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REDUCING AND PERCEIVING DESIGN FIXATION: INITIAL RESULTS FROM AN NSF-SPONSORED WORKSHOP

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ABSTRACT

This study evaluated the effects of design fixation in a group of engineering design faculty, and also provides evidence for approaches to overcome design fixation. Three conditions were compared, a control, a fixation group whom were provided with an example solution and a defixation group whom were also given materials to reduce their design fixation. Measures included indications of design fixation and participant perceptions. This study also indicates that design fixation can be mitigated. This study demonstrates engineering design faculty show significant evidence of design fixation yet only partially perceive its effects. The group of participants in this study, due to their background in engineering design research and experience with student design teams, was expected to have more accurate perceptions of design fixation than the typical participant. Understanding the incongruities between participant perceptions and quantitative design outcomes are particularly of interest to researchers of design methods. For this study, evidence exists that designers, even those that study and teach design, do not know when they are being influenced or fixated by misleading information.

Keywords: fixation, analogy, creative design, design cognition

1. INTRODUCTION

How designers think about a design problem, reason about problem-relevant information, and are able to generate novel problem solutions is a critical aspect of understanding and improving the design process. The study of such questions falls in the field of cognitive-based engineering design and requires methods and knowledge from the field of cognitive psychology, integrated with process knowledge and participants from the field of engineering design. In January, 2008, an NSF sponsored workshop was held in Knoxville, TN, as part of the CMMI Grantees Meeting. The workshop entitled "Discussion on Individual and Team-Based Innovation" brought 50 educators and researchers from the field of engineering design together for a day to learn about current work and discuss potential directions for new research in the area of cognitive-based engineering design.

As part of the workshop, participants took part in a formal cognitive study on the role of fixation and the use of analogies to overcome fixation. This paper presents the results of this study, which had 2 major goals. The first goal was to allow participants to experience a formal and rigorous cognitive experiment so that they might begin incorporating such studies into their own research.

The second goal of the study was to advance the state of the field of cognitive-based engineering design by learning (1) if engineering educators themselves experience design fixation during a design problem solving exercise, (2) how design fixation can be overcome by adding to the current knowledge base of the field, and (3) whether the participants accurately perceive the effects of providing an example solution and materials to reduce design fixation. This group of researchers has some experience in design application, but they also think about the process of design through teaching courses in design and through research in the broader field of design. It is interesting to see if this unique group of participants is susceptible to design fixation, and if they understand the role of analogy in overcoming that fixation. The paper will review the literature on cognitive-based engineering design, overview the experiment and results, and then discuss the perception of the participants to the mechanisms of design fixation based on a post-experiment survey.

2. BACKGROUND / PREVIOUS WORK

A number of studies have shown that design fixation effects can occur when example solutions are introduced to participants [1-4]. Jansson & Smith were the first to apply an experimental approach to study engineering design fixation. It was found that showing example solutions can reduce the range of design solutions generated by a designer, and that aspects of the example solution, including aspects that were shown to violate goals of the problem statement, can find their way into the designers' solutions [1]. A number of later experiments by others used the same and similar design problems to further investigate the issue of design fixation [5, 6]. Purcell & Gero suggested that the susceptibility of a designer to fixation may depend on the discipline of the designer, and that design fixation is more likely if the example problem embodies principles that are in line with the knowledge base of that discipline [5]. These studies demonstrate that introducing examples can cause design fixation, resulting in less creativity during ideation.

2.1 Possible Approaches to Overcoming Design Fixation

Numerous methods have been employed by researchers in an attempt to break design fixation. Using the same fixating examples as Jansson & Smith, Chrysikou & Weisberg found that including defixation instructions in an individual setting could negate the fixating effects of the examples [6]. Another possible approach to breaking design fixation is to help the designer find a new way to frame the problem, which may lead to new and improved solutions. The power of analogical inspiration is supported by empirical evidence, as well as by example s of professional designers using analogies to solve problems [7-10].

