pahl et al., 2007). Sakae et al. (2016) review 174 design methods and determine 13 clusters based on the designerly activities conducted and design thinking involved in their application, distributed to the design problem analysis, idea generation and idea evaluation framework.

Cross' (2008) distinction of creativity and rationality methods is frequently referred to in the literature. Creative design methods adopt a freewheeling approach and are mostly devised to be used within the idea generation phase. They aim to enhance creative thinking, eliminate mental blocks, and enhance the flow, quantity, variety and novelty of ideas (Cross, 2008). The most well-known examples include brainstorming (Osborn, 1963), nominal group technique (Aurum & Gardiner, 2003), brainwriting (Baxter, 1995), 6-3-5 (Wright, 1998), C-Sketch (Shah et al., 2001), Synectics (Cross, 2008), TRIZ (Gonçalves et al., 2014), SCAMPER (Baxter, 1995) and mind mapping (Aurum & Gardiner, 2003).

While creative methods are more concerned with idea generation, rational methods address a wider range of phases and activities within the design process, from problem clarification to detail design, and are performed through a more systematic approach (Cross, 2008). They are mostly devised for exploring a design problem and evaluating alternatives. Commonly known examples include checklists (Gonçalves et al., 2014), objectives tree (Cross, 2008), function analysis (Cross, 2008), morphological chart (Ritchey, 2018) and weighted objectives (Cross, 2008).

Classification of design tools

While many of the design methods serve as a guidance by offering a procedure, methods such as 6-3-5, C-Sketch and morphological chart contain some instruments, such as matrixes, in order to be used within the design process. These instruments are regarded as design tools and can be in form of card decks, posters, or worksheets (Roy & Warren, 2019; Wölfel & Merritt, 2013; Yoon et al., 2016). Design tools can be utilized within a design method to support the procedure; they can also be used on their own, serving similar purposes as design methods. Card decks are the most commonly used among such design tools. Haritaipan (2019) investigated 112 design tools and identified that card-based design tools constitute 89%. The reasons for their popularity are explained as simplicity, tangibility, facilitating creativity and supporting inspiration and communication (Beck et al., 2008; Carneiro et al., 2012; Wölfel & Merritt, 2013; Yoon et al., 2016).

As in the case of design methods, some classifications were made within the design tools. Miemis (2012) classified design tools considering their purposes, Roy and Warren (2019) considering their stimuli, and Haritaipan (2019) considering whether they provide inspiration or call for action. In the light of these classifications, design tools can be grouped under two main and six sub-categories: idea triggering design tools that involve random triggers, context related triggers or instructions; and guiding design tools that involve tactics, checklists or information.

Idea triggering design tools aim to bring forth novel solutions through some written or illustrated prompts. They can contain random triggers as in the cases of Creative Whack Pack (Smith, 1998), Thinkpak (Lucero & Arrasvuori, 2010) and Designercise (Haritaipan, 2019), context related triggers as in the cases of IoT Service Kit (Haritaipan, 2019) and PLEX Cards (Lucero & Arrasvuori, 2010), or instructions as in the cases of Oblique Strategies (Wölfel & Merritt, 2013) and Design Heuristics (Daly et al., 2012).

Guiding design tools aim to direct designers within the design process. They can provide tactics as in the cases of Meta Cards (Roy & Warren, 2019) and IDEO method cards (Wölfel & Merritt, 2013), checklists as in the case of MethodKit (Haritaipan, 2019), or information as in the cases of i/o cards (Carneiro et al., 2012), iD cards (Roy & Warren, 2019) and Energy Trumps (Haritaipan, 2019).

Criticisms towards design methods and tools

It is acknowledged that design methods and tools aid the design process; on the other hand, it has also be claimed that although numerous design methods and tools for idea generation are available, particularly novice designers who may not have yet developed the necessary designer skills may have difficulties in moving away from tight rules (Lawson & Dorst, 2009), have problems in generating diverse and novel ideas, and may face fixation (Bruseberg & McDonagh-Philp, 2002; Daly et al., 2012; Linsey et al., 2010; Sio et al., 2015; Vasconcelos & Crilly, 2016). Kris (2000) and Haritaipan (2019) attribute the problem to the ineffectiveness of design methods and tools. The argument is that existing methods and tools enable procedures, tactics and triggers already known to and applied by the designer, remaining short in supporting the creative process with the *unknown* and with *illogical thinking*.

In addition to the ineffectiveness of design methods, another criticism is that many design methods and tools are not experimentally tested (Corremans, 2011; Haritaipan, 2019; Roy & Warren, 2019). Design methods and tools are developed with the purpose of helping designers overcome difficulties within various stages of the design process. Therefore, they should be seen as a treatment and tested in an experimental setting in order to assess their effects on designers' performance and impacts on design process outcomes. In that way, the results can be used for improving design methods and related tools, and for guiding designers in the selection of reliable tools required for specific stages in their design processes, as in the cases of Corremans (2011), Daalhuizen et al. (2014), and Daly et al. (2012).

This article proposes a new idea triggering design tool, Fictionation, that aims to enhance the outcomes of idea generation in terms of variety and novelty by using *illogical thinking* and *what-if* scenarios of design fiction. Furthermore, it presents the results of an experimental study that tests the effects of the tool through the RNEV (Refined Novelty and Explored Variety) technique (Bayırlı & Börekçi, 2022) which was developed to overcome flaws (Bayırlı & Börekçi, 2022; Jagtap, 2018; Nelson et al., 2009; Verhaegen et al., 2013) identified in the procedure of the mostly used assessment technique, the effectiveness measures of Shah et al. (2003). RNEV offers a systematic technique (FBS ontology) for decomposing ideas and refined versions of the calculation procedures of novelty and variety metrics (explored variety) in order to reach more robust results.

