FORMING A METHOD MINDSET: THE ROLE OF KNOWLEDGE AND PREFERENCE IN FACILITATING HEURISTIC METHOD USAGE IN DESIGN

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ABSTRACT
Both systematic and heuristic methods are common practice when designing. Yet, in teaching students how to design, heuristic methods are typically only granted a secondary role. So, how do designers and students develop a mindset for using heuristic methods? In this paper, we study how prior knowledge (about heuristic methods and their usage) and preference (for using heuristic methods) relate to the reported use of heuristic methods when designing. Drawing on a survey among 304 students enrolled in a master-level course on design theory and methodology, we investigated method usage for five activities in the basic design cycle: (1) analysis, (2) synthesis, (3) simulation, (4) evaluation and (5) decision-making. The results of the study showed that knowledge and preference both influence method usage. Additionally, the results showed that for all activities except evaluation, knowledge indirectly influenced method usage through a 'complementary' mediation of method preference.

Keywords: Heuristics, Method mindset, Method teaching

1 INTRODUCTION

Rules of thumb and heuristics are indispensable when designing. The use of heuristic methods aids designers to effectively take decisions and – in many cases – keep going in situations of high uncertainty and/or information overload [1]. They also allow designers to navigate through large solution spaces; for example, when narrowing in on a particular aspect of a design task through a 'primary generator' [2] or by making conjectures (propositions) about the final solution prior to analyzing its underlying problem [3]. Given this, teaching students to use heuristics and rules of thumb would constitute a natural part in design and engineering education. Yet, heuristic methods are typically given a secondary role in teaching students how to go about when designing. The present study addresses this dichotomy in design.

We approach the use of heuristics through the idea of a *method mindset*. Andreasen [4] argues that a proper mindset is an important prerequisite to use a method effectively. He recognizes that possessing sufficient theoretical and practical knowledge about a method constitutes an important first step in forming a proper mindset. Knowledge in many ways determines the extent to which designers are able to use a method to their benefit. Additionally, Person, Daalhuizen and Gattol [5] found that *preference* (for using a method) influences method usage as well and is part of method mindset as well. It follows that in order to alter students' method usage to incorporate more heuristics and rules of thumb, educators need to put extra emphasis on the development of their students' heuristic method mindset.

In this paper, we test the proposition that a method mindset is a precursor to the use of heuristic methods. In particular, we study how prior *knowledge* (about heuristic methods and their usage) and *preference* (for using heuristic methods) relate to the reported use of heuristic methods when designing. Drawing on a survey among 304 students participating in a master-level course on design theory and methodology, we investigate method usage for five activities in the basic design cycle [6]: (1) analysis, (2) synthesis, (3) simulation, (4) evaluation and (5) decision-making. The goal of our analysis is to understand how knowledge and preference contribute to the use of methods for different types of design activities.

The contribution of our study is two-fold. First, we add to a new, yet growing body of empirical studies on the formation of method mindset in design (see e.g. [5], [7]). By taking a mindset approach, we are able to unfold some of the confusion surrounding heuristic method usage in design and, for example, its interrelation with the individual designer and its impact on their design activities. Second, we reveal how knowledge and preference jointly influence heuristic methods usage and how knowledge plays a mediating role on method usage through preference. In doing so, we draw attention to the importance of design teaching that goes beyond the mere acquisition of methodological knowledge to teaching that also incorporate a clear focus on developing a preference for certain types of methods. Thus, in proposing a 'mindset approach' to teaching design, we hope to spark the education of students who choose and apply both heuristic and systematic methods in response to different design situations and in line with their own personal preferences in approaching design.

2 THE USE OF HEURISTICS IN DESIGN

In the past decades, systematic methods have come to dominate engineering design and product development education [8]. This situation is slowly changing. In recent years, heuristic methods have received increasing interest (see e.g. [9]). Their relevance for design practice and education is becoming more accepted, particularly in the context of (developing) design expertise. Studies on design expertise consistently show that experts very often rely on intuitive strategies and that they explain their performance to a large extent (see e.g. [10]). We are also quick to note that the importance of intuition – and the heuristic methods associated with it – have long been present in design research under other labels such as 'bounded rationality' (see e.g. [11]). In this sense, heuristics also continue to fulfil an important part of the contemporary discourse on design methodology (see eg [12], [13]).

