DECISION MAKING IN THE CONCEPTUAL PHASE OF DESIGN PROCESSES:

A DESCRIPTIVE STUDY CONTRIBUTING FOR THE STRATEGIC ADEQUACY AND OVERALL QUALITY OF DESIGN OUTCOMES

PHD THESIS | VOLUME I AND VOLUME II

Candidate Rita Assoreira Almendra

Supervisor Prof. Doutor Fernando Moreira da Silva

Co-Supervisors Prof. Doutor Henri Christiaans
Prof. Doutor José Pinto Duarte

President Reitor da Universidade Técnica de Lisboa,
Professor Catedrático, Doutor Fernando Ramôa Ribeiro

Jury Doutor Henri Christiaans,
Professor Associado da Technical University of Delft

Doutor Vasco Afonso da Silva Branco,
Professor Associado da Universidade de Aveiro

Doutor Eduardo Alberto Vieira de Meireles Corte-Real,
Professor Associado da Escola Superior de Design do
Instituto de Artes Visuais, Design e Marketing - IADE,
na qualidade de especialista

Doutor Fernando Moreira da Silva, Professor Associado da
Faculdade de Arquitectura da Universidade Técnica de Lisboa

Doutor José Manuel Pinto Duarte, Professor Associado da
Faculdade de Arquitectura da Universidade Técnica de Lisboa

Doutor Pedro Manuel da Silva Picaluga Nevado, Professor
Auxiliar do Instituto Superior de Economia e Gestão da
Universidade Técnica de Lisboa

Doutor João Paulo do Rosário Martins, Professor Auxiliar da
Faculdade de Arquitectura da Universidade Técnica de Lisboa

FACULDADE DE ARQUITECTURA
UNIVERSIDADE TÉCNICA DE LISBOA

Lisbon, 2010

Author of the cover Image
Sofia Juliana Freitas

Author of the image animation
Mónica Loureiro

Editorial Design
Sandra Belela Lopes

PhD Thesis |

Decision Making in the Conceptual Phase of Design Processes:

a descriptive study contributing for the strategic adequacy and overall quality of design outcomes

Candidate | Rita Assoreira Almendra
Supervisor | Prof. Doutor Fernando Moreira da Silva
Co-Supervisors | Prof. Doutor Henri Christiaans
Prof. Doutor José Pinto Duarte

President | Reitor da Universidade Técnica de Lisboa,
Professor Catedrático, Doutor Fernando Ramôa Ribeiro

Jury | Doutor Henri Christiaans,
Professor Associado da Technical University of Delft

Doutor Vasco Afonso da Silva Branco,
Professor Associado da Universidade de Aveiro

Doutor Eduardo Alberto Vieira de Meireles Corte-Real,
Professor Associado da Escola Superior de Design do Instituto de Artes Visuais, Design e Marketing - IADE, na qualidade de especialista

Doutor Fernando Moreira da Silva, Professor Associado da Faculdade de Arquitectura da Universidade Técnica de Lisboa

Doutor José Manuel Pinto Duarte, Professor Associado da Faculdade de Arquitectura da Universidade Técnica de Lisboa

Doutor Pedro Manuel da Silva Picaluga Nevado,
Professor Auxiliar do Instituto Superior de Economia e Gestão da Universidade Técnica de Lisboa

Doutor João Paulo do Rosário Martins, Professor Auxiliar da Faculdade de Arquitectura da Universidade Técnica de Lisboa

FACULDADE DE ARQUITECTURA
UNIVERSIDADE TÉCNICA DE LISBOA

(Dedication)

Dedicatória(s)

I dedicate this work to Eduardo Martinez Afonso Dias, a designer of reference, a natural born teacher and most important a human being of excellence. With him I learned to improve my human and professional skills and it is truly a privilege to have him as a friend.

Also dedicate it to my students, the ones I had, I have and the ones yet to come for they are the reason of this research.

Acknowledgments

To the Faculty of Architecture of the Technical University of Lisbon that has created the PhD Program in Design and hosted my PhD process;

To all the members of the Jury that honour me with their appraisal of my research work;

To FCT (Foundation for Science and Technology) that has granted me a scholarship during the last three years to help me accomplish my research works;

To my supervisors, Professor Fernando Moreira da Silva, and Professor José Pinto Duarte that have guided me along this challenging knowledge process; their diverse approaches have enriched my work in a relevant way; A special thanks to Professor Henri Christiaans that due to his expertise had a more keen contact with my work. His orientation was unique in nature, commitment and demand. Due to him I had the chance to enlarge my knowledge in this field and to learn immensely about design and design research.

