DEVELOPMENT OF PORTABILITY DESIGN HEURISTICS

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Abstract

Product portability is defined as a product's ability to be easily and safely carried and be used in a variety of situations without increasing the user's effort and workload. Product portability can greatly enhance human experience during product use, and, thus, is set to be a design goal in many design pro projects. Despite the importance, however, systematic methods that guide realizing portability during the product concept design stage do not seem available at this time. To address the lack of design tools, this study presents a set of ready-to-use design heuristics for realizing product portability and a new brainstorming-based design method that utilizes the design heuristics. An example design problem and solution alternatives developed on the basis of the design heuristics and the design method are presented for the illustration purpose. The portability design heuristics are expected to greatly facilitate creating various portable systems.

Keywords: Conceptual design, Design methodology, Design methods, Design heuristics, Product portability

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1 INTRODUCTION

Portable products are increasingly utilized as they help enhance human lives in various contexts. For example, currently, numerous people use mobile devices to efficiently perform daily tasks, such as checking emails, communicating with co-workers, making reservations, shopping, etc. Also, various wireless sensors are being developed to build portable products that realize ubiquitous healthcare. Such portable products are considered to be the key element of real-time patient monitoring, which is expected to enable early detection of symptoms and diagnoses, and, therefore, timely interventions (Gay and Leijdekkers, 2007; Park and Jayaraman, 2003).

Despite the wide use of portable products and their apparent benefits, however, little research has been conducted concerning the design of portable products. To the authors' best knowledge, design theories, methods or tools specifically for realizing product portability are not available at this time. This is problematic as it hampers effectively and efficiently developing portable products.

As an effort towards addressing the aforementioned problem, this study presents a set of portability design heuristics developed through analyzing existing portable systems and also introduces a new product design method based on the heuristics set.

A design heuristic is a specific design strategy using readily accessible information to guide problem solving (Pearl, 1984). Multiple existing design tools provide general design heuristics for artifact design; such design tools include TRIZ (Altshuller, 1996), Design Heuristics (Daly et al., 2010; Daly et al., 2012a; Yilmaz and Seifert, 2010; Yilmaz et al., 2011a; Yilmaz et al., 2014), SCAMPER (Eberle, 1996), lateral thinking (de Bono, 1970) and transformation design theory (Singh et al., 2007; Weaver et al., 2008; Weaver et al., 2010). However, the existing design heuristics were not developed specifically for supporting the design for portability; and, thus, their usefulness for designing portable products has not been evaluated to date.

2 LITERATURE REVIEW

2.1 Design of portable products

A previous study has proposed criteria for portable products (Mital et al., 1989). According to Mital et al. (1989), a portable product must be moved from one place to another without requiring mechanical aids, be carried around without causing excessive fatigues and be resistant to damages during its use and transportation. The design of portable products can be challenging as it needs to satisfy multiple criteria. Despite the difficulty, however, the design of portable products has not been extensively investigated, and, few design methods/tools specifically for realizing product portability seem currently available.

2.2 Design ideation methods

Various ideation methods have been developed to support general design problem solving. They include: lateral thinking (de Bono, 1970), SCAMPER (Eberle, 1996), transformation design theory (Singh et al., 2007; Weaver et al., 2008; Weaver et al., 2010), TRIZ (Altshuller, 1996) and Design Heuristics (Daly et al., 2010; Daly et al., 2012a; Yilmaz and Seifert, 2010; Yilmaz et al., 2011a; Yilmaz et al., 2014).

Lateral thinking (de Bono, 1970) is a collection of ideation methods for "thinking outside the box." It helps designers to look at a problem from unorthodox perspectives and generate non-obvious ideas. The lateral thinking methods utilize "provocations" to disrupt conventional thinking.

SCAMPER (Eberle, 1996) is an extension of the Osborn's checklists (1953) and provides a set of design heuristics for design problem solving. Its design heuristics are: substitute, combine, adapt, modify, put to other uses, eliminate and reverse/rearrange.

Transformation design theory offers a set of transformational principles and facilitators for developing transforming/state-changing products. The principles describe different ways in which transformation is achieved and the facilitators are design constructs that aid in transformation (Weaver et al., 2010). The transformation design theory was established by constructing a database of existing transformers (products, patents and biological examples) and identifying the principles and facilitators using both induction and deduction.