Problem background

The Fictionation tool is built on a set of design studio course observations of students in the 3rd year of our 4-year undergraduate programme, on the conduct of industrial design projects. A fixation issue was observed in numerous occasions among the students during the idea generation phase of a 7-week project with fixed problem boundaries. Although it is natural that the range of ideas explored during ideation include commonly available solutions, it is also expected that the ideas include freely explored diversions from the familiar (Daalhuizen et al., 2014; Daly et al., 2016). Many of the student-generated ideas were comparable to those already on the market. Similar challenges have been studied by others, including Bruseberg and McDonagh-Philp (2002), Daly et al. (2012), Linsey et al. (2010), Sio et al. (2015) and Vasconcelos and Crilly (2016). Another observation concerned a mental barrier that students created for themselves. During idea generation, many students stated that they initially had a creative concept, but lacked confidence in pursuing it due to project constraints. Students reflected their concerns as e.g., "the idea has a lovely form, but cannot it be produced", and although they found their form representation worthy of developing and submitting as a final design solution, production techniques and material limitations presented a setback for them. The barriers that students defined, had a disruptive effect on the flow they needed to be in during idea generation (Jones, 1980; Lawson, 2000), which should be undertaken without early set constraints or judgments (Osborn, 1963) to allow the exploration of the design problem together with solution concepts generated in response to it (Dorst & Cross, 2001). Once a concept is attained matching the design problem as understood, then the designer can proceed to resolving feasibility through design development (Baxter, 1995; Cross, 2008; Wright, 1998). Therefore, it was established that there was a need for supporting students within the idea generation process with a systematic procedure.

The fictionation idea generation tool

The idea behind the Fictionation tool was to alleviate concerns and break down mental barriers that students create for themselves during idea generation in order to foster an environment of creative invention. Therefore, first, all possible design-related considerations were compiled for determining the content of the Fictionation tool. Then the tool cards were developed and finalised through a pilot study.

Peer debriefing for design considerations

A peer debriefing session was held and a designer's likely design considerations during ideation were determined with the participation of eight design experts experienced in both practice and education. The experts were handed post-its and instructed to think about the factors that are considered (i.e., such as concerns, constraints, objectives, issues, values) during ideation within a design project and list them based on their personal experiences as designers, instructors and past students. As a result, 118 factors on post-it notes were obtained. These notes were affixed to a wall to form a gallery, and were reviewed for categorization. Under the moderation of the first author, the eight experts examined the factors in terms of their context, eliminated duplications, and compiled them under the headings of form, function, and interaction. The session resulted in the identification of a total of 21 considerations (groups of factors). Following the session, the collected 21 considerations were shared with

Table 1 Considerations scored by the experts

Considerations	p1	p2	p3	p4	p5	p6	p7	p8	Average
Existing products	8	9	9	9	10	10	10	10	9.4
User	8	8	9	9	9	10	10	10	9.1
Anthropometric measurements	7	9	9	9	9	9	9	10	8.9
Purpose	8	8	8	9	9	9	10	10	8.9
Production techniques	7	7	8	9	9	9	10	10	8.6
Gravity	7	7	8	8	9	9	10	10	8.5
Technological restrictions	7	8	8	8	9	9	9	10	8.5
Accustomed interactions	7	8	8	8	9	9	9	10	8.5
Cost	6	7	7	8	8	9	9	10	8
Sense organ	6	7	7	7	7	8	9	10	7.6
Ergonomics	3	4	5	5	5	5	6	6	4.9
Material	4	4	4	4	5	5	5	5	4.5
Structure	2	2	3	3	3	3	4	4	3
Proportions	2	2	2	2	3	3	4	6	3
Balance	1	2	2	3	4	4	4	4	3
Contextual restrictions	2	2	3	3	3	3	2	2	2.5
Future trends	1	1	2	2	2	3	3	4	2.3
Dimensions	1	2	2	2	2	2	3	3	2.1
Weight	1	1	1	2	2	2	2	2	1.6
Surface finish	1	1	1	1	1	2	3	3	1.6
Color	1	1	1	1	1	1	1	2	1.1

the same design experts via an online survey to be ranked on a scale from 1 to 10 based on their worth for idea generation; Table 1 displays the resulting scores.

Fictionation cards content and design

The idea behind the Fictionation tool overlaps with design fiction and the name of the tool comes from the combination of the words *fiction* and *generation*. Design fiction, which was first suggested by the science fiction writer Bruce Sterling, is a recent approach in design that enables designers to create imaginary worlds in which considerations, constraints, limitations and rules are defined by them (Bleecker, 2010; Dunne & Raby, 2013). In this imaginary world, it is possible to think differently than in the real world (Celik et al., 2024; Franke, 2010; Tanenbaum, 2014). In order to create imaginary worlds, design fiction suggests the usage of *what-if* scenarios that allow for a debate and brainstorming to test future possibilities or criticize alternative presents (Knutz et al., 2014).

The Fictionation cards contain some *what-if* questions that aim to trigger diverse and novel ideas by eliminating limiting constraints. The top ten considerations that received the highest grades from the eight experts (Table 1) were determined as the content of the *what-if* questions. In order to increase the diversity of the cards and thus the diversity of the outcomes, the obtained topic headings (form, function, and interaction) were also integrated to the considerations (Table 2). At the end, 30 cards (10 considerations × 3 headings) were obtained. The cards containing *what-if* questions related with *form* were colored blue, *function* were colored green and *interaction* were colored red; a logo was designed and printed at the back side of the cards (55 × 85 mm). The usage scenario of the cards involves reading the information on the cards and generating ideas accordingly. For example, having chosen the card on the right in Fig. 1 the designer is expected to imagine a world where there is no gravity and generate form alternatives for the design problem in hand accordingly. Following a pilot study that was conducted to test the content and usage of the Fictionation tool, *place* was added as a new consideration category to the card deck, resulting in a total of 33 cards (Fig. 2; 11 considerations × 3 headings, orange cards show the back sides).