To all the researchers of De.:SID research project, my dear colleagues, that have made possible to build up knowledge essential to this study;

To Professor Luís António dos Santos Romão, coordinator of De.:SID and a dear friend that along these four years, generously offered me his time and knowledge allowing me to share my doubts and to discuss key issues of my work;

To all my students in general that give me the chance each day to learn and to feel highly motivated to embrace the cause of design and design education;

To the Portuguese students that graciously accepted to participate in the experiments of this research. They are: Alexandre Neves, Ana Costa Gomes, Ana Raquel Rodrigues, Ana Rita Henriques, Ana Serrazina, Ana Sousa, Andreia Patrício, Catarina Ferreira, Cátia Silva, Daniel Pera, David Francisco, Federica Colombo, Fernando Alhinho, Filipe Cabaças, Filipe Costa, Filipe Martins, Guilherme Amaral, Inês Camilo, Iva Machado, Joana Dias, Joana Higino, João Fagulha, Joaquim Gonçalves, Liliana Teixeira, Luisa Leitão, Manuel Damião Ferreira, Maria Gutierrez, Maria Rosário Jané, Mariana Branco, Mariana Campos, Mariana Coutinho, Marianne Caupers, Milene Gonçalves, Natália Rocha, Nuno Pires da Silva, Patrícia Couto, Patrícia Ferreira, Patrícia Pereira, Paulo Gonçalves, Pedro Gomes, Raquel Coelho, Rita Costa, Rita Rodriguez, Rita Seabra de Sousa, Samuel Bjork Fanhais, Sara Faneco, Sara Fontana, Sara Garcia, Sofia Floriano, Sofia Freitas, Teresa Mira.

To the Dutch students that enthusiastically agreed to participate in one of the experiments of this study. They are: François Boaziz; Pieter van Dijk, Thatcher Peskens, Marjolein van Houten, Leonard Schurg, Annette Voesenek, Arno Pont and Kika Lamers.

To Ana Laura Santos that helped me with the dutch participants.

To Nuno Aboim, master students from Instituto Superior Técnico (IST) that assisted me during the experiments;

To Milene Gonçalves, my dear student since her first year in the Faculty, now also a PhD researcher and a good friend, for monitoring the group experiments and coding the verbal protocols. Her dedication and commitment to the work made all the difference.

To the members of the jury of Verbal protocol experiment done namely: Eduardo Corte Real (IADE) , Lia Santos (ESBAL), José Alves Pereira (FA), José Rui Marcelino (FA); Catarina Cardoso(CP) João Rocha (UE) Luís Romão (FA)

To the company Climar, Sistemas de Iluminação SA, its CEO Engº José Sucena and other administrators as well as the staff members that made possible to create an experiment linking industry to education that contributed meaningfully to this study.

To the company CIMP, its CEO Drª Renata Camargo and its staff that had made possible the creation of a week experiment developed inside the company that allowed us to study design processes in a professional context;

To Sandra Belela, a dear student and a friend, for the graphic design work she has done in this thesis;

To Mónica Loureiro, another special student and friend, for the animation she did for graphic design of this document.

To João Ferreira, an eternal friend that helped me with the presentation.

To all my friends especially those that encouraged me in respect to this work such as Rui Marcelino, Inês Simões, Eduarda Abbondanza, Vitor Correia, Vítor Santos e Lúcia Carmona.

To Professora Maria João Durão for her affective and empathic support;

To Professora Maria Calado for her care and concern with me and my work and for her continuous encouragement;

To Paulo who has helped me along this journey with generosity and understanding;

And finally, to my family,
To my mother, always there to support me in my hectic daily life,
To my brother António, a super uncle and a special friend.
To Inês, David and Vicente for the moments I deprived them from my presence and for the amazing strength they gave me through their affection and unconditional love in this intense period of work.

And to *.*.*.*.* my life, my rock, my eternal love

Epigraph

“If you don’t know where you are going, any road will get you there.”
Lewis Carrol

“It’s a poor sort of memory that only works backwards.”
Lewis Carrol

“Alles van waarde is weerloos”
Translaction: “All of value is defenseless”
Lucebert,   in De zeer oude zingt”, 1974.