Additionally, it is common in today's design methodology literature to speak of *all methods* as being heuristic in nature: methods can enhance success but do not guarantee it ([6]; [14]). However, in order to distinguish between different methods in design, we focus on the amount of information processing prescribed by different types of methods. We build on the work of Gigerenzer and his colleagues on the use of heuristics in decision making, who defined heuristics as "efficient cognitive processes that ignore information" ([15], pp. 1). Inspired by their emphasis on information processing, we position methods on a continuous scale ranging from 'methods that prescribe to take into account as complete information as possible' to 'methods that prescribe to take into account only certain pieces of information while ignoring most'. The more a design method resembles the former, the more it can be considered to be systematic in nature; the more a method resembles the latter, the more it can be considered to be heuristic in nature. In this light, methods vary in the extent that they require a designer to seek optimal versus satisfactory results. Following the distinction as outlined above, we define systematic and heuristic methods as follows. A systematic method prompts a person to include as much information as possible in aiming to reach optimal rather than sufficient results. A heuristic method prompts a person to focus their mind on particular information in aiming to reach sufficient rather than optimal results. We note that the term 'heuristic' has been used in different ways in the design literature, and other definitions of a 'heuristic' in design have been put forward. For example, Von der Weth and Frankenberger [16] defined heuristics as "rules for making rules" which are used "to generate action plans for situations for which no useful routine behaviour exists" (p. 368). Quite differently, Daly and her colleagues [7] have defined heuristic as "cognitive prompts that point designers towards exploration of design variations" (p. 606).

Despite this growing interest in heuristics and rules of thumb, they still play a secondary role in design education, overshadowed by the overwhelming attention given to systematic methods. Given their elusive nature in design research and teaching, the use of heuristic methods in design deserves to be a topic for research in its own right. A more detailed understanding of the use of heuristic methods can serve as a stepping stone to a firmer role in design teaching. In doing so, the concept of a *method mindset* provides an interesting departure point for investigating how design professionals and design students come to use different types of methods.

According to Andreasen [4], a method mindset forms "an important part of a mental framework leading to the execution of a method". As noted earlier, Andreasen recognizes that a method mindset encompasses at the very least knowledge about a certain method and its use. In forming a method mindset, he distinguishes four interrelated elements: (1) understanding of the task and context, (2) understanding the theory behind the method, (3) mastering and proper use of the method and (4) the ability to assess the proper use of the method and its outcomes. Overall, these elements encompass knowledge about understanding the prerequisites for using a method (know-what) as well as the skills and ability needed to use it effectively (know-how).

However, from an educational perspective, prior (theoretical) knowledge about the use of a method, and the (practical) skills needed to execute it, are not sufficient. Learning to use a new method requires students to develop an appreciation and ultimately preference to work with a method (or certain types of methods). From practice, it is a well-known fact that designers favour to work in idiosyncratic ways. Most educators would therefore agree that motivation and interest, as captured in the designer's general preference for a method, are key factors in determining whether he or she will use a certain method to their benefit. Following the lead of earlier empirical studies on the components of a method mindset [5], we therefore adhere to the view that in (methodological) design education, developing a general preference for using a (certain type of) method becomes as important as developing the knowledge needed to use the method.

In facilitating method usage, acquiring knowledge certainly remains an integral part in the formation of a method mindset. But, by using a method extensively, students not only start to understand how a method works, they also learn to appreciate it, allowing the method to become a natural part of their repertoire. Once a general preference for a specific method has been developed, students will be more prone to use it. This argumentation is summarized in the conceptual model below (Figure 1). In this model, following Andreasen, knowledge about the use of heuristic methods has a direct influence on how likely someone is to use a heuristic method (path c'). In addition, knowledge also has an indirect influence on how likely someone is to use a heuristic method through his or her preference for a heuristic method (path a and b).

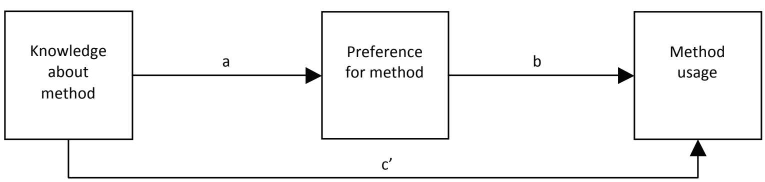

Figure 1. Conceptual model

3 METHOD

For testing the conceptual model, we analyzed data on students' reported method usage from the Delft Method Study [17]. The study is a research initiative hosted by the Delft University of Technology. One of the main motivations behind this research initiative is to contribute to the better understanding of the role of methods in design by drawing on empirical data. In 2011, we studied how design students experienced using different methods during a series of design exercises. The students were all enrolled in a master-level course on design theory and methodology. The design exercise constituted a mandatory assignment and was carried out electronically. From an educational perspective, the purpose of the assignment was to stimulate discussion on the role of methods in design and to help the students to critically reflect on their own method usage. In targeting these learning objectives, we devised the design exercise in a way so that the students could compare their experiences with different types of methods. For a more detailed description of the methodological approach see [17] in which the authors addressed individual differences in method usage and [5] the formation of a mindset for using systematic methods respectively. A comparative study on the use of systematic and heuristic methods has also been submitted to this conference [18].