Within the literature a number of approaches to enhancing analogical retrieval and use have been noted. Some of these depend on the expertise of the participants, and some are more general findings. Visual analogies can improve design problem solving for both novice and expert architects [7]. Experts tend to use significantly more analogies than novices do [11]. Tseng et al. found that the effectiveness of analogical inspiration in design was dependent on the timing of when the inspiring information is given, as well as how apparently similar the information is to the problem being solved. More specifically, information that shares similar keywords or domains can be applied to problem solving even if the information is given before the designer has begun work on the problem, while information that is relevant but does not share similarity of keywords or domains only affects problem solving when the designer has already begun work on the problem [12].

2.2 The Perception of Being Fixated

One reason why design fixation is difficult to overcome is that designers are often not conscious of the fact that they are fixated. Ward, *et al.,* found that the examples were not constraining the subjects consciously by causing them to believe they should produce solutions similar to the given examples, but rather subconsciously constraining them; when participants were asked to avoid producing solutions that were similar to the examples, the similarity between the examples and generated solutions did not significantly decrease when compared to participants' solutions who were not told to avoid solutions similar to the given examples. In general, participants did not have control over their use of the knowledge gained from the examples. These results suggest that designers are unaware that they are being negatively influenced by example solutions or previously generated solutions [3, 13].

3. RESEARCH QUESTIONS

Design fixation is a common problem for both inexperienced and experienced designers. In this study we seek to answer three research questions: (1) Do engineering educators experience design fixation? (2) How can design fixation be overcome? (3) Do the participants accurately perceive the effects of the provided examples and of the materials to reduce design fixation? We describe these three research questions, our associated hypotheses and our motivation for answering these questions are discussed in the following sections. In the study completed in this work, three experimental conditions are implemented: a control, a fixation condition where a poor example is presented and a defixation condition where the poor example is given along with a list of possible solution directions to consider; these conditions are referred to in presenting our hypotheses and defined in Section 4. In addition, all participants filled out a survey prior to the workshop that obtained demographic information and perceptions about the design process.

3.1 Evidence of Design Fixation

For this study, we explore the effects of fixation on experienced academic engineering designers. The group of participants for this experiment has a unique background, which makes them interesting to study. All of the participants were attending a workshop on the cognitive aspects of engineering design and developing cognitive experiments in engineering design. They have clear interest in design and cognition. In addition, most of this group has experience teaching design and most are researchers in design. Therefore, this group is aware of design methods, they have spent time thinking about many of the issues related to design, particularly the "fuzzy-front end", and they are likely to be aware of some of the difficulties designers have during idea generation. They are also likely to be aware of methods such as design-by-analogy and some of the short-comings of traditional group brainstorming. Overcoming design fixation is a difficult task. Yet, because of this group's background in design theory and methods with their knowledge and skills, might they be able to more effectively overcome design fixation? We therefore seek to answer the following research question and make the hypothesis:

Research Question 1: Do academic engineering design educators show evidence of design fixation?

Hypothesis 1: Academic engineering design educators will show evidence of design fixation. They will produce fewer total ideas when provided with an example solution and repeat ideas from the provided example as compared to the control group.

3.2 Overcoming Design Fixation

Prior research has shown that it is possible to reduce design fixation by instructing participants to not focus on the negative aspects of the design [6]. This is clearly one approach for reducing fixation but based on anecdotal commentary in the design literature, it is likely there are other approaches to reducing fixation. Many product design books describe the benefits of functions, analogies, categories and back-of-the-envelope calculations in the design process [14-17]. In addition, analogy is noted as a tool for innovative design and a prolifically implemented strategy by designers [9, 18, 19]. These observations lead to the following research question and hypothesis:

Research Question 2: What can engineers do to reduce their fixation on particular design solutions? Can analogies, functions, categories of energy sources and back-of-the-envelope calculations assist in overcoming design fixation?

Hypothesis: Design fixation can be reduced. The defixation group will produce more ideas and repeat fewer ideas from the provided example solution than the fixation group. The defixation group will implement more analogies than the other two conditions.

3.3 Participant Perceptions

Participants' perceptions frequently are not consistent with quantitative outcomes of their performance [3, 20, 21]. Unfortunately, perceptions are easily obtainable and may be the basis an individual or a company uses to choose to implement a particular method. For example, one of the reasons for group Brainstorming's popularity, in spite of numerous studies contradicting its purported effectiveness, is that individuals feel more productive during group brainstorming than when generating ideas alone [20]. In contrast to the participant's perceptions of productivity, numerous studies quantitatively demonstrate a reduction in the number of ideas per person when comparing brainstorming in a group to individual brainstorming [see 22 for a review].