Experimental study on the effects of the fictionation tool

Design methods and tools have been evaluated based on feedback obtained from their users on whether they have benefitted from these in their design processes (Corremans, 2011; Haritaipan, 2019; Roy & Warren, 2019). However, due to the ill-structured nature of design problems and the complexity of the design activity, it is difficult to express learning outcomes in words (Dorst & Reymen, 2004). It has been suggested that a newly developed design method or tool should be evaluated through an experimental study (Corremans, 2011). With this objective, an experimental study was conducted to test the Fictionation tool. A pretest–posttest experimental design (Campbell & Stanley, 1963) was adopted for the study to examine the effects of the proposed Fictionation tool, that was the treatment (Fig. 2). The experiment used a control group and an experiment group that was subjected to the treatment.

Participants

The experimental study was announced to the 3rd year industrial design students at Middle East Technical University as an idea generation workshop and the first 24 volunteers (17 female and 7 male students, aged 21–24) constituted the participants of the study. The participants were randomly placed in groups which at the end were formed as 9 female and 3 male students for the control group, and 8 female and 4 male students for the experiment group. All participants had similar experiences and taken the same level compulsory undergraduate courses in which they gained the knowledge and skills needed for the fulfilment of the workshop tasks, such as conducting a design process, carrying out idea generation, and sketching.

Procedure

The experiment took place in classroom settings in the faculty building, familiar to the participants and similar to their studio classes where they generally work. Workshops were conducted separately for the control and experiments groups and both were asked to generate ideas for an electric kettle using hand-drawn sketches on sheets containing charts to be filled in. The procedures of both groups contained two sessions in order to compare pretest and posttest results (Figs. 3, 4). The participants of the control group were asked to generate 32 ideas (16 in the first session and 16 in the second session) in a total of 90 min (45 min for the first session and 45 min for the second session) using their own ways.

Table 2 Contents of the fictionation cards

Considerations	Form	Function	Interaction
New Technologies	What if there were new technologies that are not present in the contemporary world, how would the form of the product be regarding that technology?	What if there were new technologies that are not present in the contemporary world, how would the function of the product change regarding that technology?	What if there were new technologies that are not present in the contemporary world, how would the user interact with the product regarding that technology?
Existing Products	What if the product had an unusual form that is different than the ones in the market, how would the form of the product be?	What if the product had an unusual form that is different than the ones in the market, how would the function of the product change?	What if the product had an unusual form that is different than the ones in the market, how would the user interact with the product?
Production Techniques	What if the contemporary production techniques allowed you to realize anything, how would the product's form be?	What if the contemporary production techniques allowed you to realize anything, how would the function of the product change?	What if the contemporary production techniques allowed you to realize anything, how would the user interact with the product?
Gravity	What if there were no gravity, how would the form of the product be?	What if there were no gravity, how would the function of the product change?	What if there were no gravity, how would the user interact with the product?
Cost	What if there were no economic constraints, how would the form of the product be?	What if there were no economic constraints, how would the function of the product change?	What if there were no economic constraints, how would the user interact with the product?
Sense Organ	What if the user interacted with the product through a different sense organ, how would the form of the product be?	What if the user interacted with the product through a different sense organ, how would the function of the product change?	What if the user interacted with the product through a different sense organ, how would the user interact with the product?
User	What if the product were designed for an extraordinary user, how would the form of the product be?	What if the product were designed for an extraordinary user, how would the function of the product change?	What if the product were designed for an extraordinary user, how would the user interact with the product?
Anthropometric Measurements	What if the anthropometric measurements of the user changed, how would the form of the product be?	What if the anthropometric measurements of the user changed, how would the function of the product change?	What if the anthropometric measurements of the user changed, how would the user interact with the product?

Table 2 (continued)

Considerations	Form	Function	Interaction
Accustomed Interactions	What if there were a different interaction with the product than the accustomed one, how would the form of the product be?	What if there were a different interaction with the product than the accustomed one, how would the function of the product change?	What if there were a different interaction with the product than the accustomed one, how would the user interact with the product?
Purpose	What if the product were designed for an extraordinary purpose, how would the form of the product be?	What if the product were designed for an extraordinary purpose, how would the function of the product change?	What if the product were designed for an extraordinary purpose, how would the user interact with the product?
Place	What if the product were designed for an extraordinary place, how would the form of the product be?	What if the product were designed for an extraordinary place, how would the function of the product change?	What if the product were designed for an extraordinary place, how would the user interact with the product?

Fig. 1 Left: Cards of the Fictionation idea generation tool. Right: Example of a card

Same as the control group, participants of the experiment group were asked to generate 16 ideas within 45 min using their own ways in the first session. On the other hand, they were asked to use the Fictionation tool in the second session. The second session started with a 5 min presentation in which participants were informed about the procedure and usage of the Fictionation tool. Then, they were delivered with the Fictionation cards and asked to select eight. They were left free in either skimming through the cards to read the scenarios on them and choose, or picking the cards randomly. Based on the *what-if* scenarios described on the selected cards, participants were asked to carry out idea generation on distributed sheets, with time kept for a duration of 5 min for each card (Fig. 5).

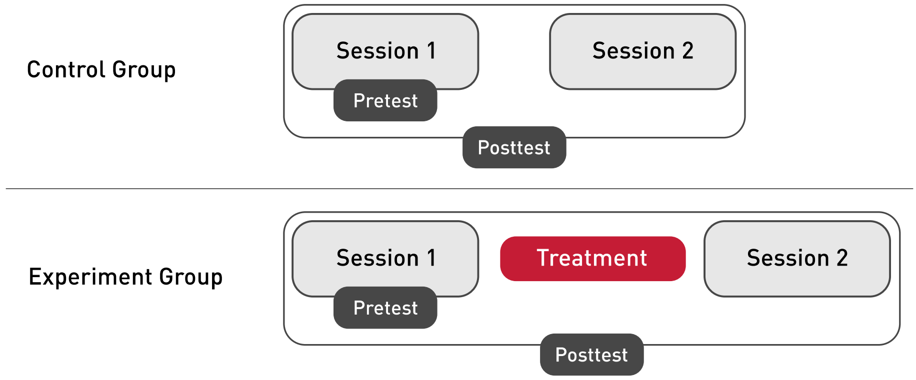

Fig. 2 Pretest–posttest structure of the experiment

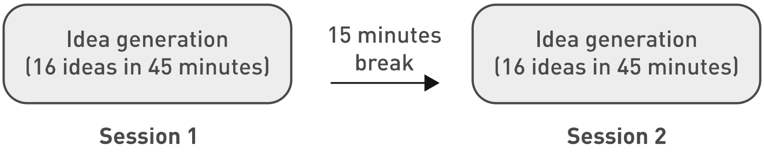

Fig. 3 Procedure of the control group

Fig. 4 Procedure of the experiment group

Fig. 5 A snapshot from the workshop of the experiment group

Data analysis

At the end of the study, 384 sketches (32 sketches × 12 participants) were obtained from the control group (Fig. 6) and 384 sketches (32 sketches × 12 participants) were obtained from the experiment group (Fig. 7).

