USING DESIGN HEURISTICS IN IDEA GENERATION: DOES IT TAKE EXPERTISE TO BENEFIT?

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ABSTRACT

This paper presents a study that examines how well-known methods for idea generation can be advantageously combined. It investigates *Method 6-3-5,* a group technique for six developers who successively refine three initial ideas under tight time constraints (within five minutes per round). In the conducted experiments, this commonly used brainwriting technique was complemented with a set of design heuristics that should help the participants to abstract the problem and should guide them to potential solutions.

The study (with $N = 88$ participants in total) compares first and third year B.Eng. students in a Mechanical Engineering programme with young professionals holding more than one year working experience. For evaluating the solutions that the participants generated, metrics were employed that measured the variety and the quantity of the ideas. The paper also analyses if more experience permits engineers to overcome the 'fixation' to an initial design.

Keywords: Creativity, conceptual design, design heuristics, brainwriting techniques, design fixation

1 INTRODUCTION

During the last decades research changed perception on creativity. It is no longer seen as an unchangeable ability that fortune blindly favours individuals with. Today it is assumed that everyone has a creative potential that can be developed and that the role of education is to facilitate the exploration of it [1].

1.1 Brainwriting techniques

Method 6-3-5 is a commonly used brainwriting technique, cf. [2]. Based on the concept of Osborn's brainstorming, this team-based method aims at quickly exploring the solution space and producing a great number of ideas (up to 108 ideas in only 30 minutes). As in other creativity techniques 'freewheeling is welcomed, quantity is wanted, combinations and improvements are sought, criticism ruled out' during application [3].

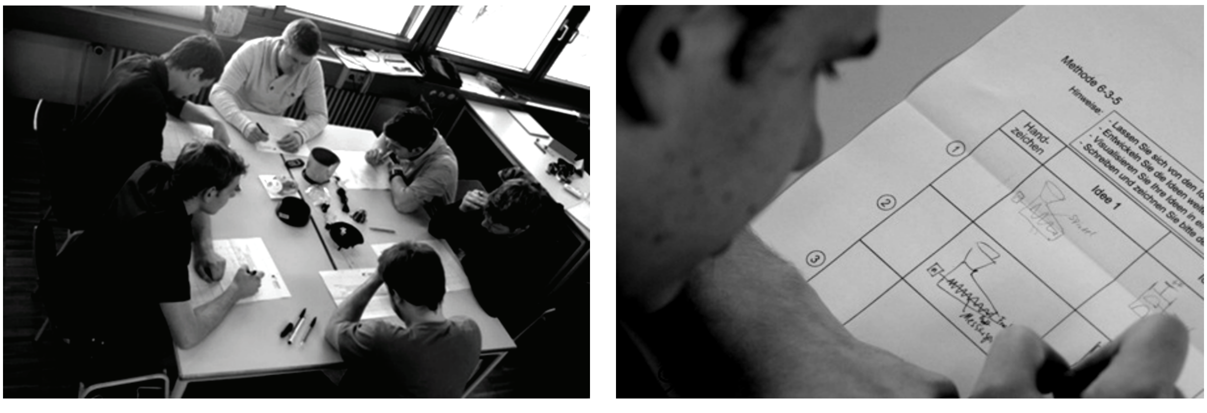


Figure 1. Brainwriting session

The technique involves six participants (who are optionally supervised by a moderator), cf. *Figure 1*. Per round, each participant is asked to generate three ideas. The ideas are put down on a worksheet in form of short text and sketches. After five minutes the worksheet is passed on to the next participant. The technique encourages the participants to refine the ideas of others, but they also can choose to interrupt that chain of ideas and add complete new thoughts. After six rounds the group has produced a total of up to 108 ideas in just half an hour.

1.2 Design heuristics

Design heuristics are intended to 'drop mental ballast' and liberate developers from the confinement to existing solutions. They should serve as 'cognitive shortcuts that encourage exploration of novel directions' [4]. In our study we provided some of the participants with Osborn's checklist [3] which includes nine generic mechanisms of inventive idea generation [5], namely

- substitute
- combine
- adapt
- magnify
- modify
- put to another use
- eliminate
- re-arrange
- reverse,

also known under the mnemonic SCAMMPERR.