Abstract

This research focuses on the design process and more specifically on the way decision making can influence the design process' outcomes in its strategic adequacy and overall quality.

The study is centred on the conceptual phase of the design process and, in general, aims to describe the behaviour along the process of design students and professional Portuguese designers both at the educational and business level. It should result in a descriptive model to support the understanding of design process management in terms of its critical variables.

This descriptive model is based on the identification of the key parameters of design processes concerning its strategic adequacy and overall quality.

In methodological terms it is a mixed methods research with a clear dominance of qualitative methods integrating an active research where experiments either in simulated situations or in real context play a key role. Quantitative methods were also used and they served the purpose of triangulating data in order to have a more consistent and rigorous description of the design process and its main structural elements.

Data gathering occurred in the education and business areas, partly separately and partly combined. Furthermore, in the field of education a comparison of the performance of both Portuguese and Dutch university students was made. That helped to validate some findings of previous studies but also to understand the role different Design curricula can have in the performance of students.

The main conclusion of the study is that decision making togehter with information and knowledge management, and idea generation are the fundamental aspects to be addressed in design processes when both strategic adequacy and good quality of the design outcomes are pursued.

Another important finding is that decision making is better understood through the use of a few central parameters. These parameters were used in the creation of a descriptive decision making model that equates decision making at three different levels that are highly dependent on information/knowledge management and Idea generation.

At a macro level, which regards the mindset of the designer, we make a distinction into two elements: a) the *design strategy* with its three types – *problem driven*, *solution driven* and *integration driven*; and b) the *creative cognitive processes* that present two modes of action: the *exploratory* one that has to do with operations such as contextual shifting, functional inference and hypothesis testing; and the *generative* one that is related with analogical transfer, association, retrieval and synthesis.

At an intermediate level we have *decisions* that can have a *Framing, Key* or *Enabler nature*. And finally, we have the micro level of the model, the operationalization of the mindset, where the *decision strategy* and the *decision mode* are chosen. The *decision strategy* presents three types of behavior: the *compensatory rule based;* the *non compensatory rule based* and the *negotiated compensatory /non compensatory* one and it is clearly linked with the way decisions are taken in processing information. The *mode of decision* is linked with group dynamics and focuses on the way teams organize themselves while working and deciding.

Keywords

Design process,
Design experiments,
Decision-making in Design,
Design conceptual phase;
Mixed methods research

Resumo

Este é um trabalho de investigação sobre processos de projecto e mais especificamente sobre a forma como a tomada de decisão pode influenciar os resultados destes em termos da sua adequação estratégica e qualidade global. O estudo incide sobre a fase conceptual dos processos de projecto e procura descrever o comportamento dos projectistas tanto ao nível do Ensino (estudantes finalistas) como ao nível das empresas.

Um dos resultados previstos era a criação de um modelo descritivo que suportasse a compreensão da gestão de processos de projecto nas suas variáveis mais críticas. Este modelo descritivo deveria basear-se na identificação de parâmetros chave dos processos de design no que concerne a sua adequação estratégica e qualidade global.

Em termos metodológicos trata-se de uma investigação mista com claro domínio de métodos qualitativos de investigação activa como são as experiências videogravadas de processos de projecto, tanto em situação de simulação como em situação de contexto real.

Os métodos quantitativos foram também utlizados e serviram o propósito da triangulação metodológica de dados por forma a obter-se uma descrição o mais rigorosa e consistente possível dos processos de projecto e seus elementos estruturantes. A recolha de dados deu-se tanto no contexto de ensino como no contexto empresarial portugueses tendo-se efectuado experiências em que estas duas áreas de intervenção interagiram.

Ademais foi feita uma comparação do desempenho de estudantes universitários Portugueses e Holandeses do Curso de Design. Esta análise almejava confirmar informação obtida em estudos anteriores e assim validar o presente estudo e também visava perceber o papel que diferentes currículos de ensino podem ter na performance dos alunos finalistas.

A conclusão fundamental deste estudo é a de que a tomada de decisão a par com a gestão de informação e conhecimento e a geração de ideias são aspectos fundamentais a serem acedidos nos processos de projecto quando se persegue a sua adequação estratégica e uma boa qualidade global destes.