The two types of data analysis techniques in the literature described for evaluating idea generation are process-based and outcome-based (Jagtap, 2018; Shah et al., 2000). Process-based techniques are used to discover cognitive occurrences within a design process, whereas outcome-based techniques use the outcomes of a design process to see the effect of a treatment (Ericsson & Simon, 1993). In that sense outcome-based techniques are more appropriate to look into the effects of the Fictionation tool. The mostly used outcome-based technique in the literature is the effectiveness measures offered by Shah et al. (2003). However, some flaws were determined in the procedure of the technique (Bayırlı & Börekçi, 2022; Jagtap, 2018; Nelson et al., 2009; Verhaegen et al., 2013) therefore, the RNEV technique offered by Bayırlı and Börekçi (2022) was used to analyze the outcomes of the experiment.

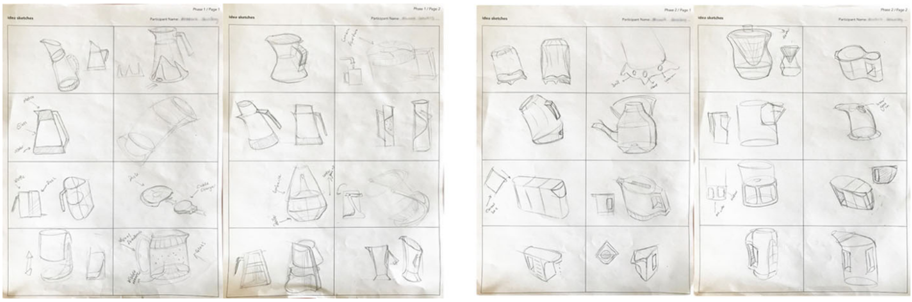

Fig. 6 Sketches of a participant from the control group. Left: Sketch sheets from session 1. Right: Sketch sheets from session 2

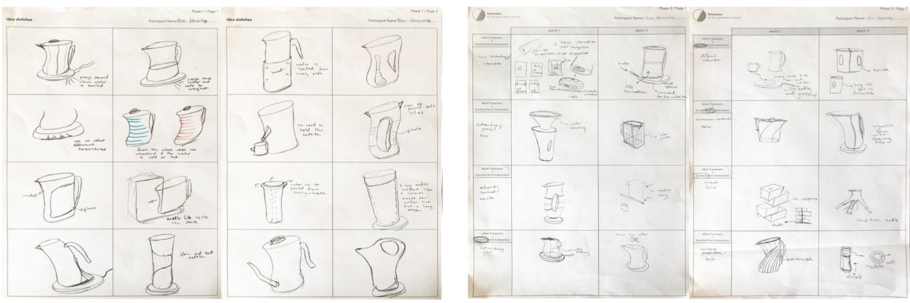

Fig. 7 Sketches of a participant from the experiment group. Left: Sketch sheets from session 1. Right: Sketch sheets from session 2, with a column on the left for the *what-if* scenario

Coding and intercoder reliability

The 768 sketches in total (384 each for the control and experiment groups) were evaluated by three coders using the RNEV technique. First, the sketches were encoded using the FBS ontology (Gero & Kannengiesser, 2014). While coder 1 obtained 39 categories, coder 2 obtained 40 and coder 3 obtained 37 categories (Appendix 1). The intercoder reliability between the coders was calculated using the formula of Miles and Huberman (1994) through calculating the ratio between the number of agreements and the total number of agreements and disagreements. Codes that represent the same concept but in a different way such as *opaque* and *not transparent* were evaluated as an agreement. Reliability values of 0.81 between coders 1 and 2, 0.792 between coders 1 and 3 and 0.789 between coders 2 and 3 were obtained. The mean of these reliability values is 0,797 which can be interpreted as a perfect agreement (Landis & Koch, 1977). Coders then came together and decided on the final categories that constitute the genealogy tree (Shah et al., 2003).

Constructing the genealogy tree

The sketches were placed in the genealogy tree considering their relevant categories. Some sketches were placed under more than one category as they offer information related to multiple categories. For example, the sketch in Fig. 8 was placed under four categories for the ideas of having a *partially transparent body*, *no handle*, *a handheld usage* and *the additional function of making tea.*

At the end, a total of 2539 ideas identified within the 768 sketches were placed under the relevant branches of the tree diagram, distributing into 84 categories. Figure 9 presents the names of the branches (categories) and number of sketches placed under them. At the highest level, the genealogy tree branches into four themes: form, interaction, source, and additional function. 1799 ideas related with the form of the kettle were placed under the theme of *form*, 649 ideas related with the interaction between the user and the product were placed under the theme of *interaction*, 38 ideas related with the source that the product uses were placed under the theme of *source* and 53 ideas offering an additional function to the product other than boiling the water were placed under the theme of *additional function*.