2 RESEARCH QUESTIONS

In research on design expertise, the relationship between expertise and creativity is related to be a close one [6]. In our study on idea generation techniques, we have been particularly interested in

- differences in the results of novice and experienced designers
- benefits from using design heuristics (for each these study groups)

3 EVALUATION METHOD

In order to explore the effects of design expertise and design heuristics on the solution space generated with help of brainwriting techniques, a series of factorial experiments was conducted. The analysis of the obtained data was based on a specifically developed set of metrics.

3.1 Participants

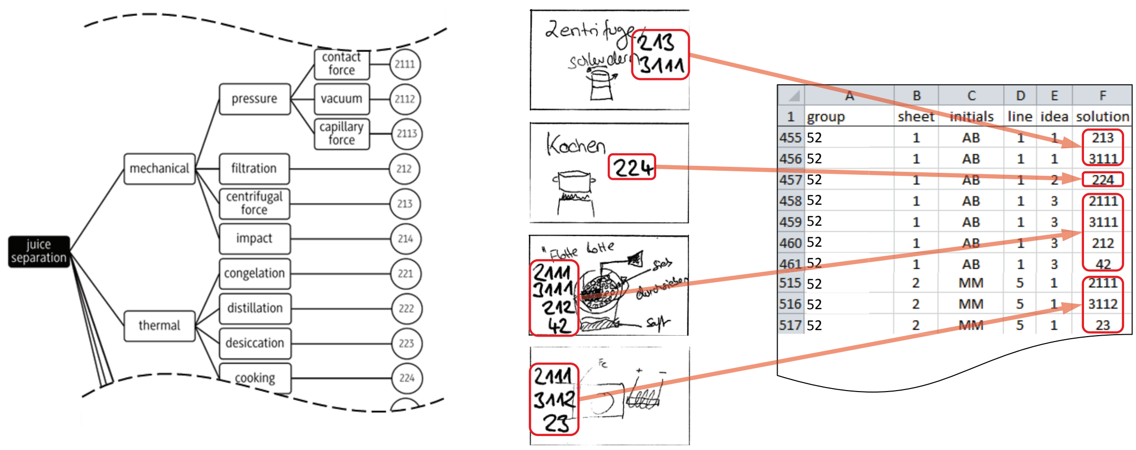
In total, $N = 88$ engineering design students participated in the experiments. The participants have been selected with respect to their formal degree of expertise: The *novices* are undergraduate students enrolled in the first ($N = 55$) and third ($N = 20$) year of a B.Eng. programme in Mechanical Engineering. The more experienced designers are *young professionals* ($N = 13$) who worked between one and three years in industry before taking up part-time studies in an M.Eng. programme. The participants worked in teams with a nominal group size of six.

3.2 Task

In our experiments we confronted the participants with a typical open-ended design problem. We asked all participants to find novel solutions for extracting juice from citrus fruits. The group of young professionals has been more experienced (not only in general terms but also) in that specific field of knowledge since they analysed (benchmarking, functional analysis, Design of Experiments, use tests, cost analysis) a citrus press in their M.Eng. course on Product Development methods.

3.3 Data analysis

All solutions that the groups have generated in the experiment were systematically classified, see *Figure 2a)*. Two evaluators inspected every completed field on the worksheet and coded them according to the classification system, like shown in *Figure 2b)*. The total number of solutions contained in the analysed worksheets was 2924.



(a) (b)

Figure 2. (a) Excerpt from the classification system, (b) coding of solutions

3.4 Metrics

The coded solutions then were analysed in a Pivot table. For measuring the effectiveness of idea generation empirically, we mainly used two objective metrics [7]: one describes how *diverse* solutions are and another how *many* there are. The *variety V* of the generated solution space was assessed by counting the number of non-redundant ideas, i.e. the number of solution categories addressed by a group. Within each solution category we counted how many times a group has used an idea on their worksheets *(quantity Q)*. The diagram in *Figure 3* arranges the solution categories in decreasing order.

