Improving Design Processes through better Decision-Making: an experiment with a decision making support tool

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Abstract: This study gives a descriptive approach in the way Longueville et al. [1] defines it: aiming at modeling in order to study, understand, represent and re-use existing decision-making processes. The study reported here is based upon previous research done by the same authors in which a comparison was made between Verbal Protocol experiments (VP) done by final year design students of two European countries that addressed decision making during the conceptual design phase. As an outcome of those VP two conclusions are central to the current study: a) abductive reasoning supporting designing gains visibility through analysis based upon decision-making; b) design as a decision-making process could bridge, significantly, design education and design practice in organizations.

Having this departure point a decision support tool (DMTool) was created based upon: a) the information access and use; the idea generation; the constraints identification and propagation; the process analysis and evaluation. The experiment was done with 32 design students (teams of 5/6 each) that had to solve a design problem suggested by a company. The DMTool, its use along the design process, its evaluation and contributions to design process will be presented in this paper.

Key words: Decision-Making, Design Thinking, Design Processes, Design Conceptual Phase, Design Experiment

1. Introduction

Decision-making is a field of study that is constantly addressed in all domain knowledge areas being the main driver of those studies the cognitive assessment of how decision making occurs.

Although it is possible to find different categorizations regarding the nature of the approaches done to decision making processes we assume as Sarma [2] proposes there are three main streams: Descriptive that uses models and theories to describe and explain human decision-making behavior by studying human beliefs and preferences as they are; Normative that utilizes axioms to make optimal decisions studying mainly the logic of decision making and nature of rationality in an attempt to suggest how good decisions ought to be made, and Prescriptive that develops techniques and aids for supporting and improving human decision making.

Along with this definition of the nature of approaches to this topic several nomenclatures had emerged in recent years. Among them there is the naturalistic decision making (NDM), a descriptive approach, that in the words of Endsley et al. [3] “evolved as a focused effort to describe how people make decisions in the real world”. This particular approach was initially based upon the work of Gary Klein [4-6] and is seen by Endsley et al. [3] as rejecting some previous research on design theory. The critic regards mainly the normative nature of these
theories instead of being descriptive. Reason why they fail in capturing critical aspects of how people decide mainly when dealing with “ill-structured problems, uncertainty, time stress, risk, multiple and changing goals, multiple individuals”. More recently NDM expanded its analysis to macro cognition incorporating the work of Klein at all. [7] that had their focus on the behavior of experts providing a theoretical viewpoint that includes processes such as attention management, mental simulation, mental model development, uncertainty management and course of action generation. Klein et all. [7] describe some aspects of the cognitive experience such as problem detection, sense making and situation assessment, coordination, planning, adaptation and replanning that are contrasted with micro cognitive processes studied by the traditional psychology such as memory and attention.

1.1. Decision-Making in Design Process

Decision making in design processes is in our view dependent on three substantive elements: a) knowledge access and management; b) thinking and communication skills, and c) use of a strategy or plan to solve problems and provide solutions.

As Qiu et all. [8] defend it “decision-making is a knowledge-intensive activity with knowledge being its raw materials, work-in-process, by-products and finished goods.” Therefore, the ability to manage knowledge with proficiency is significantly influential in terms of the competitiveness of decision makers, particularly when we consider the global knowledge society.

The way knowledge is supporting decision making is illustrated in Figure 1.

![Figure 1 - Utilising knowledge to support decision making for solving problem](Image)

Figure 1 shows how knowledge is structured to help in problem definition, solution development and solution selection as Haque et al., [9] and Kreitner and Kinicki, [10] suggested. The idea is that decision making must adopt a customer centric strategy that is basically sustained by three issues: a) requirement of knowledge from the hands of the right person at the right time; b) customizing knowledge needed to keep update on what is happening; and c) using expert choice to aid the team in structuring and documenting.

2.2 Decision Making – dynamics of group decision

Deciding individually is different from group decisions, and it influences the outcomes of design processes. Also important is the role of the leader of each process since it will be the one who formally has the responsibility of organizing the work and of planning tasks and work to be done. Leader and members should also have the ability to manage conflict and to overcome situations of blockage or of low motivation. According to Huitt [11] individual differences in problem solving and decision making must be taken into account to adequately
understand the dynamics of these processes. Personal characteristics of the group members clearly influence these processes in the way that they make use of specific techniques in problem solving.