TRIZ is a collection of problem solving tools developed through extensive analyses of over two hundred thousand patents across many different fields (Altshuller, 1996; Fey and Rivin, 2005; Otto and Wood, 2001). It provides a variety of heuristics for solving problems represented in the form of contradictions. TRIZ is known to help designers efficiently develop innovative solutions for difficult problems (Altshuller, 1996).

Design Heuristics were developed by analyzing past award-winning innovative products and identifying recurring solution principles (Daly et al., 2012b). In a manner similar to the design heuristics of TRIZ, the design tool provides a total of 77 design heuristics. They were intended to help designers better explore solution spaces and develop non-obvious solutions. Empirical investigations demonstrated that the Design Heuristics were effective at generating a large set of distinct design solutions for different design problems (Daly et al., 2012b; Yilmaz and Seifert, 2010; Yilmaz and Seifert, 2011b; Yilmaz et al., 2014). The Design Heuristics were provided in heuristic cards, each of which contains a descriptive title and instructions on how to use the heuristic in solving design problems (Kramer, 2014).

While the existing ideation methods described above are known to be useful for solving design problems in general, their utility for portable product design has not been evaluated.

3 THE PORTABILITY DESIGN HEURISTICS

This study provides a set of design heuristics for creating portable products. In what follows, detailed descriptions on how the heuristics were established, what they are, how they can be utilized for design problem solving are presented along with illustrative examples of their applications.

3.1 Development of the portability design heuristics

In this study, a three-step procedure based on the inductive approach was employed to develop the portability design heuristics. The inductive approach involves an empirical study of existing products/systems in developing relevant heuristics (Altshuller, 1996; Keese et al., 2007; Weaver et al., 2010; Daly et al., 2012a). The heuristics development process is described in Figure 1.

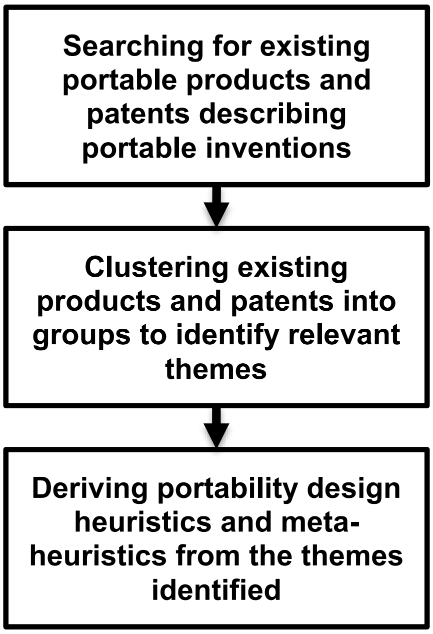

Figure 1.The procedure for identifying portability design heuristics and meta-heuristics

The process started by searching for existing portable products and patents describing portable inventions. Descriptions of existing portable products were found by keyword searches using the internet search engines (i.e., Google and Naver) and multiple text materials (i.e., online magazines and books). The patent documents on portable design were also collected from the US Patent and Trademark Office (UPSPTO) database, the single largest national collection of patents and published applications. Keywords, such as “portable,” “convenient,” and “handy” were used for searching for both existing products and patent documents. Descriptions of about 150 existing products and patent documents were collected and examined for this study.

The descriptions of the existing products/patents were analysed and a summary in a standardized format was generated for each. The standardized format consists of items, such as limitations of the product's precedents, visual and verbal descriptions of the product and the underlying ideas for realizing portability. Summarizing the raw data in the standardized format assisted in fully understanding the existing products and inventions (Ross, 2006).
The existing products and patents were grouped according to similarity using the KJ method – the procedure of the KJ method is depicted in Figure 2. The KJ method is widely used to organize large, unordered qualitative data and discover patterns and meanings in an inductive manner (Kawakita, 1991).
After the grouping, each group of products and patents was examined to identify the common underlying theme and design heuristics were established accordingly.