Um segundo contributo deste trabalho é a descriminação de um conjunto de parâmetros que servem a melhor compreensão dos processos de tomada de decisão no projecto.

Estes parâmetros integram um modelo descritivo de tomada de decisão criado e que equaciona a tomada de decisão em três níveis distintos que são interdependentes da gestão de informação e conhecimento e da geração de ideias.

O modelo criado apresenta num nível macro, respeitante à 'mindset' do projectista e que tem dois elementos a considerar: a) a *estratégia de projecto* que pode ser de três tipos: *guiada pelo problema; guiada pela solução; guiada pela integração*; e b) os *processos cognitivos criativos* que assumem dois modos de acção: o *exploratório*, que tem a ver com operações tais como a alteração contextual, a inferência funcional, o teste de hipóteses e, o *generativo*, que se relaciona com a transferência analógica, a associação, a recuperação de elementos/informação e a síntese.

Num nível intermédio as decisões podem ser de três distintas naturezas: de Enquadramento (Framing), Chave (Key) e Facilitadoras (Enabler).

Por fim temos o nível micro do modelo, que corresponde à operacionalização da 'mindset' e que compreende a *estratégia da decisão* e o *modo de decisão*.

Quanto à estratégia de decisão esta pode ser: a) baseada em regras de compensação, b) baseada em regras de não compensação ou c) mista numa negociação das duas primeiras. O modo de decisão está intimamente ligado às dinâmicas de grupo e foca-se na forma como os grupos organizam o projecto e decidem.

Palavras Chave

Processo de Projecto,
Experiências de Projecto,
Tomada de Decisão em Projecto,
Fase Conceptual de Projecto;
Investigação Mista

General Index

(Note: the other Appendix integrate the DVD placed in the back cover of this document)

APPENDIX LIST

APPENDIX AA; APPENDIX AB; APPENDIX AC; APPENDIX AD; APPENDIX AE; APPENDIX AF; APPENDIX AG; APPENDIX AH; APPENDIX AI; APPENDIX AJ; APPENDIX AK; APPENDIX AL; APPENDIX AM; APPENDIX AN; APPENDIX AO; APPENDIX AP; APPENDIX AQ; APPENDIX AR; APPENDIX AS; APPENDIX AT; APPENDIX AU; APPENDIX AV; APPENDIX AW; APPENDIX AX; APPENDIX AY; APPENDIX AZ; APPENDIX B; APPENDIX C; APPENDIX D; APPENDIX E; APPENDIX F; APPENDIX G; APPENDIX H; APPENDIX I; APPENDIX J; APPENDIX K; APPENDIX L; APPENDIX M; APPENDIX N; APPENDIX O; APPENDIX P; APPENDIX Q; APPENDIX R; APPENDIX S; APPENDIX T; APPENDIX U; APPENDIX V; APPENDIX W; APPENDIX X; APPENDIX Y; APPENDIX Z;

Index of Figures

Index of tables

List of Acronyms and Abbreviations

CEO | Chief Executive Officer. The executive who is responsible for a company's operations, usually the President or the Chairman of the Board.

CIA | Critical Incident Analysis

CIMP | Centro Internacional de Merchandising e Promoções

De.:SID | Design as a company's strategic resource: Study of the impacts of Design

FCT | Foundation for the Science and the Technology

NDM | Naturalistic Decision Making

SPSS | Statistical Package for Social Sciences

VPA | Verbal Protocol Analysis

Part one: Presentation of research

CHAPTER I - INTRODUCTION

1. RESEARCH AND PROBLEM CONTEXTUALIZATION

1.1 The Research Contextualization

The research developed in the context of the present thesis is related with two of the categories Nigel Cross (2006, p101) defined in its taxonomy of the field of design research: the *design epistemology*, meaning the study of "designerly ways of knowing"[1] and the *design praxiology* that is to say the study of the practices and processes of design.

According to Cross (2006, p.101) the first category is related with the ability of people to design and includes "empirical studies of design behaviour but it also includes theoretical deliberation and reflection on the nature of design ability. It also relates strongly to considerations of how people learn to design, to studies of the development of design ability in individuals and how that development might best be nurtured in design education".

The second category has to do with tactics and strategies of designing and has as it "major area of design research the methodology: the study of the processes of design, and the development and application of techniques which aid the designer." (2006, p101)

1.2. The Problem Contextualization

The present study is then focused on the design process and the way designers behave and act along it.