The group of participants in this study has experience with design methods and is at least somewhat familiar with their shortcomings. In addition, the majority of this group has taught design classes and observed their students' performance. Therefore, it is likely that the participants in this study will be much more aware of the effects of the provided example and additional defixation materials on their performance than participants who do not study design. In contrast, the prior literature indicates that the participants are likely to inaccurately perceive the effects of the example and the defixation materials. Therefore we seek to answer the following research question and test the related hypothesis:

Research Question 3: How well do participant perceptions of the results correspond to the quantitative results?

Hypothesis 3: Participants will inaccurately perceive the effects of the example solution and associated defixation materials. Results from survey questions collecting the participants' perceptions will be inconsistent with the quantitative metrics.

4. EXPERIMENTAL METHOD

The experiment evaluates the effects of fixation on experienced academic engineering designers. To answer the research questions and hypotheses, we implement three experimental conditions: a control, a fixation and a defixation condition. All participants are given the same experimental procedure and documentation media. The fixation condition is provided with an example solution. The defixation condition is also provided with the example and additional materials to potentially break the design fixation (detailed below in Sections 4.1-4.3). All participants are told that the goal of the experiment is to generate as many solutions to the design problem as possible, where a prize will be given to participants with the greatest number of solutions. This prize is an incentive for participants to devote serious effort to the design activity. All conditions end with a short post-experiment survey, which measures prior exposure to the design problem, perceptions of participants' performance and perceived influence of the provided example solution.

4.1 Description of the Design Problem

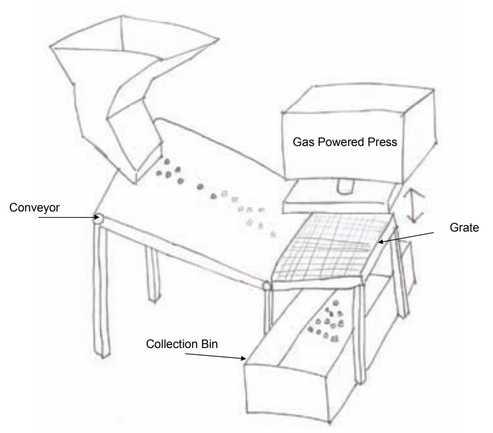
All participants are provided with the same design problem. The design problem is to design a device to quickly shell peanuts for use in places like Haiti and West African countries and is based on a real-world problem posted on ThinkCycle [23]. This problem is chosen because it is a real world problem appropriate for an engineer, and the problem has a diverse set of available solutions. This problem has also been used in previous research on idea generation [24-26]. It is very unlikely that any of the participants would have extensive prior experience in solving this problem, yet shelling a peanut is a task all of the participants have likely experienced.

4.2 Control Group

The control group is given the design problem as stated above. They are not provided with an example solution or alternative representation of the problem.

4.3 Experimental Fixation Group

The fixation group is given the design problem and an additional poor example solution (Figure 1). They are not given an alternative representation of the problem. The example solution uses a gasoline powered press to crush the shell, and does not separate the nut from the shell. This solution is difficult to control in terms of damaging the peanut, complex, and costly to manufacture for the West African environment. The participants all had graduate degrees in engineering so they should possess the knowledge needed to identify these short-comings. In addition, these particular functional solution elements were commonly generated by participants in a prior experiment [24, 25]. Common solutions to design problems create greater fixation (fewer total solutions) than unusual solutions [27, 28].



This system uses a gas powered press to crush the peanut shell. The shell and peanut then fall into a collection bin.

Figure 1: Example solution provided to the participants in the fixation group.

4.4 Experimental Defixation Group

The defixation group is presented with the design problem as above and also alternative representations of the problem. The alternative representations provide a brief functional description, useful analogies, a list of available energy sources and a quick back-of-the-envelope calculation result.