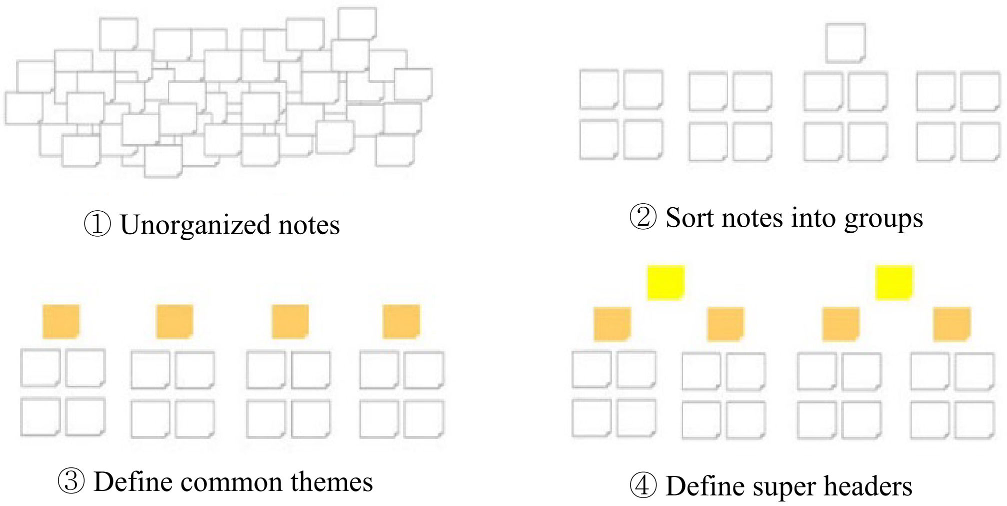

Figure 2. The general procedure of the KJ method

Figure 3 shows some existing products that led to a portability design heuristic through the grouping process described above. The portable microwave in Figure 3(a) has a handle on top. The handle makes it easier to hold and carry the product. Figure 3(b) shows an iron-like bread toaster, which has a flat surface for baking one side of bread. The toaster is given the shape of a clothes iron with a grip attached for ease of use. In Figure 3(c), a console game controller is integrated into a handheld gaming device in a manner conducive to holding. The example products shown in Figure 3 were clustered into a group, and, then, a design heuristic, "Provide grips/handles for portability," was established as they all capitalized upon the use of grips/handles to enhance portability.

(a) (b) (c)

Figure 3. Example products clustered into a group

The heuristics resulting from the grouping analysis can be grouped again according to similarity so as to define higher-level heuristics (Figure 2). Such higher-level heuristics were termed meta-heuristics. For example, three heuristics, "Transform," "Segment," and "Use nesting" could be grouped together to yield a higher-level heuristic, "Shrink in size."

3.2 Design heuristics and meta-heuristics for portable product design

A total of 27 heuristics and 8 meta-heuristics for designing portable products were determined from the process described in the previous section. They are provided in Table 1.

Table 1. Meta-heuristics and heuristics for portable product design

Meta-heuristic	Heuristic	Description
Shrink in size	Transform	Transform an object for easy carriage (e.g. fold, roll, transform, etc.)
	Segment	Divide an object into independent parts or make an object sectional
	Use nesting	Place one object inside another
Use advanced materials	Utilize elasticity	Use elastic materials
	Select waterproof materials	Use new materials which are waterproof
	Select flexible materials	Replace customary constructions with flexible material
	Select light materials	Use materials light enough to hold with hand(s)
Add protection	Use rigid outer protection	Provide rigid outer protection to improve portability
	Provide within a container	Store the content inside a container protecting from external stresses
Extract	Utilize what is already portable	Extract parts from an object and integrate them to what is already portable
	Extract essential parts	Extract only essential parts/properties from an object to maintain original functionality
Universalize	Standardize	Standardize products, components and interfaces
	Provide an intermediary or a connector	Provide an intermediary/connector
	Use multiple connectors	Provide ways for interfacing with multiple devices/elements
Provide power supply	Include battery	Store energy in batteries and use them as energy source
	Provide energy through harvesting	Provide energy through harvesting as power source
	Convert energy	Convert energy to generate power
Simplify	Organize/unclutter	Group objects performing related functions
	Combine into one	Combine multiple entities with different functions into one entity
	Reduce unnecessary parts	Reduce unnecessary parts while maintaining original functionality
	Add multiple functions	Add multiple functions to a single object
Provide ease of use	Reduce stress	Reduce stresses on the human body
	Provide grips/handles	Attach grips or handles
	Attach wheels	Attach wheels to an object
	Provide adjustability	Provide adjustability to enhance flexibility
	Use fixture	Fixate not to fall down and get damaged
	Attach to body parts	Design a product to be a wearable

3.3 Application of the portability design heuristics and meta-heuristics

The portability design heuristics and meta-heuristics shown in Table 1 provide insights of how products can be designed to offer portability, and, thus, could assist designers in exploring the solution space for a given portability design problem. As a means for effectively utilizing the heuristics and meta-heuristics, this study proposes using a booklet detailing them (Figure 4) as reference during a brainstorming session. The booklet describes the design heuristics and meta-heuristics, and contains verbal and visual descriptions of corresponding example products and patents.