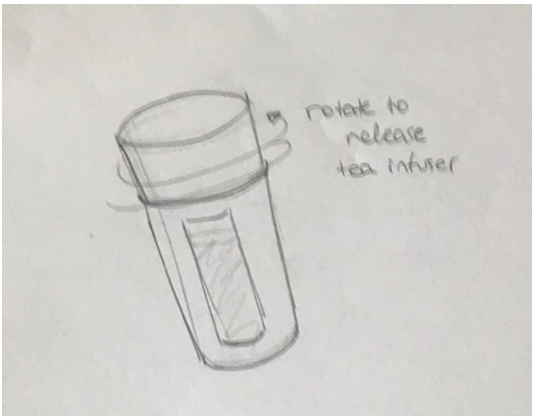

Fig. 8 Example of a sketch with multiple ideas placed under multiple categories

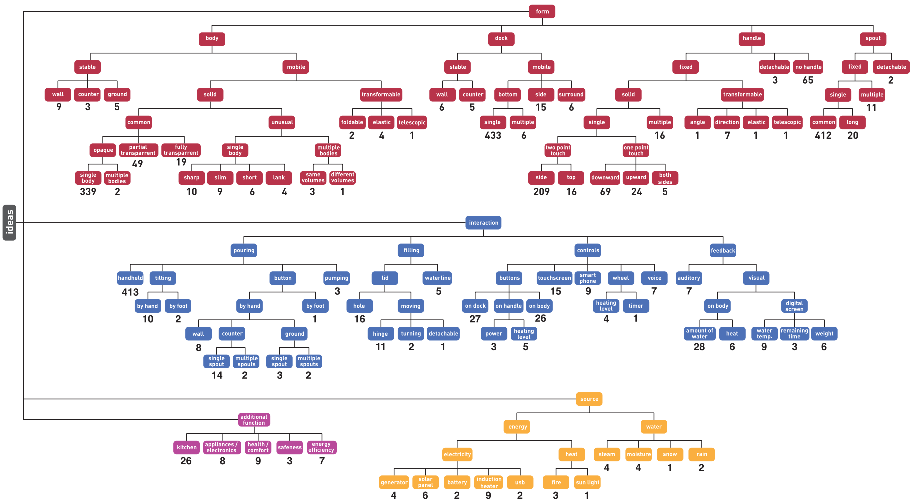

Fig. 9 Breakdown of the genealogy tree representing the distribution of the 2539 ideas identified in the 768 sketches

Novelty scores

The Fictionation tool was tested in terms of its effects on the design outcomes using the RNEV technique (Bayırlı & Börekçi, 2022). For that purpose, first the genealogy tree was divided into sub genealogy trees in which they contain ideas generated within session 1 (pretest) and session 1 + 2 (posttest) for the control and experiment groups separately.

For calculating the novelty scores of the participants, first, the novelty scores of the categories were calculated using formula (1).

$$[(T - S)/T \times 10] \tag{1}$$

While T represents the total number of ideas placed under a corresponding theme, i.e., *form*, *interaction*, *source,* or *additional function*, S represents the total number of ideas that the calculated sub-category includes. For example, the novelty score of the category of *sharp* within the theme of *form* was calculated considering the number of the ideas under the theme of *form*, which was 1799. There were 10 ideas in the category of *sharp*. The novelty score of that category was calculated as ${}^{(1799-10)x10}/_{1799} = 9.944$. Likewise, the novelty score of the category of *hinge* within the theme of *interaction* was calculated considering the number of the ideas under the theme of *interaction*, which was 649. There were 11 ideas in the category of *hinge*. The novelty score of that category was calculated as ${}^{(649-11)x10}/_{649} = 9.831$. The novelty scores of all 84 categories were calculated and the results are presented in Appendix 2.

Using the obtained novelty scores of the categories, the novelty scores of the participants were calculated using formula (2).

$$[(I_1 x S_1) + (I_2 x S_2) + (I_3 x S_3) + \cdots]/_{I_1 + I_2 + I_3 + \cdots} \tag{2}$$

In this formula, I_1 represents the total number of ideas that the participant generated related to a specific category, S_1 represents the novelty score of that category. Novelty scores

Table 3 Pretest and posttest scores of the participants

	Participant #	Pretest		Posttest	
		Novelty (out of 10)	Explored variety (out of 10)	Novelty (out of 10)	Explored variety (out of 10)
Control Group	p1	7.685	3.719	7.716	4.646
	p4	7.733	4.253	7.580	4.843
	p6	7.684	3.373	7.608	3.836
	p7	7.634	2.013	7.520	2.822
	p10	8.088	4.017	7.801	5.621
	p11	7.553	3.042	7.467	4.733
	p15	7.604	1.981	7.548	2.382
	p17	7.682	3.325	7.655	4.182
	p18	7.771	3.160	7.583	3.200
	p20	7.975	4.230	7.627	4.701
	p22	7.972	4.929	7.882	5.291
	p23	7.627	2.649	7.413	2.649
	Mean	7.755	3.391	7.617	4.076
	Std. Deviation	0.169	0.901	0.134	1.083
Experiment Group	p2	8.266	4.434	8.333	6.423
	p3	7.808	4.127	7.983	5.283
	p5	7.377	2.940	8.148	6.164
	p8	7.772	3.381	7.987	4.858
	p9	7.423	2.704	7.914	4.552
	p12	7.451	2.296	8.031	5.731
	p13	7.569	3.593	7.950	5.739
	p14	7.577	3.616	7.821	5.228
	p16	7.896	4.497	8.007	5.786
	p19	7.663	2.783	7.877	4.678
	p21	7.688	3.695	7.916	6.022
	p24	7.974	4.395	8.110	6.093
	Mean	7.705	3.538	8.006	5.546
	Std. Deviation	0.257	0.740	0.138	0.617

of all participants for both the pretest and the posttest were thus calculated, and the results are presented in Table 3.