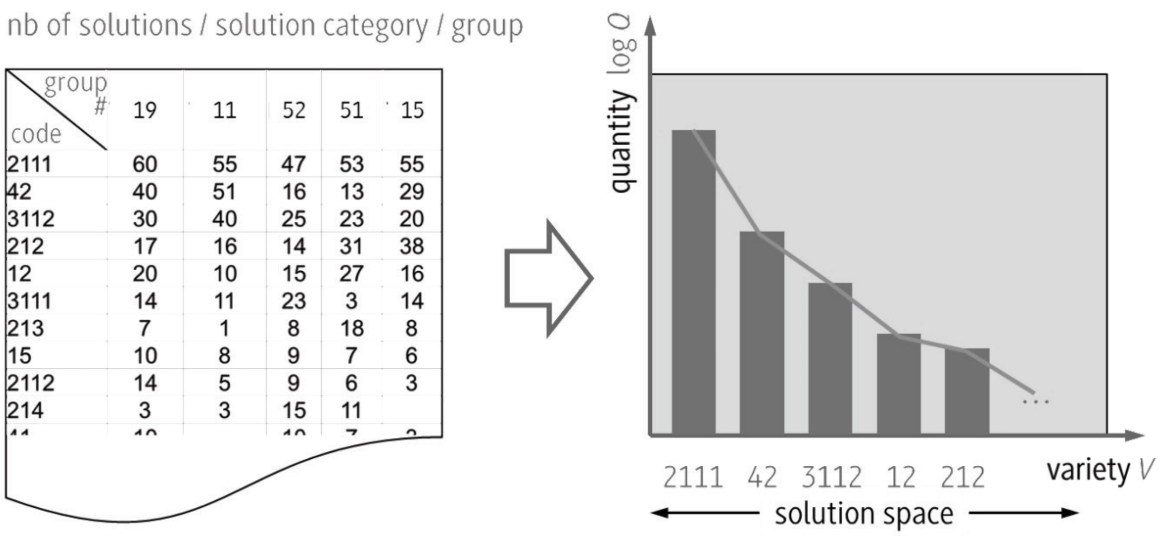


Figure 3. Procedure

In a regression analysis, we found that the function $Q(V)$ is nearly exponentially distributed, see *Figure 4*:

$$Q(V) = ae^{bV}, \tag{1}$$

with an elevated coefficient of determination $R^2 > 0.89 \ldots 0.98$ for all groups.

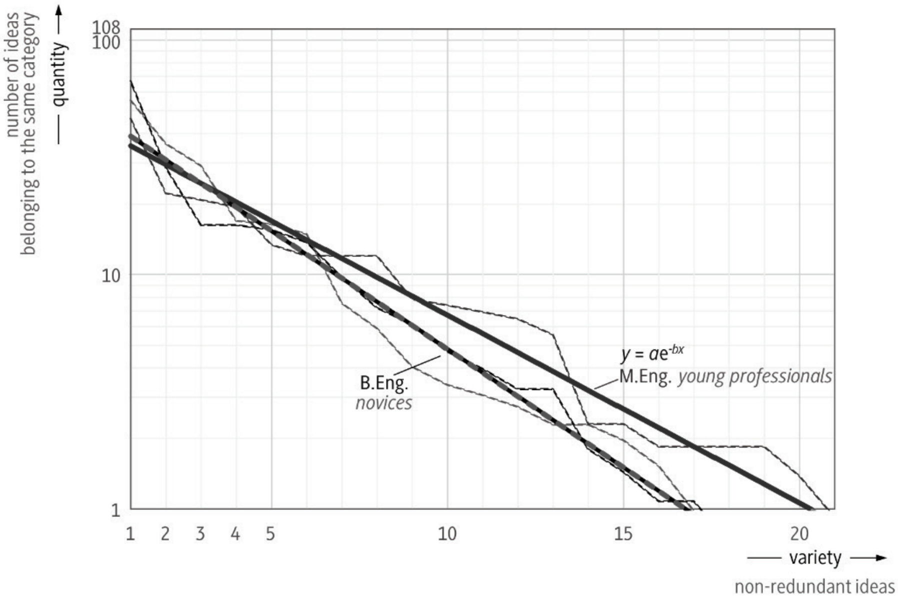


Figure 4. Regression analysis

The intersection of this frequency distribution with the axes furnishes two characteristic values:

- the corrected number of non-redundant ideas $V(Q = 1) = -(\ln a) / b$ (2)
- the corrected quantity in which the most frequent idea has been used $Q(V = 1) = ae^b$ (3)

4 RESULTS

It might astonish at first sight that novices produce more ideas than their more experienced peers. But we found evidence that novice group's repeat well-known solutions without developing alternatives, see *Figure 5*. Out of the 108 fields in total, one extreme group (#11) used their 'favourite idea' $Q(V = 1) = 80$ times, while they only developed $V(Q = 1) = 12$ different ideas. This phenomenon is also called design fixation [8].

