THE USE OF SYSTEMATIC AND HEURISTIC METHODS IN THE BASIC DESIGN CYCLE: A COMPARATIVE SURVEY OF STUDENTS' METHOD USAGE

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ABSTRACT
In the present paper, we study the reported use of systematic and heuristic methods for 304 students enrolled in a master-level course on design theory and methodology. What to teach design and engineering students about methods is an important topic for discussion. One reason for this is that the experiences of design educators when using methods in their teaching do not always sit well with how methods are portrayed in the literature. Based on self-reports of the students, we study the use of systematic and heuristic methods for the five activities in the basic design cycle: (1) analysis, (2) synthesis, (3) simulation, (4) evaluation, and (5) decision-making. The results of our study suggest that systematic and heuristic methods fulfil different roles for the students when designing. The students reported to use heuristic methods significantly more for synthesis, while they reported to use systematic methods significantly more for evaluation and decision-making. In understanding the potential origin of these use practices, we call for more in-depth studies on method usage in design, for instance related to the role of preference and knowledge on systematic and heuristic methods usage.

Keywords: Method teaching, heuristic methods, systematic methods

1 INTRODUCTION

It is hard to envision design and engineering education without methods, as they are intrinsically entwined in the professional practice of design. Methods assist designers and provide support in their day-to-day practices. For instance, methods help designers to systematically reason through alternative solutions and to coordinate their work with other professionals in new product and service development. Methods are also intrinsically entwined in the academization of design. They have long been an area of interest for design scholars and educators. In the past, numerous research projects have resulted in a method or tool. Today, method development still remains an important part of research in design, with the design community being able to look back on a long tradition of method development [1]. Given this, it is not surprising that teaching students about methods (and how to use them effectively) holds a central place in design and engineering education.

However, *what* to teach students about methods and their usage, and *which* types of methods to teach *when*, form important topics for discussion. One reason for this is that the expectations commonly associated with method teaching are often very different from the actual experiences of design educators when using methods in their teaching [2]. In design and engineering education, *systematic* methods are often given a prominent role in teaching students about the fundamentals of design. In fact, the use of systematic methods often constitutes the backbone in teaching students how to design. In doing so, systematic methods are introduced to learn about all types of design activities as they are assumed to provide students with structured procedures in learning how to go about when designing and how to acquire certain design capabilities. However, despite their wide use in education, methods as systematic procedures do not fully capture the unruly reality of design in practice. Studies suggest that professional designers very often utilize rules-of-thumb or heuristic methods and that these methods actually add to their performance [see e.g. 3]. So, what should educators focus on when teaching students about methods in design? And, what role should systematic and heuristic methods fulfil in this teaching? In answering these questions, an important first step is to understand when students find it relevant to use different types of methods.

In the present study, we draw on the reported use of systematic and heuristic methods of 304 students enrolled in a master-level course on design theory and methodology. We empirically study their reported use of systematic and heuristic methods for the five activities in the basic design cycle [4]: (1) analysis, (2) synthesis, (3) simulation, (4) evaluation, and (5) decision-making. We also provide a detailed description of how we devised the questionnaire for our study.

While there is a long tradition of method development in design, there are few empirical studies on how methods function for designers and students. As a result, in advancing research on engineering and design education, the contribution of our study is two-fold. First, we add to a small but growing body of empirical studies on method usage in design. In doing so, we unveil distinct differences in the reported use of systematic and heuristic methods. As educators try to tailor their teaching efforts to the real world problems of designers, understanding such differences is useful to better clarify the role different types of methods might play when designing. Second, with few empirical studies on method usage on design, we provide a first set of questions to assess the use of systematic and heuristic methods. In exploring method usage in the classroom, educators may benefit from our questions in initiating discussions among their students and/or in executing new studies on method usage in their specific discipline.

2 INFORMATION PROCESSING IN SYSTEMATIC AND HEURISTIC METHOD USAGE

In adapting the work of Gigerenzer and Brighton [5] on the use of heuristics in decision making to design into design, Daalhuizen, Person and Gattol [6] propose that design methods can be positioned on a continuum ranging from ‘methods prescribing the processing of as much information as possible’ to ‘methods prescribing the processing of only certain information while ignoring most’. They conclude that the more a design method suggests incorporating as much information as possible, the more it can be considered to be systematic in nature. In contrast, the more a method suggests ignoring information and only focusing on specific issues, the more it can be considered to be heuristic in nature.

We note that in the literature on design methodology – where much emphasis is placed on the development and use of methods that are systematic in nature – all methods are generally described as being heuristic in nature in a different sense than described by Daalhuizen, Person and Gattol [6]. That is, a well-executed and appropriately used method is seen to raise the probability of success but it cannot guarantee it [4], positioning design methods on the heuristic side of the heuristic-algorithmic axis.