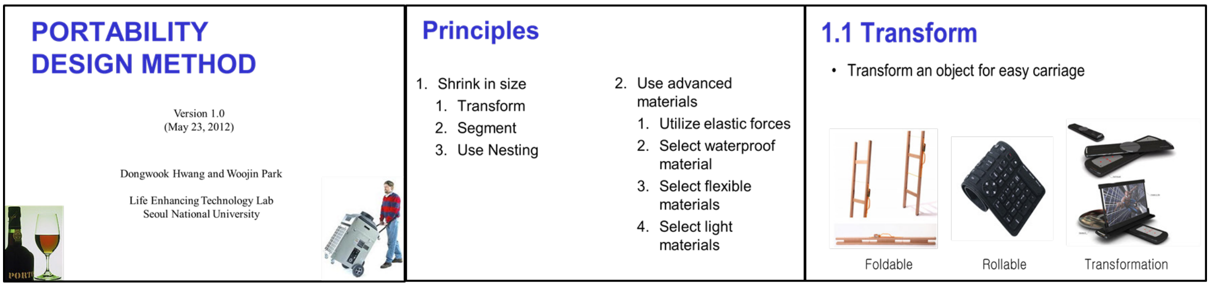

Figure 4. The booklet of the portability design heuristics

A brainstorming session consists of three phases: the idea purge, idea triggering and idea evaluation phases. During the idea purge phase, a design problem is stated clearly to the design team. Each individual in the design team quickly writes ideas on a sheet of paper, which are solution alternatives or related concepts. Then, during the idea triggering phase, the participating individuals go through the ideas from the idea purge phase and combine, connect or improve them to trigger new ideas. Traditionally, no idea-spurring stimuli are given to the individuals to assist in triggering new ideas. However, in our proposed brainstorming method, the booklet is provided to the individuals as such stimuli. During the idea triggering phase, individuals are encouraged to study the design heuristics, meta-heuristics and examples in the booklet and utilize them as references in generating solution ideas. The contents of the booklet are expected to improve idea triggering. The use of heuristics/meta-heuristics is thought to support generating diverse new ideas by enabling “thinking outside the box” (Yilmaz and Seifert, 2011b). The idea triggering phase continues until no more new ideas are generated. Lastly, during the idea evaluation phase, the designer team evaluates the generated solution alternatives and selects one or a few good ones as the recommended solutions.

In the brainstorming process above, the booklet is provided to the designers at the beginning of the idea triggering phase after the completion of the idea purge phase. This was based on the findings of Tseng et al. (2008). According to Tseng et al. (2008), timing of when idea-spurring stimuli are given can affect ideation performance – in their study, individuals who received stimuli at the middle of an ideation session were found to generate more distinct and novel solutions than those at the beginning. It is possible that receiving stimuli at the beginning of an ideation session leads to design fixation.

3.4 Design problem solving example

To illustrate the use of the portability design heuristics and meta-heuristics, the brainstorming process presented in Section 3.2 was employed to solve an example portability design problem. The design problem was to create a next-generation cup noodle that is significantly more portable than the existing cup noodle products while retaining all the functions of the existing products. The problem statement was as follows:

“Currently, the instant cup noodles are already portable compared with the noodle soups served at restaurants. A food company wishes to improve its cup noodles’ portability to the next level so that their next products can have major competitive advantages in the market. The new portable cup noodle design must enable customers to safely and comfortably carry as many units as possible while traveling and use them in any conditions/situations. The new design solution should be inexpensive and convenient to use. The new design solution should not compromise the product quality in terms of appearance and flavor.”

Eight male and eight female Seoul National University students participated in solving the design problem. Having participated in an ideation workshop, they were familiar with the use of brainstorming for generating design alternatives. Each participant conducted ideation based on the brainstorming process presented in Section 3.2. The booklet was provided to each participant at the beginning of the idea triggering phase.

A variety of conceptual designs were generated from the ideation session. In what follows, some of the solutions are presented as examples, along with the design heuristics utilized.