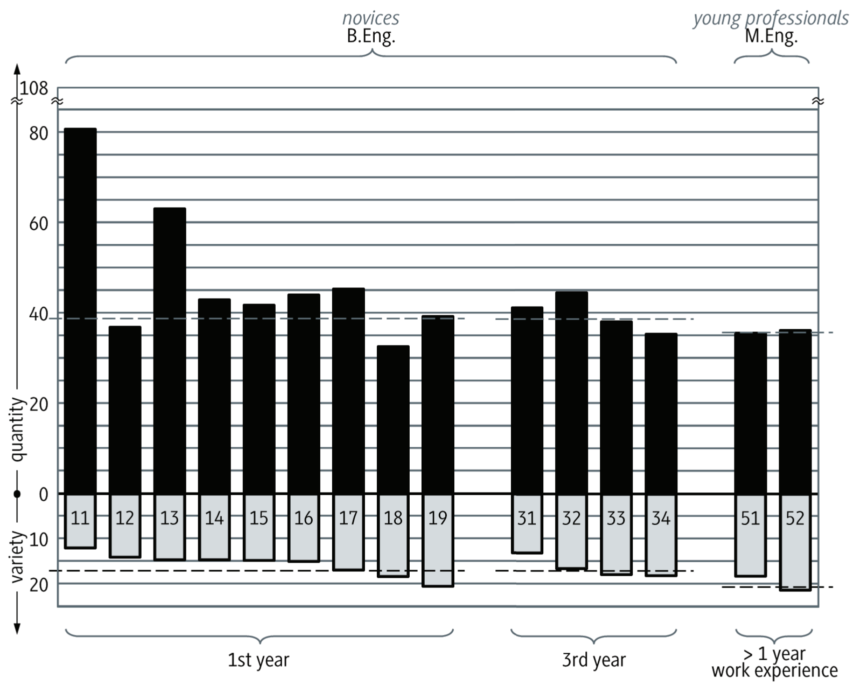


Figure 5. Variety and quantity of ideas for different levels of expertise

The difference in the respective average of first and third year B.Eng. students was 'microscopic', cf. *Table 1.* Thus, *novices* generated a variety of $V(Q = 1) \approx 17$ non-redundant ideas per working group and used their most ‘popular’ idea in $Q(V = 1) \approx 39$ fields of a worksheet. By gaining more experience, designers seem to lose their fixation to standard solutions. The variety of solutions found by the *young professionals* raises slightly to an average of $V(Q = 1) \approx 20$ non-redundant ideas. This makes also drop the quantity of identical basic ideas to $Q(V = 1) \approx 35$ in average per group.

Table 1. Average values.

level of expertise		$V(Q = 1)$ non-redundant ideas	$Q(V = 1)$ most frequent idea
novices *B.Eng.*	*1st year*	**16.79**	**39.0**
	3rd year	**16.78**	**38.9**
young professionals *M.Eng.*		**20.4**	**35.4**

In the experiments, the additional use of heuristics makes productivity of *novices* drop but has no influence on their ‘wealth’ of ideas. Out of the 108 fields that a group had to complete, the novices filled around 96. The worksheets of groups that we asked to work with heuristics were less complete. They only managed to create 77 solution fields *(Figure 6a)*. In the same time, the number of non-redundant ideas was nearly not affected (around 20 solutions with and without heuristics), see *Figure 6b)*.

The *young professionals* group is a little more ‘productive’ (completing 101 fields). Interestingly, there is almost no difference if young professionals were using heuristics or not, *(Figure 6a)*. But the number of non-redundant ideas is reduced by half if this group uses heuristics (46 to 23), see *Figure 6b)*.