2. Aim of the research
The overall aim of the research is to provide building blocks or tools to designers that facilitate decision making in the design process. Based on previous studies (partly performed by ourselves) we first give a descriptive model of decision making in design. Next we have tried to generate a Decision Making Tool (DMTool) as support for designers to analyze decision making in design processes. In both the model and the DMTool the aforementioned three elements are taken into account.

In order to test the DMTool an experiment was conducted in which 2 student design teams were asked to solve a design problem, one with the help of the tool.

Descriptive model, DMTool and experiment will now successively be described.

3. A descriptive model
The descriptive model of decision making is presented in Figure 2. It equates decision making at three different levels:

a) a micro level – where decision making is defined according to the following descriptors: 1). Decision Strategy where we can find 3 distinct strategies: a non-compensatory rule based strategy meaning that, as defined by Rothrock, and Yin [12], under such a strategy designers generally do not make use of all available information and trade-offs are often ignored; a compensatory rule based strategy where information is processed exhaustively and trade-offs need to be made between attribute cues; and finally the negotiated strategy where designers use both previous ones trying to balance their decision constrained by several aspects such as time, expertise, level of information etecetera., (2) Manner of Decision that has to do with the dynamics of groups in terms of decision making and that includes 3 modes: Co-operation that implies negotiation where the facilitator does it WITH people, seeks integration of people’s ideas, leader prompts and enables people to decide; Authocracy, a type of direction where the facilitator does it FOR people; it can be either autocratic or it can get a consultative direction mode; and Autonomy that implies delegation where the facilitator gives it TO people; it can be a structured delegation where a procedure or a more broad approach must be followed.

b) a linkage level – that includes Decision Nature, that was defined by the authors [13] has being of three types: Framing decisions - decisions made during the period when a designer mentally ‘frames’ the object; Key Decisions - those made on moments when the (preparation of the) product creation occurs and Enabler Decisions - that signify mental object representation instants.

c) a macro level - as depending on: (1) knowledge management, (2) creative cognitive processes where two modes are identified: exploratory that has to do with operations such as contextual shifting, functional inference and hypothesis testing; and generative that is related with analogical transfer, association, retrieval and synthesis, (3) design strategy that as Christiaans and Restrepo [14-15] mentioned can assume three different orientations in terms of the way assignments are approached by designers: problem oriented when there are descriptions made in terms of abstract relations and concepts; process oriented, when the process rules the design development and product oriented when from the beginning there are descriptions of the possible solutions.
As an outcome of this mindset and its operationalization we have twenty seven types of possible solutions that are resultant from the different conjugation of the model’s identified descriptors.

4. The DMTool

DMTool is a folder created in excel (meant to be developed as autonomous software) that has four main areas: a) information access and use, where the phase of the process, the type of information, degree of importance and use, source of information and application are addressed; b) idea generation that needs to be explored in terms of phase of the process, nature of idea, degree of innovation, degree of applicability, positive points and negative points, source, application and use, c) process that allows designers to register the stages of process, the tasks to be performed, dates, responsible persons, the control of the process state, the iterations; the reasons behind iterations, tools to be used, occasion of use, expected benefits and real benefits; and d) evaluation with two types of reflections to be made: upon the produced outcome and about the outcome improvement regarding aspects such as positive and negative points of the solution, degree of innovation, degree of feasibility and degree of business adequacy; added value and proposed changes and tools to be used in change. (See Figure 3)

The first three issues are operational drivers to support decision making since hypothetically knowledge and idea generation monitoring and control help decision making accuracy, efficiency and coherence. The process assessment helps decision makers controlling the plan and to have an overview of their moves along time – a macro perspective of the approach in progress that was intended to promote communication among members.

Finally, the evaluation review will allow decision makers to have a critical reflective consideration of both the produced outcome and its possible improvement making explicit what usually design students never do: ‘what it could be if.’ This “reflection-after-results” aims to develop in students a critical consciousness of their own processes as well as the ability to define corrective procedures in order to improve their own design performance.
5. The experiment

An experiment was conducted with the following objectives: (1) the observation and description of decision making of student design teams in the conceptual phase of the design process, and (2) the test and validation of the model and the DMTool.