Some of the analogies were identified using the WordTree Design-by-Analogy Method with the key word of "remove" and "shell" to find the associated hypernyms and troponyms from WordNet [26].

4.5 Participants

Fifty engineering academics expressed interest in attending the NSF sponsored workshop: "Discussion on Individual and Team-Based Innovation." Thirty-eight from this group filled out the online pre-survey for the workshop and thirty-four actually attended the workshop. These thirty-four participants are randomly assigned to one of three conditions prior to the workshop with equally distributing senior and junior faculty (assistant professors). The study serves to demonstrate to the workshop participants an example cognitive study in engineering design while at the same time providing useful experimental data. Based on the pre-workshop survey results, which are only partially presented here, participants are faculty members (85%), plus a few research scientists and graduate students (12%) and federal government employees (3%). There were no participants from industry. Almost half the participants are assistant professors (45%). 12% are associate professors and 27% are full professors. Most participants have mechanical engineering backgrounds. Most have at least one year of industrial experience (64%) and have consulted with industry at least once (79%). There is also a high representation of women relative to the field of engineering (33% females, 67% males).

A number of pre-registered intended participants did not attend the beginning of the workshop so three participants were switched to different groups to compensate. Unintentionally, they were switched from the defixation condition to a different condition and they therefore had briefly seen the defixation materials. Therefore these three participants were removed from the data set.

5. METRICS

To understand the effects of design fixation and evaluate the research questions, a set of measures are employed. To quantify the degree of fixation five metrics are implemented: (1) number of ideas, (2) number of times features from the example solution appear in the generated concepts, (3) number of energy domains and (4) percentage of the solutions that employ a gas engine. To evaluate the effects of providing fixation reduction materials, the number of analogies is also measured.

5.1 Quantity of ideas

Building from the procedure developed by Shah, *et al*. [29], a set of procedural rules are defined for what constitutes a single idea, see Linsey, *et al*., [24] for more details. Our basic definition for an idea is something that solves one or more functions of the design as defined by the functional basis (a clearly defined and tested language for expressing design functions [30]). The total number of unique (non-redundant, non-repeated) ideas is calculated for each person.

5.2 Repeated Example Solution Features

The number of times each participant employs one of the example design features is counted. One of the authors evaluated all of the data while a second rater measured two from each condition or 18% of the data. In half of the cases, the two raters had identical scores for the number of repeated features and their Pearson's Correlation Coefficient [31] was 0.97 indicating the measure is highly reliable.

5.3 Energy Domains and Percentage of Solutions Employing a Gas Engine

In addition to recording the quantity of ideas, the number of energy sources used by each participant is analyzed. These energy sources are categorized into sixteen energy categories (wind, solar, water streams, captured rain water at a height, water (other), human, animal, nuclear, electrical outlet, fire, gas engine, engine (other), fuel cell, fluid density difference, chemical, genetic). The original tally included eighteen categories, but it was found, due to the universality of gravity, that the two gravity driven categories are difficult to measure reliably between raters, and were thus removed. The total of all energy sources used by each participant is recorded. Since the goal is to determine the breadth of energy sources, a participant receives the same score regardless of whether they use an energy source

Table 1: Sample size for each condition

Group	Sample Size
Control	9
Fixation	12
Defixation	10

once or multiple times. Since the defixation materials provided a list of energy sources to directly break fixation on the gas engine, the percentage of solutions using a gas engine is also measured.

6. RESULTS: DESIGN FIXATION

A key outcome of this study is on understanding design fixation, participants' perception of it and how to break fixation when it occurs. Figures 2 and 3 illustrate examples of participants with high and low degrees of fixation (samples sizes are in Table 1). Four measures are implemented to assess each participant's degree of fixation. From these measures a participants' fixation may be ascertained and the hypotheses tested.