Explored variety scores

In the context of calculating variety, RNEV technique (Bayırlı & Börekçi, 2022) offers to calculate the proportion of explored solutions of a person within the overall genealogy tree

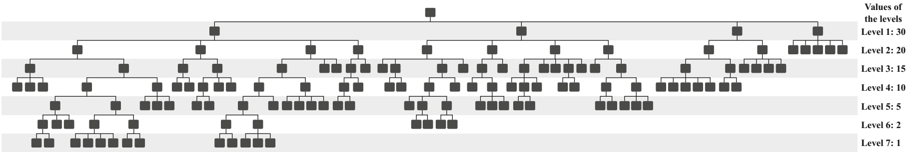

Fig. 10 Reconfigured genealogy tree displaying the same-level branches and level values

(explored variety) in order to overcome the determined flaws (Bayırlı & Börekçi, 2022; Jagtap, 2018; Nelson et al., 2009; Verhaegen et al., 2013) of the effectiveness measures of Shah et al. (2003).

For calculating the explored variety scores of the participants, first the genealogy tree was reconfigured in a way that positioned all themes side-by-side in order to align each level for their branch count (Fig. 10). On the genealogy tree, Level 1 has 4 branches, Level 2 has 15, Level 3 has 28, Level 4 has 34, Level 5 has 28, Level 6 has 11, and Level 7 has 13. The seven hierarchical levels in the genealogy tree were assigned values from top to bottom as 30, 20, 15, 10, 5, 2 and 1 respectively, in order to create greater variety between scores at different levels (Shah et al., 2003). The variety score of the genealogy tree was calculated using formula (3).

$$[(N_1 - 1)xL_1] + [(N_2 - 1)xL_2] + [(N_3 - 1)xL_3] + \cdots \tag{3}$$

In this formula, N represents the total number of branches in a certain level, L represents the value of that level. In this respect, the variety score of the genealogy tree was calculated as: $[(4 - 1)x30]+[(15 - 1)x20]+[(28 - 1)x15]+[(34 - 1)x10]+[(28 - 1)x5]+[(11 - 1)x2]$ $+[(13 - 1)x1] = 1272$.

The variety score of the genealogy tree was used to measure the explored variety scores of the participants by proportioning their exploration within the overall genealogy tree using formula (4).

$$\left(V_p x10\right)/_{V_g} \tag{4}$$

In this formula, V_p represents the variety score of the participant, V_g represents the variety score of the overall genealogy tree. For example, during the pretest, Participant 1 (p1) proposed ideas for the overall genealogy tree, marked in red (Fig. 11). However, since these idea categories are connected to the upper levels, p1 has also automatically offered ideas for the categories marked in blue. Therefore, the categories marked in both red and blue are counted while calculating the variety score. The categories that are marked in black are those for which p1 did not offer any idea. In that sense, the variety score of p1 is calculated using Formula (3) as $[(3 - 1)x30]+[(9 - 1)x20]+[(9 - 1)x15]+[(10 - 1)x10]+[(8 - 1)x5]+$ $[(4 - 1)x2] + [(3 - 1)x1] = 473$

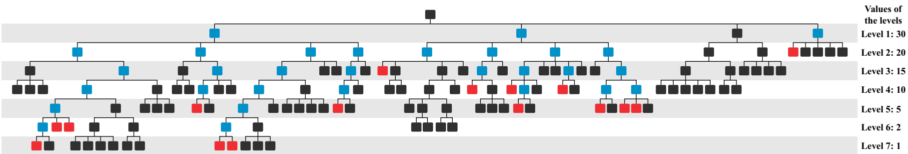

Fig. 11 Genealogy tree of P1 within pretest

The explored variety score of p1 is calculated using Formula (4) as $(473x10)/1272 = 3.719$. Explored variety scores of all participants for both the pretest and the posttest were thus calculated, and the results are presented in Table 3.

Results and discussion

The results of the analysis include the genealogy tree of the entire pool of design ideas generated for the pretest and posttest by both participant groups (control and experiment), individual genealogy trees of all participants, novelty scores of the genealogy tree categories, individual novelty scores of all participants, variety scores of the genealogy tree, and explored variety scores of all participants. The means and standard deviations for the pretest and posttest novelty and explored variety scores were also calculated for both groups. This allowed a comparison of the scores for an effect of the treatment, as well as the visualisation of the design solution spaces for the reflection of dimensional changes.

Comparing the scores

Comparing the pretest and posttest novelty scores, it is seen that for the control group 11 out of 12 participant scores decreased, whereas all the participant scores of the experiment group increased. Cohen's *d* results present that there is a -0.9073 effect between pretest and posttest novelty scores of the control group and there is a 1.4587 effect between pretest and posttest novelty scores of the experiment group. Considering the benchmarks suggested by Cohen (1988), the results show a negative large effect between the pretest and posttest results of the control group and a positive large effect between the pretest and posttest results of the experiment group. The decrease in the novelty scores of the control group participants can be attributed to the situation in which the participants used all of their novel ideas within the first session and ran out of novel ideas in the second session. On the other hand, the increase in the novelty scores of the experiment group participants can be attributed to the Fictionation idea generation tool. Furthermore, the number of the ideas that took place under the categories having a novelty score higher than 9.900 did not change between the sessions for the control group (55 for the first session and 55 for the second session). On the other hand, this number increased from 50 to 111 between the sessions for the experiment group. In that sense, it is possible to claim that the Fictionation idea generation tool enabled the participants to offer more novel ideas.

Comparing the pretest and posttest explored variety scores, the results show that the increase in the explored variety scores of the experiment group participants is bigger than those of the control group participants. Cohen's *d* results present that there is a 0.6870 effect between pretest and posttest explored variety scores of the control group and a 2.9462 effect between pretest and posttest explored variety scores of the experiment group. Besides, while eight new idea categories were determined between the pretest and posttest of the control group, this number was 27 for the experiment group. Therefore, the experiment group performed a bigger leap in terms of offering new ideas that took place under new categories compared to the control group. In that sense, it is possible to claim that the Fictionation idea generation tool enabled the participants to offer more various ideas.

Design solution space visualizations

The development of the genealogy tree allowed for the same information to be represented as a design solution space. While looking for the effect of the treatment, instead of presenting a shift between design solution spaces of pretest and posttest results, presenting a dimensional change in terms of growth or decrease would be more meaningful. A series of visualizations (entire design solution space, pretest and posttest design solution spaces for control and experiment groups separately) were generated in order to inspect the changes in the dimensions of the pretest and posttest design solution spaces in reference to the overall design solution space.