One week prior to performing the exercise, a web-questionnaire was distributed among the students in the course. In the questionnaire the students were asked to report on their prior experiences with methods in design. They did so by indicating their agreement/disagreement to a number of statements on seven-point scales. The statements (items) were devised to capture different facets of the students' experiences. In developing the statements, we compiled larger lists of items for each area of interest and asked academic experts in design to review them in terms of clarity and appropriateness. The final selection of statements was based on comments of the design experts. Several statements were selected for each area of interest, which is known to further improve the reliability of scales for a questionnaire. In total, we collected 304 questionnaires. All data originated from this questionnaire. For the analyses in this paper we focus only on a subset of the data, namely the students' preconceptions and experiences with systematic methods in design.

The students' knowledge about systematic methods was operationalized in terms of (1) their prior training in using heuristic methods (i.e., the amount of training they had received in using heuristic methods) and (2) their prior experience in using heuristic methods (i.e., how skilled they felt in using heuristic methods). Prior training and experience was measured by three items each. Their general preference for heuristic methods was assessed in four items. The students' use of heuristic methods when designing was assessed over the basic design cycle, as conceptualized by Roozenburg and Eekels [6]. The basic design cycle comprises the following activities: (1) analysis, (2) synthesis, (3) simulation, (4) evaluation, and (5) decision making in design. Following the procedure above, the degree to which students used heuristic methods for the different activities was measured with multiple items for each activity.

4 RESULTS

In testing our conceptual model, we began by comparing the reported usage of heuristic methods for the different activities in the basic design cycle. Prior to comparing the mean scores for the different activities, we conducted exploratory factory analyses to assess the reliability of the scales of each activity. For each activity, only one component was extracted based on Kaiser's criterion of Eigenvalues > 1. All scales showed high reliabilities with all Cronbach's alphas exceeding .76. We therefore derived separate index scores for their self-reports on the use of heuristic methods for each basic design cycle activity by averaging across the items for each scale (see Table 1).

We then compared the mean scores for the different activities in order to assess the perceived usefulness of heuristic methods across the basic design cycle. A repeated-measures ANOVA (with a Greenhouse-Geisser correction) showed a main effect of the within-subjects factor *basic design cycle activity*, indicating that the reported heuristic method usage in the five design cycle activities differed statistically, $F(3.31, 1001.31) = 80.40$, $p < .001$, $\eta_p^2 = .21$). Post-hoc pairwise comparisons (with Bonferroni correction) revealed that students reported different usage of heuristic methods over the basic design cycle. In short, heuristic methods were more frequently used for activities such as analysis and synthesis and less frequently used for evaluation and decision-making.

Table 1. Reported heuristic method usage over the basic design cycle, N = 304

	Mean (SD)	
A. Analysis (α = 0.821)	**4.70 (1.133)**	B > **A** > C, D, E*
B. Synthesis (α = 0.813)	**5.34 (1.132)**	**B** > A, C, D, E*
C. Simulation (α = 0.765)	**4.47 (1.767)**	A, B > **C** > D, E*
D. Evaluation (α = 0.826)	**4.06 (1.292)**	A, B, C > **D***
E. Decision-making (α = 0.800)	**4.24 (1.220)**	A, B, C > **E***

* Pair-wise comparisons (alpha-levels adjusted using Bonferroni) were significant at $p < .001$

Next, in understanding the formation of a method mindset, we studied the effects of knowledge and preference on the reported use of heuristic methods for different activities. We performed five separate mediation analyses incorporating the students' reported knowledge and preference for heuristic methods as well as their reported usage of heuristic methods in each of the five activities in the basic design cycle. Prior to performing the mediation analyses, we conducted exploratory factor analyses to assess the reliability of the scales for heuristic method knowledge and preference. For both heuristic method knowledge and preference, only one component was extracted based on Kaiser's criterion of Eigenvalues > 1. Both scales showed very high reliability with Cronbach's alphas exceeding .92 for knowledge and .85 for preference. We therefore derived separate index scores for heuristic method knowledge and preference by averaging across the items for each scale.