However, in order to distinguish between different types of design methods in this paper, we place methods on an information processing axis, allowing distinction between heuristic and systematic methods in design. Moreover, in terms of understanding the position of heuristics in design, we also note that an interest in intuition – which heuristic methods are commonly associated with – has long been visible in research on design; for example, in discussions on ‘bounded rationality’ [see e.g. 7]. Moreover, studies on design expertise consistently show that design professionals often rely on intuition and that their use of distinct (intuitive) strategies in large part explains their superior performance [see e.g. 8].

That said, analyzing methods in terms of information processing opens up possibilities to better understand the role different methods fulfil for designers and students. For example, the type of information processing seems to be (1) distinct for different types of design activities and (2) distinct for different types of designers (students). For instance, in generating design solutions through the use of a morphological chart [9] or selecting a solution through the use of a Harris profile [10], design students are encouraged to account for as much information as possible. In contrast, by departing from a primary generator [11] and pursuing the first solution that comes to mind as advised with conjecture-analysis [12], students are recommended to cope with complexity (information overload) by focusing their attention on specific pieces of information, guided by their intuition. Given this, the relevance of using different types of methods seems to differ depending on the activity at hand. However, how such

usage plays out in design practice and education has not yet been systematically studied in the literature.
Thus, intrigued by the proposition above, we set out to study how students use systematic and heuristic methods when designing. The following research question guided our inquiry:

> *For what design activities are the use of systematic and heuristic methods deemed more or less relevant?*

3 METHOD

In answering our research question, we studied students' self-reports on method usage when designing. The Delft Method Study is a research initiative hosted by the Department of Product Innovation Management at the Faculty of Industrial Design Engineering, Delft University of Technology (for a more detailed description of the initiative see Daalhuizen, Person and Gattol [6]). Earlier reports from the Delft Method study by the authors of this paper address individual differences in method usage [6], as well as the formation of a mindset for using systematic [13] and heuristic [14] methods.
The students were all enrolled in a master-level course on design theory and methodology given by the Faculty of Industrial Design Engineering. Our questionnaire constituted a mandatory assignment in the course. It was distributed digitally through an online questionnaire. From an educational perspective, the purpose of the questionnaire was to stimulate discussion on the role of methods in design and to help the students to critically reflect on their own method usage prior to taking part in a classroom discussion. In targeting these learning objectives, we devised a comprehensive set of questions on method usage in design and asked the students to complete the questionnaire in a take-home assignment as they reflected on their own ways of designing.
The students described and reflected on their method usage by indicating their agreement/disagreement to a number of statements on seven-point scales. As a pioneering effort in understanding method usage in design quantitatively, we could not adopt any tested scales from the literature. This meant that we had to develop new scales for our study.
In developing the scales, we compiled larger sets of statements (items) for each area of interest (scale) and asked academic experts and students in design to review them in terms of clarity and appropriateness. Based on their comments, we selected several statements for each area of interest, which is a well-known practice to improve the reliability of scales in questionnaire studies [see e.g. 15].
In total, we collected 304 questionnaires. For the analyses in this paper, we focus on a subset of the students answers, namely their reported usage of systematic and heuristic methods over the basic design cycle covering design activities in terms of (1) analysis, (2) synthesis, (3) simulation, (4) evaluation, and (5) decision making [4].

4 RESULTS

The reported age of the students participating in our study ranged from 20 to 32 years with a mean age of 23.3 years (43% women). The students had the possibility to opt out from having their answers included in the study. While answering and reflecting on the statements in the questionnaire was a mandatory assignment, to submit the answers for our study was voluntarily. No student requested to have his/her answers excluded from the study.
In analyzing the students' self-reports on the use of systematic and heuristic methods, we compare both the scores for each statement (item) and the mean scores across all statements relating to each design activity (scale). With a new scale and few empirical studies on method usage in general, we do this to showcase the items we used in our study and to more fully depict how the students reported on their method usage. Prior to comparing the mean scores for the different activities, we conducted exploratory factory analyses to assess the reliability of the scales for each activity. For each activity, only one component was extracted based on Kaiser's criterion of Eigenvalues > 1. All scales showed sufficient reliability with Cronbach's alpha exceeding .74. We therefore derived separate index (mean) scores for the students' reported usage of systematic and heuristics methods. We did this by averaging the scores for the items in relation to each scale. We carried out paired-sample t-tests in comparing the use of systematic and heuristic methods.
The results of our study show that the reported use of heuristic and systematic methods varies for different activities in the basic design cycle (see Table 1). For *analysis*, there is a significant difference

for two of the statements. Both these statements concern analysis in terms of forming an understanding about a basic design problem or challenge. Specifically, the students reported significantly higher usage of systematic methods than for heuristic methods in analysis. However, due to the limited size of these differences, there is no significant difference in the reported use of systematic (M = 4.84, SD = 1.13) and heuristic (M = 4.70, SD = 1.13) methods when averaging the scores across all the statements, $t(303) = 1.51$, $p = 0.132$.

For *synthesis*, there is a significant difference for all the statements. There is also a significant difference when comparing the reported mean use of systematic (M = 4.39, SD = 1.31) and heuristic (M = 5.34, SD = 1.13) methods across all statements; $t(303) = -8.73$, $p < .001$. In short, heuristic methods are used more often than systematic methods.