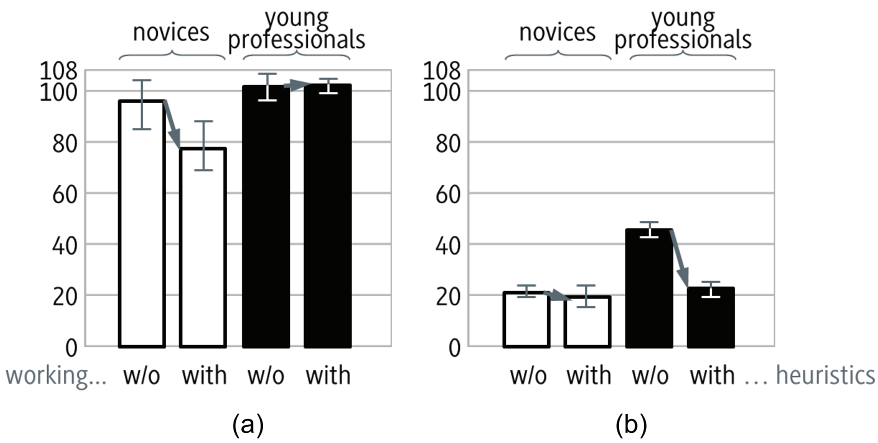


Figure 6. Number of (a) completed fields and (b) non redundant-ideas per group (minimum, average and maximum values indicated)

In order to understand if participants were ‘building on the ideas of others’ [9], we examined the brainwriting worksheets in detail and analysed how long an initial idea was refined during a session. Therefore we counted the number of rounds (= lines on the worksheet) of continuous work on an initial idea *(Figure 7)*. In average, *novice* groups work over 4 rounds on an initial idea and there is almost no difference whether they were using heuristics or not. But the results of the *young professionals* vary: When using heuristics, the *young professionals* were working significantly longer on an initial idea (rise from 2.5 to 4.9 lines). In combination with the results shown in *Figure 6,* it can be assumed that experienced participants of a brainwriting session (young professionals) changed their behaviour if they are supported by heuristics.

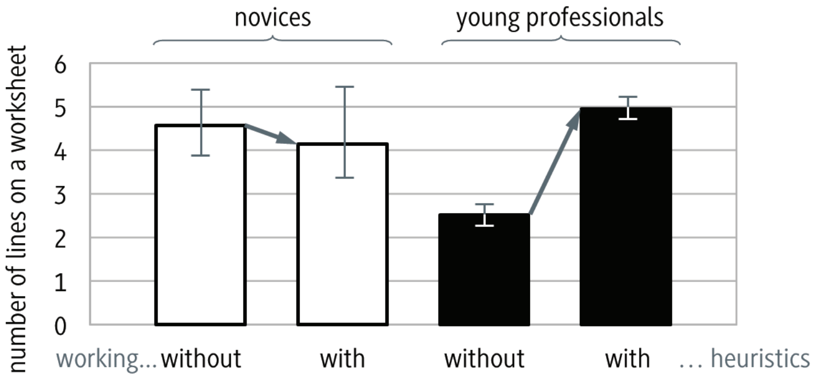


Figure 7. Continuous work on an initial idea
(minimum, average and maximum values indicated)

5 DISCUSSION AND CONCLUSION

In this paper, we describe a detailed procedure for analysing a solution space based on a problem-specific classification system that decomposes ideas to partial solutions. This enables to measure the variety and quantity of partial solutions. In future studies, studying the combination of partial solutions might bring further insights.

In our study, we were interested in how design expertise effects idea generation with brainwriting techniques. With the experiments we can confirm the findings of other authors stating that *novices* tend to develop concepts which are 'often either replications of, or minor changes to existing concepts' [4]. Compared to novices, the young professionals group created more *diverse* solutions, but *less in quantity*.

Combining brainwriting techniques with *design heuristics* globally attenuated quantitative idea production. But we found a qualitative improvement in the work of young professionals who, contrary to novices, intensified their interaction by building their solutions on those of others. Thus, we answer the question asked in the title of this paper with 'yes': It also takes some experience to benefit from support with design heuristics.

In future research, it also might be interesting to enlarge the spectrum of expertise of the study group, comparing novices not only to advanced beginners but also to competent problem solvers, experts, masters and even visionaries [10] on one side and to persons totally unrelated to engineering design on the other.

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