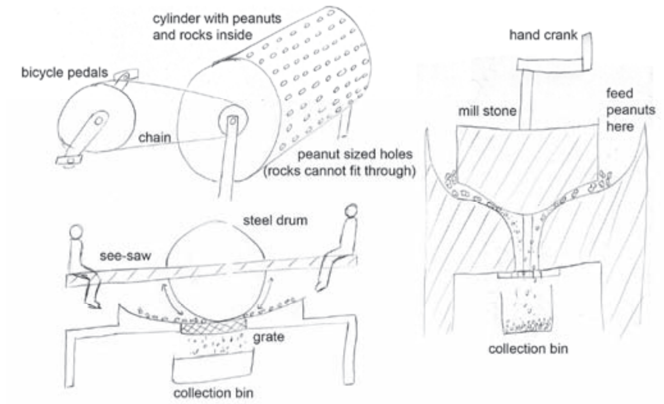


Figure 2: A set of solutions showing a low degree of fixation on the provided example solution.

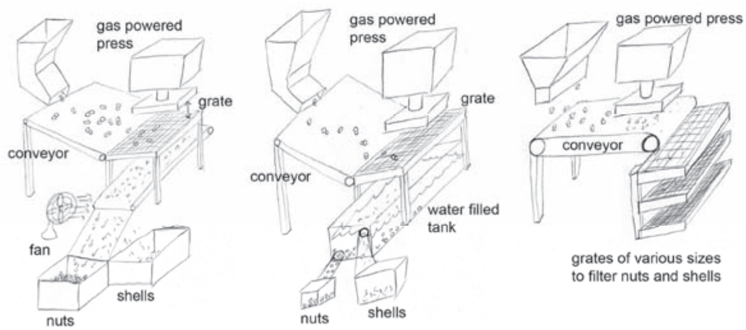


Figure 3: A set of solutions showing a high degree of fixation on the provided example solution.

The number of non-redundant ideas varies across the three conditions (Figure 4). An ANOVA shows a statistically significant effect across the fixation conditions ($F=3.7$, $p<0.04$) [1]. A t-test shows that the control group produces more ideas than the fixation group ($t=2.94$, $p<0.02$). The other pair-wise comparisons are not statistically significant.

The variation in the number of non-redundant ideas indicates that the example solution did cause design fixation resulting in fewer ideas being generated. The trend in this data is that the defixation group produces more ideas than the fixation group indicating that the additional materials assisted in reducing their fixation. This trend is not quite statistically significant.

[1] The data is not normally distributed but ANOVA is robust for departures from normality. The rest of the assumptions for ANOVA are met.

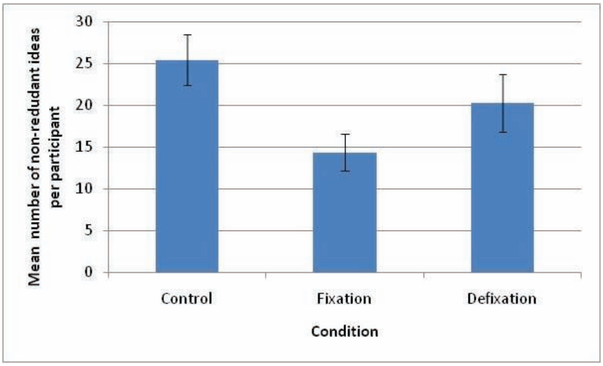


Figure 4: The fixation group produced fewer ideas than either the control group or the defixation group. Each error bar is plus/minus one standard error.

6.1 Number of Example Solution Features Used

The number of times the participants reuse features from the provided example solution differs across the three conditions and ranges from one to forty-three (Figure 5). The control group did not see the example but they still may think of the same features that are present in the example. This data does not meet the assumptions for a standard ANOVA since Shapiro-Wilk's test of normality shows the data is not normally distributed and Levene's Test for Equality of Variances shows that the variances are not homogenous, therefore a Kruskal-Wallis ANOVA is implemented instead. ANOVA can be used when there are only small departures from normality but if there are also unequal variances across the groups, a different approach is required. A Kruskal-Wallis ANOVA is analogous to a standard ANOVA but is the non-parametric statistical equivalent and evaluates the relative ranks of the data points. Implementing a Kruskal-Wallis ANOVA, there is a significant difference across the three conditions ($H=7.3$, $df=2$, $p=0.026$, $N=31$).