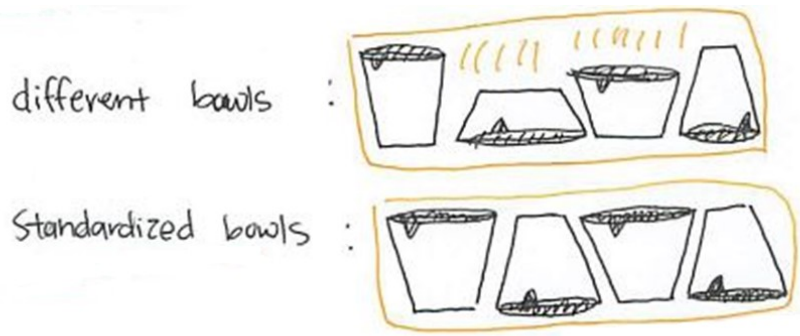

Figure 5. An example solution based on the design heuristic "Standardize"

The concept in Figure 5 is generated based on the design heuristic "Standardize." When storing multiple cup noodles in a space, standardizing the bowl size and shape can reduce wasted space.

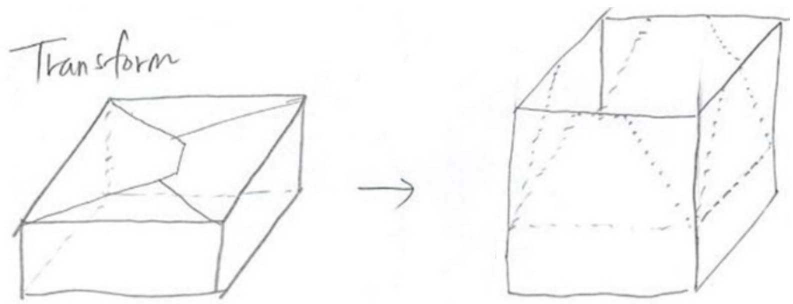

Figure 6. An example solution based on the design heuristic "Transform"

The concept in Figure 6 resulted from the design heuristic "Transform." When in use, the top lid of the new cup noodle bowl is unfolded to create extra space for water and content. The bowl is box-shaped, which facilitates storing multiple units with little waste of space.

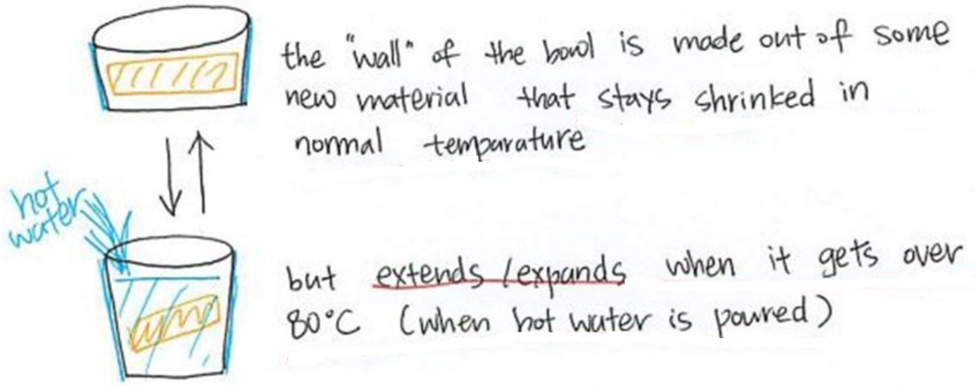

Figure 7. An example solution based on the design heuristics "Transform" & "Select flexible material"

The new cup noodle design presented in Figure 7 was based on the design heuristics "Transform" and "Select flexible material." The container is made of a shape-changing material which expands when hot water is poured into it.