For *simulation,* there is a significant difference for all the statements. However, in averaging the scores across the different statements, there is no significant difference in the reported use of systematic (M = 4.39, SD = 1.12) and heuristic (M = 4.47, SD = 1.77) methods, $t(303) = -0.865$, $p = 0.388$. The reason for this is that systematic and heuristic methods score high (and low) on different (individual) statements, cancelling each other out in terms of the reported mean usage for using systematic or heuristic methods for simulation activities.

For *evaluation*, there is a significant difference for all the statements. There is also a significant difference when comparing the reported mean use of systematic (M = 5.01, SD = 1.14) and heuristic (M = 4.06, SD = 1.29) methods across all statements, $t(303) = 9.27$, $p < .001$. In short, systematic methods are used more often than heuristics methods.

For *decision-making*, there is a significant difference for all the statements. There is also a significant difference when comparing the reported mean use of systematic (M = 5.00, SD = 1.12) and heuristic (M = 4.24, SD = 1.22) methods across all statements, $t(303) = 9.27$, $p < .001$. In short, systematic methods are used more often than heuristics methods.

Table 1. Reported use of systematic and heuristic methods over the basic design cycle, N = 304

	Systematic Methods Mean (SD)	**Heuristic Methods Mean (SD)**
Analysis (α_S = 0.838, α_H = 0.821)	**4.84 (1.129)**	**4.70 (1.133)**
1. ... form an understanding of the problems surrounding product ideas.*	4.97 (1.368)	4.66 (1.437)
2. ... explore design problems.	5.00 (1.329)	5.06 (1.374)
3. ... understanding design challenges.*	4.78 (1.373)	4.52 (1.407)
4. ... understand what to design.	4.62 (1.437)	4.56 (1.399)
Synthesis (α_S = 0.803, α_H = 0.813)* **	**4.39 (1.311)**	**5.34 (1.132)**
1. ... generate initial proposals for my designs.***	4.26 (1.507)	5.24 (1.297)
2. ... generate ideas.***	4.43 (1.632)	5.66 (1.256)
3. ... generate concepts. ***	4.48 (1.505)	5.10 (1.420)
Simulation (α_S = 0.742, α_H = 0.765)	**4.39 (1.124)**	**4.47 (1.767)**
1. ... try out proposals of my designs.**	4.40 (1.324)	4.73 (1.310)
2. ... run through the properties of my designs.***	4.88 (1.351)	4.27 (1.397)
3. ... develop prototypes of my ideas.***	3.90 (1.470)	4.42 (1.561)
Evaluation (α_S = 0.791, α_H = 0.826)* **	**5.01 (1.137)**	**4.06 (1.292)**
1. ... test my design proposals.***	4.87 (1.361)	4.23 (1.544)
2. ... evaluate my design proposals.***	5.27 (1.320)	3.99 (1.496)
3. ... check the quality of my ideas.***	4.90 (1.379)	3.96 (1.458)
Decision-making (α_S = 0.796, α_H = 0.800)* **	**5.00 (1.124)**	**4.24 (1.220)**
1. ... decide which of my ideas to continue with.***	5.30 (1.332)	4.33 (1.481)
2. ... decide whether I need to redo designs.*	4.57 (1.375)	4.33 (1.491)
3. ... aid me in taking important design decisions. ***	5.15 (1.295)	4.21 (1.451)

* significant at 0.05-level
** significant at 0.01-level
*** significant at 0.001-level

5 DISCUSSION

In this paper, we studied the reported use of systematic and heuristic methods for five different activities in the basic design cycle. The results of our study suggest that different types of methods fulfil distinct roles when designing. The students reported to use systematic and heuristic methods more or less frequently for different types of activities.

While both systematic and heuristic methods are used in design practice, systematic methods have come to dominate design and engineering education. The benefits of this situation are debatable, as the practical experiences of design educators do not always sit well with how methods are portrayed in the literature [2, 16]. For example, although often portrayed as such [16], systematic methods do not always function as a straight road to success. A number of empirical studies in design have revealed that strictly following methods, like a road, does not necessarily lead to the best results [see e.g. 17, 18]. Instead, effective method usage typically depends more on how well the method fits – and is adapted to - the situation at hand. In light of this, it is relevant for educators to critically reflect on the scope of methods in teaching students and on how well different methods deliver on their promises.

In further understanding the origin of our results, we rely on information processing as a departure point for understanding differences in the use of systematic and heuristic methods. For example, in synthesizing different requirements into a concept, designers typically cannot account for all possibilities and requirements – at least not at once. So, selectively excluding information through the use of a heuristic method may prove very useful and allow a designer to keep momentum in a project. In contrast, in evaluating the feasibility of different concepts, it is natural for designers to try to account for as many different requirements as possible in order to take an informed decision on how to proceed. In doing so, trying to process as much information as possible seems logical, making systematic methods a more natural choice when designing. Building on these possibilities, we hope our results will initiate discussions in the classroom as well as further an earlier call for a more designer-centred methodology in design [19].

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