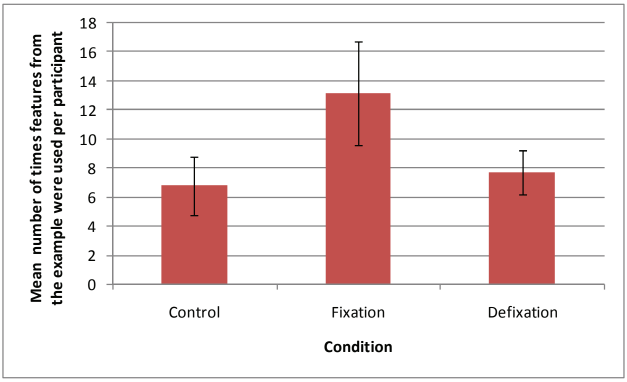


Figure 5: The fixation group repeated, on average, features from the example solution more often than the other two groups. Each error bar is plus/minus one standard error.

The number of features data also indicates that the example solution caused fixation, as the features from the example (the fixation condition) are re-used significantly more often than for the control. This data indicates that the additional materials are effective in reducing design fixation, since the defixation condition re-uses significantly fewer features from the example than the fixation condition.

6.2 Results: Energy Sources Fixation and Percentage Using a Gas Engine

In addition to the number of solutions, the energy source used in the design can be another indicator of design fixation. The defixation condition contained a categorical list of energy sources.

The fixation condition was given an example solution powered by a gas engine. It was expected that this example would fixate individuals on using a gas engine. The defixation condition was given additional information that was intended to aid in breaking the induced fixation. Individuals in the control condition were given no example on which to fixate. Both predicted effects are observed in the results (Figure 6). Again, this data does not meet the assumptions for a standard ANOVA, the data is not normally distributed and the variances are not homogenous. The Kruskal-Wallis ANOVA compares the data based on the relative rank of the results, but this approach is not accurate when there are a large number of equal outcomes as there are with this dataset.

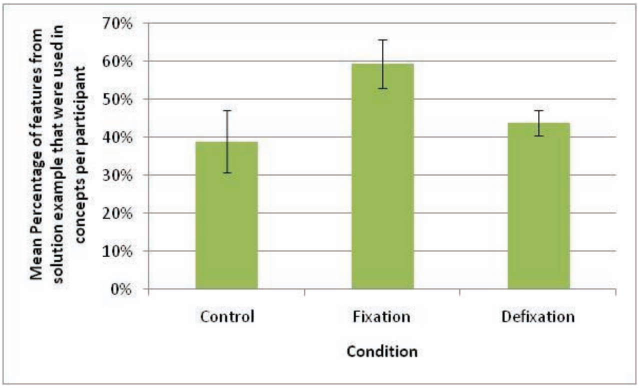


Figure 6: The fixation group used a higher percentage of the features from the example solution in their concepts. Each error bar is plus/minus one standard error.

Based on the graph, the fixation group is clearly different from the other two groups. Using a one-way ANOVA via randomization there is significant difference across the groups ($p=0.05$) [32]. The fixation group produced a larger percentage of gas powered designs than the control group, indicating the example caused fixation. The fixation group also produced a larger percentage of gas powered designs than the defixation group ($t=1.97$, $p<0.08$), demonstrating that the defixation information is effective in breaking the induced fixation. Similar to the other metrics discussed thus far, the results show that fixation is occurring and the defixation materials are having a significant impact.

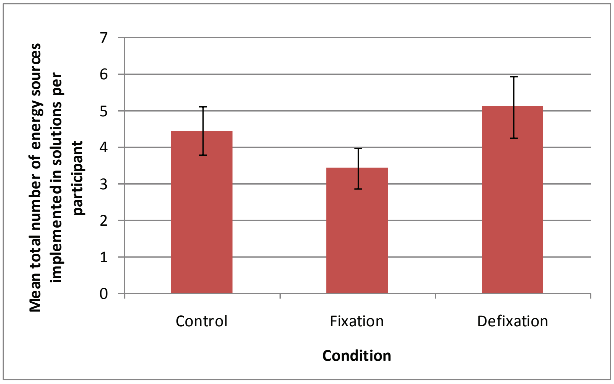


Figure 7: The defixation group used, on average, more energy sources in total than participants in the other two groups. Each error bar is plus/minus one standard error.