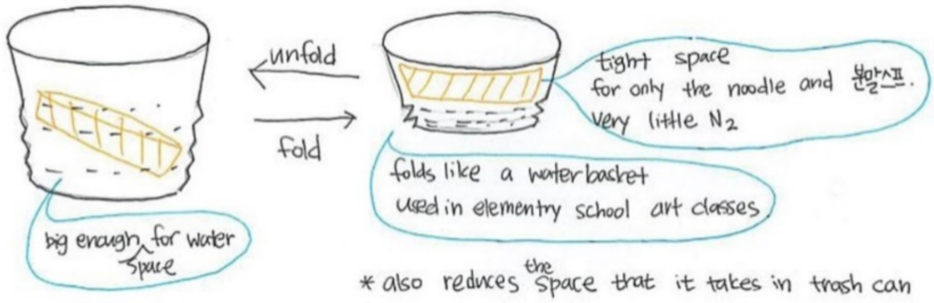

Figure 8. An example solution based on the design heuristics “Transform” & “Provide adjustment”

The “retractable container” concept shown in Figure 8 was generated based on the design heuristics “Transform” and “Provide adjustment.” The new cup noodle bowl was folded to save space, and it was unfolded to create enough space for pouring water and the rest of content. The height of unfolded bowl could be adjusted to reduce the unnecessary space in the bowl.

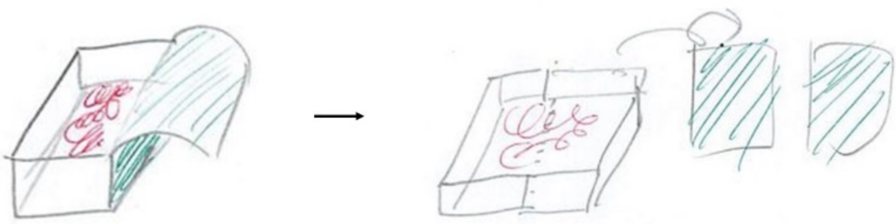

Figure 9. An example solution based on the design heuristics “Provide within a small container” & “Combine into a piece”

The design heuristics, “Provide within a small container,” and “Combine into a piece” were used to create a new design of portable cup noodle (Figure 9). The noodle was stored in a box-shaped container which accounted for the half of the volume of a noodle product; another noodle box could be put together into a piece.

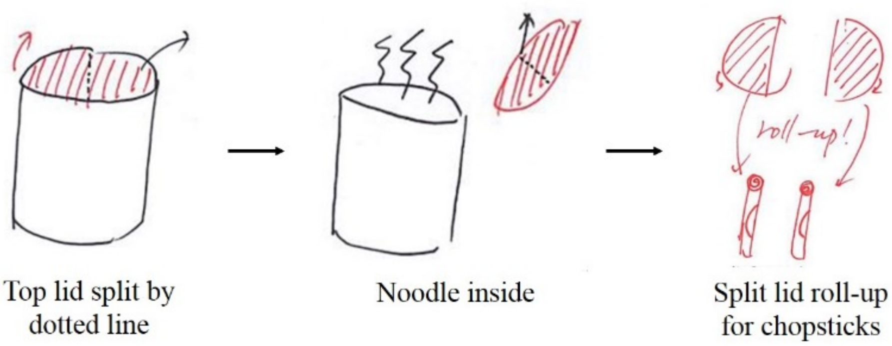

Figure 10. An example solution based on the design heuristics “Segment” & “Transform” & “Utilize what is already portable”

Three design heuristics, that is, “Segment,” “Transform,” and “Utilize what is already portable” were used together to create the concept in Figure 10. The top lid was split into two parts; each split lid was rolled up to be utilized as chopsticks. The lid was segmented from the bowl and transformed into a chopstick. This eliminates the needs for carrying chopsticks.

4 DISCUSSION & CONCLUSION

In this study, we proposed a set of design heuristics and meta-heuristics for realizing portability in product design. The portability design heuristics were extracted from a database consisting of descriptions of existing products and patents. An ideation process, which is an extension of the brainstorming method, was proposed to be used in combination with the portability design heuristics. It is expected that the portability design heuristics will help designers enhance their design performance supplementing lack of knowledge and experience.

Some limitations of the current study and future research directions are provided in what follows: first, the design heuristics and meta-heuristics were developed based on data collected from only 150 available products or patent documents. Analysing more existing products and patent documents is needed to discover other possible heuristics. Second, the meta-heuristics found in this study could be analysed with a deductive approach so as to generate more specific design heuristics. The use of deductive approach that was previously introduced in the transformation design theory (Weaver et al., 2010) might lead to finding new heuristics which could not be found by using the inductive approach alone. Third, a comparison between the portability design heuristics developed from the current study and the general design heuristics of the existing design tools, such as TRIZ, Design Heuristics and SCAMPER, is necessary for the future work. Finally, the current study did not validate the utility of the proposed heuristics and ideation method on an empirical basis. An empirical evaluation is currently underway.

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