In the generated visuals, the circles represent the categories and sub-categories of the genealogy tree and the numbers in them indicate the number of the ideas within that category. As categories contain more ideas, their circle sizes increase, and they approach the centre of the design solution space; this means ideas in these categories are commonly explored and close in distance. By contrast, as categories contains fewer ideas, their circle sizes become smaller and they approach the outer boundaries of the design solution space. These small circles are those that enlarge the boundaries of the design solution space by containing novel ideas, different than and distant to those that are more commonly explored and located centrally within that space.

Figure 12 represents the overall solution space comprising the whole of the ideas generated by both the control and the experiment groups. Furthermore, the pretest and posttest design solution spaces represented in Figs. 13 and 14 show the alteration between the covered areas, which means the explored alternatives among the control and experiment groups. While the design solution space of the control group enlarged only slightly between the pretest and posttest (Fig. 13), a quite large enlargement is visible when the pretest and posttest solution spaces of the experiment group are compared (Fig. 14). The number of circles has increased (alternative categories are explored, indicating variety), and the boundaries of the space has enlarged (the categories break down into further sub-categories, diverging from the centre, indicating novelty). In that sense, it is possible to claim that the Fictionation idea generation tool enabled the participants of the experiment group to achieve more comprehensive design solution spaces compared with those achieved by the control group.

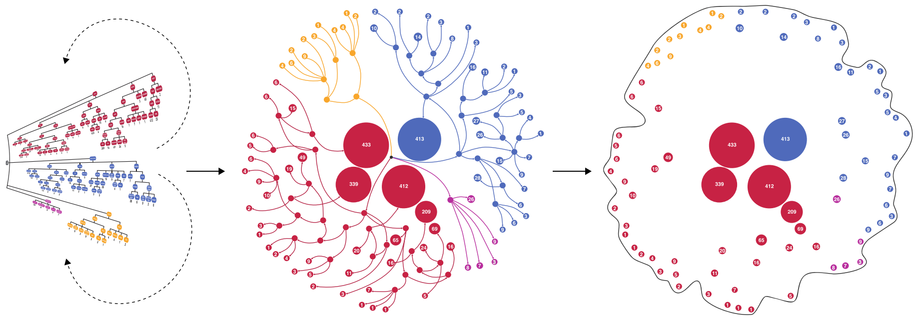

Fig. 12 Design solution space visualizations of the genealogy tree. Left: Transitioning genealogy tree. Center: Categories with branches to sub-categories, hierarchically clustering in a space set. Right: Categories without their branches to sub-categories, forming the boundaries of the set

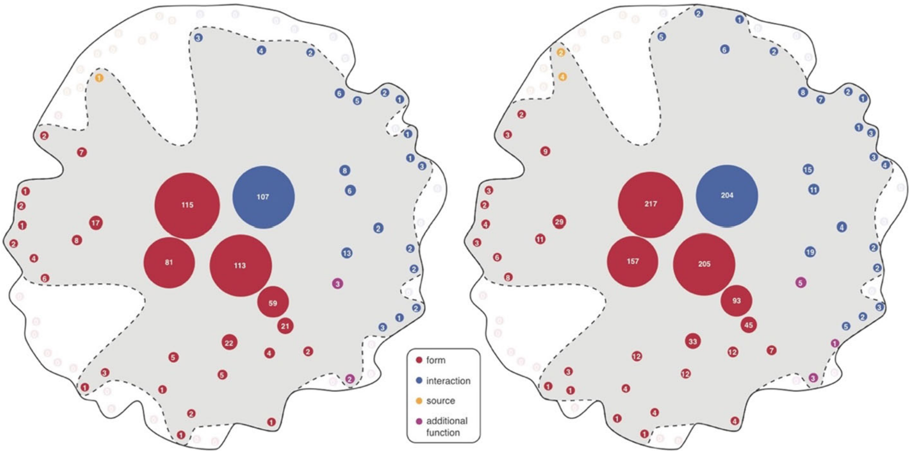

Fig. 13 Design solution space visualizations of the control group. Left: Pretest. Right: Posttest

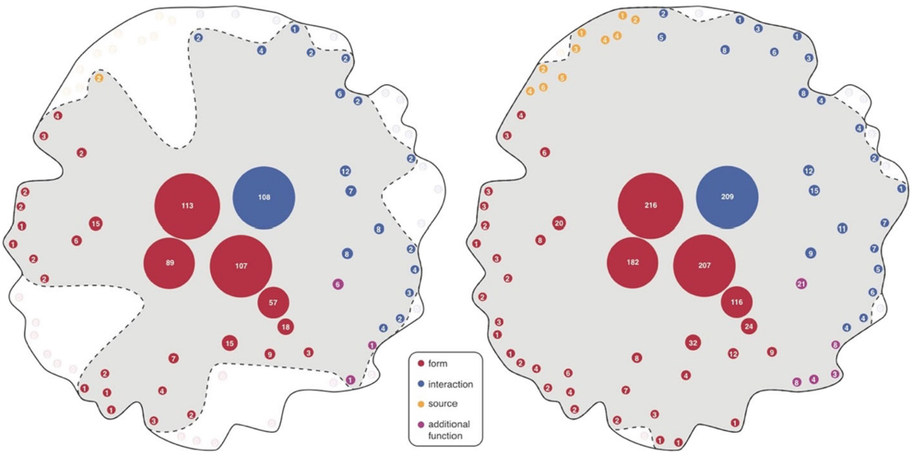

Fig. 14 Design solution space visualizations of the experiment group. Left: Pretest. Right: Posttest

Conclusion

This article presents the development and evaluation processes of Fictionation, a card-based idea generation tool that serves as an idea triggering stimuli. The implications of the study are twofold. Firstly, the results of the study made for evaluating the tool suggest that Fictionation was successful in increasing the performance of design students in terms of novelty and explored variety. The results also reveal the significance of *illogical thinking* for idea generation provided in this tool through the design fiction approach. Secondly, according to Hallinan (1994), Adodo and Agbayewa (2011) and Uysal and Banoğlu (2018), in order to reach an efficient teaching and learning environment, the academic success of students should be increased and a more homogenous student group should be obtained. Considering the mean scores and standard deviations of the control and experiment groups obtained from the pretest and posttest, the Fictionation idea generation tool can be evaluated as successful in creating an efficient teaching and learning environment by increasing the academic success of the students (*mean scores* of novelty and explored variety increased significantly between pretest and posttest results in the experiment group) and creating a more homogeneous student group by serving a narrower width between the best and the worst student in terms of academic success (*standard deviations* of novelty and explored variety both decreased between pretest and posttest results in the experiment group).