All groups received the same assignment that was delivered by a Portuguese light manufacturer named CLIMAR, Sistemas de Iluminação SA. The assignment proposed by the company was that of the creation of a product/Chandelier to a niche market (the high standard lobbies either from hotels or from emblematic buildings such as parliaments; government buildings etcetera. The proposal to be developed at the conceptual level should integrate both product and communication design. The groups had to develop the work during 5 weeks having the real possibility of working 2 times a week during at least 2 hours.

5.1. Method

5.1.1 Participants

The experiment was done with 32 final year students from the 5th year of the Design course at the Faculty of Architecture from Technical University of Lisbon. Two Erasmus students from Italy participated in the experiment – one with a fashion design background and the other one with an interior design background. The total group took part in a Master course on Design processes management optional course. The work for the experiment overlapped with these classes.

With a total of 32 students 6 groups were composed, 4 groups of 5 students and 2 group of 6 students. Three groups – 2x5 and 1x6 students – were appointed as experimental groups and three as control groups – 2x5 and 1x6 students –. The experimental groups worked with the decision making support tool (DMTool), while the control groups did not.

The selection of the groups has been based on both matching and randomization. First, the six teams were matched on the basis of their discipline: an equal number of product design and graphic design students. Next, people of both disciplines were at random placed in one of the six teams. Finally, the two Erasmus students were at random appointed to two groups.

5.1.2 Experimental design

Out of the 3 experimental (E) and the 3 control groups (C) two groups per condition (E1 and E2, C1 and C2) were selected and were meticulously followed regarding both process and the use of the DMTool. Videotaping took place for two groups while for the other two groups the more unobtrusive audiotaping was used. For the
remaining experimental (E3) and control (C3) group only the screen records and the results will be taken into account.

Table 1 shows the experimental design. A pre- and post-test was part of the study. In order to control for effects of the pre-test two of the groups were only post-tested. The same holds for the effect of observing media.

### Table 1. Experimental Design

<table>
<thead>
<tr>
<th>Student group</th>
<th>t1</th>
<th>t2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group E1</td>
<td>R</td>
<td>O1</td>
</tr>
<tr>
<td>Group C1</td>
<td>R</td>
<td>O1</td>
</tr>
<tr>
<td>Group E2</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Group C2</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

R = Random t = time/moment O = Observation X = Intervention (use of DMtool) V = video A = Audio

### 5.1.3 Procedure

Five Sessions of two hours for each group – Experimental group at Tuesday from 14.00 to 16.00; control group on Thursday at the same hour an in the same room. (although all the groups worked also in the other 2 hours time available during week being responsible for the register of activity developed). The sessions were done during the classes of the Design processes management optional course that had one of the authors as a lecturer.

All teams had to elect a leader that was briefly briefed about his/her role namely about the use of the tool and the register of information developed outside the sessions. In order to get insight in what the teams do two instruments were introduced: A diary register of all sketches, images and written documents produced along the process and a screen record book to keep record those moments that the groups worked outside the studio hours (this device only records the work developed in computer).

After the work was completed the results were evaluated by a jury of eight persons (2 from abroad) composed of 2 design teachers, 1 architect, 2 CLIMAR representatives, 1 light engineer expert and 2 light magazine directors.

### 5.2. Results

#### 5.2.1 In terms of the tools use

Teams that had to work with DMtool used it at the end of the sessions and never as a facilitator along the process. However the awareness of the issues addressed and the analyses to be made with the tool determined a more systematic approach to information, the concern with the register of it, the clear statement and a deeper analysis of the generated ideas (their potential and limitations). It gave team members a step by step awareness of the entire process.

In fact being the tool structured in well-defined topics that must be dissected in depth was the reason of the authors’ recommendation of using it at the end of each session since otherwise it could hamper the natural fluidity of the teams’ reasoning and creative process.