The total number of energy sources used in all stages of peanut shelling differed across the three conditions (Figure 7). Again this data does not meet the assumptions for a standard ANOVA (data is not normally distributed and the variances are not homogenous. There is not a significant difference across the three conditions ($H=3.28$, $df=2$, $p=0.194$, $N=31$). The fixation condition produced fewer energy sources than the defixation condition (Wilcoxon's Rank-sum test, $W_s=112.5$, $n_1=10$, $n_2=12$, $p=0.09$), suggesting that the fixation breaking extra information is effective in breaking the induced fixation. The other pair-wise comparisons are not statistically significant. These results suggest that the defixation materials assist in reducing fixation. The categories of available energy sources guide the designers in identifying solutions. In addition, the fixation condition is investigating significantly fewer energy categories than the control condition. Again this is another indication of fixation.

7. GENERAL FIXATION RESULTS DISCUSSION

The various measures related to fixation clearly illustrate that the example solution caused design fixation. This result is shown by the lower number of ideas generated, by a higher number of features from the example being used in the solutions and by fewer of energy categories being implemented in the participants' concepts. This is consistent with prior studies [1, 5, 6]. It is also important to note that the indicators of fixation are consistent across all our measures of fixation.

This fixation is of particular interest since these participants are not novice designers. All participants have the required domain knowledge to identify short-comings in the presented example solution. The short-comings in the example solution were not highlighted to the participants as in a past study [6] but this is frequently the case in a real-world situation. From these results it appears that design fixation is experienced by engineering design faculty and it is significant.

Providing participants with analogies and categories did assist in reducing their fixation on the example solution, but it did not completely eliminate it. Participants in the control group still outperformed both the fixation and the defixation group. Consistently across the measures, the defixation group showed improvements over the fixation group but remained slightly worse than the control (generally not statically significant). From this study, it cannot be determine which materials are effective in reducing the fixation but much further study is warranted.

8. RESULTS FROM POST-EXPERIMENT SURVEY

The key outcome of the survey is the participants' perception about their performance. The fixation and the defixation groups were asked, using a Likert scale, if they felt the provided example solution had influenced them and then if it had positivity or negatively influenced them (Figures 8 and 9, error bars are one standard error). Both groups felt the provided example solution had influenced them. The participants are recognizing the fact that they are being influenced by the provided design example.

The fixation group tended to believe the effect of the example solution is positive whereas the defixation group is unsure of what the influence. The differences between the groups are not significant. The participants' perceptions are in contrast to the quantitative fixation results that indicate the example is having a negative effect on the fixation group, meaning that the designer may not be aware of the negative influence.

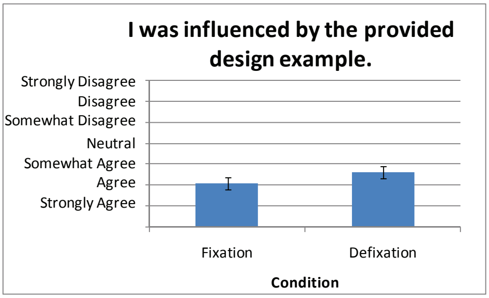


Figure 8: Participants believe they were influenced by the provided example solution.

In addition, the participants' perceptions of the defixation materials' effects were also measured (Figure 9). In this case, participants' correctly believe that the additional information is benefiting them with an average of only agree to somewhat agree (2.7) and a fairly high standard deviation (1.33). This may indicate the some of the participants' are more accurate in their perceptions. The quantitative results indicate there is a very strong positive effect in overcoming the fixation due to the provided defixation materials. While the participant perceptions are generally accurate, in this case they do not strongly match the quantitative results. There was not strong agreement by the participants, on average.

9. ADDRESSING THE RESEARCH QUESTIONS

Research Question 1: Do academic engineering design educators show evidence of design fixation?
Academic engineering design educators do show evidence of design fixation. The fixation group produced significantly fewer ideas, reused more of the features from the example solution and implemented fewer categories of energy sources than the control group. Design fixation was evidenced by the presence of a significant number of solution elements that were not appropriate for the context of the design problem. This group of participants had a high degree of knowledge and would clearly recognize the short-comings of the presented design example in other contexts.