For all our analyses we used the SPSS macro developed by [19]. Significance tests for each of the mediated effects were bootstrapped estimates for the upper and lower boundaries of Confidence

Intervals (z = 1,000). Separate regression analyses showed a direct effect of preference on method usage across activities in the basic design cycle ($\beta > 0.26$, $p < .01$), except for evaluation ($\beta > 0.12$, p = 0.17). For *evaluation*, knowledge did display a significant direct effect on usage (β = .23, $p < .001$) when controlled for preference. For all other activities, the direct and mediated effects of knowledge on method usage differed over the basic design cycle as outlined below.

For *analysis*, results from bootstrapping yielded a significant indirect effect of heuristic method knowledge on heuristic method usage of β = 0.19 (S.E. = 0.039) with a 95%-confidence interval from 0.11 to 0.26. Preference mediated the effect of knowledge on heuristic method usage for activities related to analysis – however, not exclusively, as both knowledge (β = 0.15, $p < .01$) and preference (β = 0.42, $p < .001$) significantly predicted changes in method usage when regressed simultaneously. This type of mediation can be classified as 'complementary'.

For *synthesis*, results yielded a significant indirect effect of heuristic method knowledge on heuristic method usage of β = 0.21 (S.E. = 0.039) with a 95%-confidence interval from 0.13 to 0.28. Preference mediated the effect of knowledge on heuristic method usage for activities related to synthesis – however not exclusively, as both knowledge (β = 0.11 $p < .05$) and preference (β = 0.47, $p < .001$) significantly predicted changes in method usage when regressed simultaneously. This type of mediation can be classified as 'complementary'.

For *simulation*, results yielded a significant indirect effect of heuristic method knowledge on heuristic method usage of β = 0.15 (S.E. = 0.036) with a 95%-confidence interval from 0.08 to 0.23. Preference mediated the effect of knowledge on heuristic method usage for activities related to simulation – however, not exclusively, as both knowledge (β = 0.34 $p < .001$) and preference (β = 0.44, $p < .001$) significantly predicted changes in method usage when regressed simultaneously. This type of mediation can be classified as 'complementary'.

For *decision-making,* results yielded a significant indirect effect of heuristic method knowledge on heuristic method usage of β = 0.11 (S.E. = 0.038) with a 95%-confidence interval from 0.04 to 0.19. Preference mediated the effect of knowledge on heuristic method usage for activities related to decision – however, not exclusively, as both knowledge (β = 0.12 p = 0.053) and preference (β = 0.26, $p < .01$) significantly predicted changes in method usage when regressed simultaneously. This type of mediation can be classified as 'complementary'.

In sum, for all activities but evaluation, knowledge and preference both revealed a significant effect on method usage. Our analysis also shows that knowledge indirectly influenced method usage. For four out of five activities in the basic design cycle, we find a complementary mediation effect for the knowledge-usage relationship.

5 DISCUSSION

The results of our study show that both knowledge and preference influenced heuristic method usage. They also show that knowledge indirectly influenced method usage through a 'complementary' mediation of preference. These results support Andreasen's proposition of a method mindset, in particular for heuristic methods in design.

From an educational perspective, our results point to new areas of interest for method teaching. Given that a student's method mindset greatly affects his or her method usage when designing, design educators need to go beyond the procedural aspects of method usage, and focus on the development of students' method mindsets. This is particularly true for teaching heuristic methods in design, which are typically given a secondary role in engineering and product design education. Indeed, if design educators are to teach both heuristic methods and systematic methods, they shall develop student's mindsets for both types of methods.

Additionally, in comparing the results with past research on method mindset, the current results extend previous empirical studies on systematic methods and the underlying components of a method mindset (see [5]) by replicating the results for the use of heuristic methods. However, in comparing the mediating effect of preference on heuristic method usage and on systematic method usage [5], we observe that mediation of preference for heuristic methods is weaker than the mediating influence of preference for the use of systematic methods. Moreover, for the basic design activity of evaluation, preference does show any effect on heuristic method usage. A possible explanation for this is the relatively large investment in terms of mental effort that is needed for using systematic methods. That is, when a student anticipates the need to invest a lot of mental effort in the use of a systematic method, he or she is more likely to actually use it when also having a preference for the method. In contrast, as a design student anticipates the use of heuristic method, he or she is likely to anticipate a lower investment in mental effort, rendering a slightly lower mediating effect of preference for the method. Having stated that, knowledge about either a systematic or heuristic method will influence method usage irrespective of the anticipated effort that is needed for a method's use (represented by path c' in the conceptual model in Figure 1.).

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