The DMTool facilitated especially the reflection upon: a) information: its usefulness and consistency in the whole process; b) idea generation in terms of its novelty, consistency with the solution framework, d) the cause-effect process of decision making and the degree of dependency between variables. It also gave light to some ‘missing parts’ in students’ reasoning helping them to recover information or to search for and define more information in order to proceed in a coherent manner. However, there was no clear evidence that the use of DMTool has improved in an unquestionable way the results of the, although the group with best results was using it.
It became also evident that even while the tool was a more dynamic software in order to operate as a guidance tool of the whole design process, it was necessary during a relative long period of time to train students to operate with it. The lack of habit in using a structured methodology on the part of these students made this fact more apparent but gave us also the chance to observe the potential advantages in terms of the design quality improvements if a methodology is used based upon knowledge management and decision making.

5.2.2 In terms of decision making descriptive model analysis

First of all it is of use to point out that the evaluation made by the jury was very …… and that the difference among the first three groups was minimum since the winner had a final score of 124, 01 the second of 123,87, the third of 121,81, the fourth of 110,17, the fifth of 108,16 and the sixth of 98,49. The maximum possible score was 200.

When we apply the decision making descriptive model (Figure 2) to each of the cases we find out that they correspond to 5 different types of outcomes that are the result of distinct combinations of the five areas approached in the descriptive model. Translating the final codes in terms of strategies we find out that:

- E3, the winner of the contest proposed by CLIMAR, is a ADEHK type meaning that the group was problem oriented and that engaged in a creative process where both exploratory and generative cognitive tasks were performed (here with a clear focus on exploratory ones) while decisions where taking place (with a clear weight of framing ones that gave origin to three key decisions, one of which gave origin to the final outcome); In terms of de operationalisation of the mindset the group presented two distinct visions and approaches to the problem (the vision and modus operandi of the ones with graphic background and the one of the product background) so the agreement made among the conflicting members of the group was to develop the design with a high level of autonomy in terms of decisions made along the process being the team leader responsible to keep everyone informed of the major decisions; Finally the decision strategy was a non compensatory rule based one where intuition dominated being most of the information gathered not used and no trade-offs among attributes being considered.

- C1, is a CDEHJ that is to say that in terms of mindset a product oriented group also performing a creative cognitive process that alternated from exploratory to generative tasks (with a special focus on the last ones) while developing all different natures of decisions with a particular emphasis on enabler ones having had 2 major key decisions. Its mindset implementation was one where although cooperation was evident in
establishing the plan due to the fact that all members had a deep knowledge of each other skills, autonomy prevailed in a decision strategy globally compensatory ruled based.

- E2 is also a CDEHJ and performed a quite similar approach to the brief developing its first Key decision until the end with a high level of detail and having a very systematic and consistent process.

- E1 is an ADGEK case where we are facing a group that in terms of mindset was problem oriented engaging in a creative process where exploratory and generative cognitive tasks were performed along the different nature of decisions being the exploratory task predominant and the greater number of decisions the one of framing nature. Regarding the operationalization of its mindset we were in the presence of a cooperative way of decision (although most members got passive along the time) being the decision strategy a non compensatory rule based one since they displayed a design fixation that inhibit them to reason upon knowledge available.

- C2 is an ADEGI type meaning that the team was problem oriented and its creative process was ruled by exploratory cognitive tasks being the generative ones less succeeded. In what concerns the mindset operationalization the team members where very cooperative having enjoyed clearly the fact that they were working together. There was a balance between the amount of framing and enabler decision in terms of its quantity being the key decision taken late in the process. The dominant decision strategy was one compensatory rule based what signifies a huge amount of work regarding the gathered information, the evaluation of the attributes in a very rigorous and systematic way.

- C3 is a CDEHK type since the group was product oriented and more than that having a design fixation since the beginning. Due to that fact the creative cognitive tasks performed were limited since the motivation behind each task was to “made possible that design at all cost”. The Key decision was taken early in the process and after that the enabler decisions were dominant. In terms of decision manner this group was a bit problematic having a leader that tried to exert an autocratic leadership without success. Being so the autonomic modus operandi took place and the design was developed in a very chaotic manner. Regarding the decision strategy we are facing a non compensatory rule based one since in this case we observed a complete ignorance on the part of the team members of the available information and the inability of evaluating and developing alternatives.