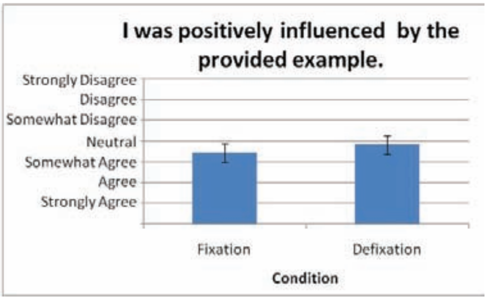


Figure 9: Participants in the fixation and the defixation group felt the example solution had a positive influence or at least were unsure that the influence was positive or not.

Question 2: What can engineers do to reduce their fixation on design solutions? Can analogies, functions, categories of energy sources and back-of-the-envelope calculations assist in overcoming design fixation?
Some of the strategies that may reduce design fixation are analogies, a functional decomposition of the problem, categories of solutions (such as energy sources) and back-of-the envelope calculations. Results from this study clearly indicate that design fixation can be significantly reduced if not eliminated through these means. The defixation group did produce significantly more ideas than the fixation group. In addition, they repeated fewer features from the example solution and implemented a greater number of different energy categories than the fixation group. The results do not indicate which materials were most effective for fixation reduction but that this set as a whole was effective.
Unlike previous studies on design fixation, this study directed participants towards the use of analogy to break design fixation. Participants in past studies likely implemented analogies since analogy is a common and effective design strategy, but our study was much more literal about analogy use. Our study provides further support for the importance and impact of analogical reasoning in design.

Additional research is needed to fully understand the type of information that eliminates design fixation including the numerous representations currently existing in the design literature and how these materials may be generated for novel design problems. Design methods currently exist for functional decomposition [14, 30, 33, 34] and for analogies [35-37]. As more approaches to reducing design fixation are discovered, new design methods will need to be developed to assist engineers.

Research Question 3: How well do participant perceptions of the results correspond to the quantitative results?
Consistent with other studies on idea generation [20], participants' perceptions of effectiveness during idea generation do not always match the quantitative outcome. The defixation group accurately perceived the additional materials were influencing them. Participants in the fixation group inaccurately believe that the example solution has a positive influence on their idea generation process. It is clear from the fixation results that the example reduces the number of ideas generated but this is not perceived by the participants. In contrast, the defixation group felt the examples influenced them but were not sure if it was positive or negative. The defixation group also correctly perceived that they were assisted by the additional information that was provided but they did not feel strongly about this. The data demonstrates that the defixation group was strongly supported by the additional materials provided. These participant perception results strongly warn against their use as an accurate measurement of ideation effectiveness.

10. CONCLUSIONS

This study evaluated design fixation, its reduction and perception in a group of mostly engineering design faculty. Results show that design fixation is a difficulty encountered even by this group, indicating the strength and importance of this effect. The participants' perceptions of the effects of provided example solution and defixation materials are generally not accurate, except with respect to defixation materials. This result is not expected for a group of individuals who study design. This is in contrast to past studies that have shown that participant evaluation of the effectiveness of idea generation sessions tend to be completely inconsistent with quantitative measures. This incongruity in perception presents a unique obstacle to engineering design methods research since one of the easiest measures to obtain is the user's perceptions of the method's effectiveness. Participant's evaluations of a method are frequently inconsistent with the quantitative measures.

This study compared three groups of participants, (1) a control group, which only received the design problem, (2) a fixation group, which also was provided a poor example solution and (3) a defixation group, which in addition to the poor solution, also received a set of materials to reduce fixation. The example solution caused design fixation, as demonstrated by a reduction in the number of ideas generated, a greater number of design features from the example being reused and fewer categories of energy sources considered. Consistent with prior studies, design fixation can be reduced. The fixation reduction materials which included functions, energy sources and analogies, significantly increased the number of ideas generated. It also reduced the frequency of design solutions that were highly similar to the example and increased the number of energy categories spanned.

Fixation is commonplace during the idea generation process and warrants much further investigation. The situations that tend to increase design fixation need to be identified and more approaches for reducing fixation should be created. Further investigation is needed into methods, team diversity and various other approaches that have the potential to reduce fixation.

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