It should be noted that the proposed Fictionation tool is tested within a narrow group using a simple design problem. The participants of the study were students who can be considered as novice designers; hence, it would be expected for them to derive maximum benefit from a stimulus. Therefore, in order to increase the reliability of the findings and generalize the results to design education and practice in a broader sense, new experiments with complex design problems and that include bigger and different samples such as professional designers with higher levels of expertise would be recommended.

Appendix 1. Proposed categories by the coders

Coder 1	Coder 2	Coder 3
Opaque body	Not transparent	Opaque
Transparent body	Transparent	Glass body
Partially transparent body	–	Transparent parts
Sharp outer form	Sharp edges	–
Touchscreen	Control with touchscreen	Touchscreen
Buttons	Control with buttons	Buttons to control heat
Different heating levels	Adjust heating degree	Various heating degrees
Dock	Have a dock	Bottom dock
–	–	Side dock
Stable onto the wall	Stable on the wall	Wall mounted
Classical handle	Two-point handle	–
–	Handheld	–
Tilting	Pour by tilting	Tilting body
–	Stable on the counter	Mounted on the counter
No handle	No handle	No handle
Gives sound signal	Sound signal	–
Long spout	Has a long spout	Long spout
–	–	Ordinary spout
Heating food	It heats meal	–
Have a hinge at lid	Has a lid	Lid with hinge
Slim outer form	–	Slim body

Coder 1	Coder 2	Coder 3
Chargeable dock	Chargeable dock	Chargeable dock
Two handles	Has two handles	Two handles
–	Control with phone	Mobile phone controlled
Multiple spout	Has various spouts	–
Measures weight	It measures weight	–
Making tea	–	Makes tea
–	Has a digital screen	–
Has an opening on the lid	Has an opening to fill water	–
Induction heater	–	Induction cooker
–	–	Mounted to the ground
–	–	Has a big container
–	Short body	–
Usb powered	Working with usb	–
Surrounding dock	–	–
Pumping to pour water	Has a pump to pour water	Has a pump
Multiple body parts	Multiple body	Various body units
–	Lank body	–
–	–	Elastic body
Downward handle	One-point handle	Downward handle
Upward handle	–	Upward handle
Pressing button to pour water	–	Pour by pressing button
Speaks with the user	Has a speaker	–
Gets energy by motion	Powered by generator	–
Solar panel	Solar panel	Solar panel
Heat with fire	Fire	Fire heated
–	Steam	Steam to water
Collects moisture	Moisture	Moisture to water
–	Rain	–
Light source	Lighting	Gives light
–	–	Watch tv
Air humidifier	Air humidifier	Air humidifier
Thermos like surface	Thermos	Thermos body

Appendix 2. Novelty scores of the categories

Form		Interaction		Source		Additional function	
Body/wall	9.950	Handheld	3.636	Generator	9.984	Kitchen	9.898
Body/counter	9.983	Tilting/by hand	9.846	Solar panel	9.976	Appliances/electronics	9.968
Body/ground	9.972	Tilting/by foot	9.969	Battery	9.992	Health/comfort	9.965
Single body	8.116	Wall	9.877	Induction heater	9.965	Safeness	9.988
Multiple bodies	9.989	Counter/single spout	9.784	USB	9.992	Energy efficiency	9.972
Partial transparent	9.728	Counter/multiple spouts	9.969	Fire	9.988		
Fully transparent	9.894	Ground/single spout	9.954	Sun light	9.996		
Sharp	9.944	Ground/multiple spouts	9.969	Steam	9.984		
Slim	9.950	Button/by foot	8.885	Moisture	9.984		
Short	9.967	Pumping	9.954	Snow	9.996		
Lank	9.978	Hole	9.753	Rain	9.992		
Same volumes	9.983	Hinge	9.831				
Different volumes	9.994	Turning	9.969				
Body/foldable	9.989	Detachable	9.985				
Body/elastic	9.978	Waterline	9.923				
Body/telescopic	9.994	On dock	9.584				
Dock/wall	9.967	Power	9.954				
Dock/counter	9.972	Button/heating level	9.923				
Dock/single	7.593	On body	9.599				
Dock/multiple	9.967	Touchscreen	9.769				
Dock/side	9.917	Smart phone	9.861				
Dock/surround	9.967	Wheel/heating level	9.938				
Handle/side	8.838	Timer	9.985				
Handle/top	9.911	Voice	9.892				
Downward	9.616	Auditory	9.892				
Upward	9.867	Amount of water	9.569				
Both sides	9.972	Heat	9.908				
Handle/multiple	9.911	Water temperature	9.861				
Angle	9.994	Remaining time	9.954				
Direction	9.961	Weight	9.908				
Handle/elastic	9.994						
Handle/telescopic	9.994						
Handle/detachable	9.983						
No handle	9.639						
Spout/common	7.710						

Form		Interaction	Source	Additional function
Long	9.889			
Spout/multiple	9.939			
Spout/detachable	9.989			

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Data availability The data that support the findings of this study are not available because survey respondents and interviewees were assured raw data would remain confidential and would not be shared.

Code availability Not applicable.

Declarations

Conflicts of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval All participants gave written informed consent to participate in the study and publish the results.

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