6. Discussion and Conclusions

Figure 5 presents in very basic ways some of the conclusions of this study focusing on issues such as creativity, knowledge management and decision making that were assessed in terms of the performance achieved by each of the six design groups. Furthermore decision making (that was approached in the last graphic on the right side of the figure, as a whole integrating different criteria) is dissected and considered in terms of its coherence, efficacy, timing, rational correctness and participation of group members (in the left side of the graphic).
A deeper analysis of the graphics presented in Figure 5 allows us to recognize for instance that a high level of creativity and a good knowledge management on the part of a group (such as E1) when it is not consistent along the time can result in a performance below the expected quality level. In the particular case of this group the presence of a charismatic leader leads to a kind of “blind reliance” of all the other team members that trusted him the success of the outcome. In the third session the drop in enthusiasm of almost all members regarding the solution proposed (both the product designers and communication ones) was observable. And while the leader had to give his attention to another project there were two severe consequences: communication among members was impoverished, motivation lowered its level, the ability to exert a judgment over the tasks to be performed and encountered solutions got numbed. Besides this lack of communication designers felt a bit subordinated along the process. On the other hand if we observe the course of for example C1 group when compared to E1 it started with lower inputs in terms of creativity and knowledge management and having found a solution around session 2 they had experienced several problems in terms of its technical and constructive aspects. In the face of that the group had a hard time deciding to abandon that alternative that was keeping everyone unsatisfied. However, between session 4 and 5 and based upon the work developed in terms of communication design a new product solution was found. This new idea boosted an expressive energy among all members that in a very mature and efficacious way developed the solution that although having a medium level of creativity (in strict terms of the object) was highly creative and competitive as a strategic product to the firm in terms of its markets, its production resources and brand consolidation. Again here it was crucial the way decision making was done by the group members. Here the leadership was shared by all, autonomy and delegation occurred extensively and there was an accurate exploitation of the personal characteristics and skills of each of the members that resulted in an optimized solution. Having made this discussion based upon two of the six groups that were studied it is now time to present some of the more important conclusions.

Regarding the DMTool

The use of a Decision making support tool is hard for the participants since it has a “non natural” modus operandi in the context of a design process that is fluid and complex in terms of information processing and exploratory and generative processes of creation. However it was clear in this study that decision making can be improved and in fact is improved already by the awareness and compulsory need of evaluation of the factors that clearly influence the quality of results. That is the case of the role of information use and knowledge management, the idea generation process; the level of thinking and communication skills and the use of a strategy or plan to achieve to the desired outcomes. Also the importance of group dynamics in decision making
and the impressive level of influence personal characteristics interaction has in the decision making process are some of the outcomes of this study. The decision manner of the team is decisive for a consistent, growing creative process as well as for a good level of communication an adequate level of thinking and a good implementation of a strategy to pursue the best solution. Finally, we have to realize that in a real and natural situation like the design course that was chosen to do the experiment there are so many variables that influence the process and the result of the group, that it is hardly possible to isolate the effect of one variable: the use of the DMTool. A more controlled experiment would ruin the validity of a realistic project.

Regarding the outcomes of the experiment
We could observe two clear approaches to the brief; one that assumed the possible solution in a very literal way having an outcome a design that we can assume as a “unique piece” and another one that developed solutions that matched a strategy of expansion of firm’s market.

It is important to consider the fact that the winning design was very controversial among the jury members being considered the best by half of them and being placed in the fourth of fifth position by the other half. This fact is related with the judgment made upon the uniqueness of the object and the direct link of this attribute with brand identity and representativeness. The designs scored in second and third places were the result of an interpretation of the problem that was not literal but included a deep analysis of the markets the firm operated (like hotel projects) having assumed since the beginning the versatile, modular and multi-use characteristics in the object.
Furthermore it is noticeable the fact that the winning group was one of continuous conflict among two parts, the graphic designers and the product designers, being the outcome achieved late in the process. It was the result of decisions made by the product designers and the graphic designers just used the design after (the last session) to develop the graphic elements needed for the contest. This fact is relevant since it shows that although the design was not properly developed due to the lack of time the idea was evaluated as being good, promising and tuned with the firm’s ambitions.
Finally it is to refer that the use of a descriptive model allow us to understand better design processes and in this particular case the way decisions are made but it is not meant to conclude nothing regarding the better strategy to pursue.

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8. References