This thesis is concerned with the study of the design process in two different contexts: in an educational setting and in a professional setting. The reason to consider these two contexts was that preliminary studies (EC, 2004, pp 19-20; EC 2006; FA Internal Report 2005) revealed a gap between design education and industry.

In fact, that relationship showed either reduced or irregular knowledge flows between them in what

1. See glossary – Appendix A

concerns the understanding of the discipline itself, its use and role; and, in terms of the design practices, the gap between education's priorities and industrial ones was also evident.

This was confirmed by the university's internal evaluation and probation reports where that gap was clearly recognized.

Also the 2004 report published by EC regarding the future of the European manufactures stated that:

"(…) Development of educational curricula has not kept pace with either the growing complexity of industry or the economy, and even less with the rapid development of new technologies. Studies are often too lengthy and too general. Furthermore, it can be argued that manufacturing is a subject that cannot be handled efficiently inside a university classroom alone. (…)"

Furthermore the European Community (2006) analysis of "Why European higher education systems must be modernised?" presents a vision of the European higher education in general that identifies that same gap:

"The performance of developed economies is closely related to their ability to create, disseminate and apply knowledge. These three poles - education, research, innovation - are known as the 'knowledge triangle'. Unfortunately, Europe has fallen behind in all three parts of the knowledge triangle, and needs to improve its performance in each of them. The problems with Europe's universities centre on the following:

European higher education is fragmented into (what are often) small national systems and sub-systems, without effective links and bridges between them;

National regulations are too often over-detailed, and this diminishes universities' responsiveness to changing learning and research needs emerging from markets and society;

Universities under-use the knowledge they produce because they and business still inhabit largely separate worlds; (…)"

Meanwhile, the Design program at the Faculty of Architecture (starting from 1992) have changed its curricula (starting in 2006 and finishing in 2009) and adapted its structure according to Bologna Process[2] having used that adjustment moment to amend the

2. Bologna process (or Bologna accords) purpose is to create the European higher education area by making academic degree standards and quality assurance standards more comparable and compatible throughout Europe. The Bologna process was a major reform created with the claimed goal of providing responses to issues such as the public responsibility for higher education and research, higher education governance, the social dimension of higher education and research, and the values and roles of higher education and research in modern, globalized, and increasingly complex societies with the most demanding qualification needs. With the Bologna process implementation, higher education systems in European countries are to be organized in such a way that: a) it is easy to move from one country to the other (within the European Higher Education Area) – for the purpose of further study or employment; b) the attractiveness of European higher education has increased, so that many people from non-European countries also come to study and/or work in Europe; c) the European Higher Education Area provides Europe with a broad, high-quality advanced knowledge base, and ensures the further development of Europe as a stable, peaceful and tolerant community benefiting from a cutting-edge European Research Area; d) there will also be a greater convergence between the U.S. and Europe as European higher education adopts aspects of the American system. (Wikipedia)

'state of the art'. In general terms it was observable a clear problem in the practice of designing where in most cases a methodological approach to design problems was not formalized and hardly internalized. That resulted in irregular final solutions in terms of overall quality, productivity, as well as strategic adequacy to markets and firm's aims[3].

In general terms, a deficiency of coherence and consistency in final products could be observed. In our opinion, that deficiency was, initially, partly attributable to the lack of methods that could structure thought, stimulate reflection and lead to the systematization of information and the creation of balanced concepts. If design methods had been applied in the proper way an adequate conceptual, functional and productive frame would have been consolidated saving time and cognitive resources to develop the necessary creativity and other competences in order to generate best informed solutions.

For that reason, it became urgent to understand design processes and actions and so we focused upon issues like how knowledge management was performed and how decisions were made along the design process.

1.2.1 Portuguese context of product design industry and its environment

It is important to make clear that the choice of the theme is intimately linked with my personal experience and knowledge as a designer and as a teacher, in the Portuguese context of product design industry and university education. My interest was reinforced with my participation in and contribution to the Evaluation Report of the Product Design Program at our University in 2005

Furthermore, the reading of the Portuguese Design Centre (CPD) analysis (2003, p.46-50) made it possible for me to understand and summarize the present situation of product design industry, as diagrammed in Figure 1. The figure presents the main stakeholders involved, their relations and existing frailties. Paths numbered

3. See Glossary

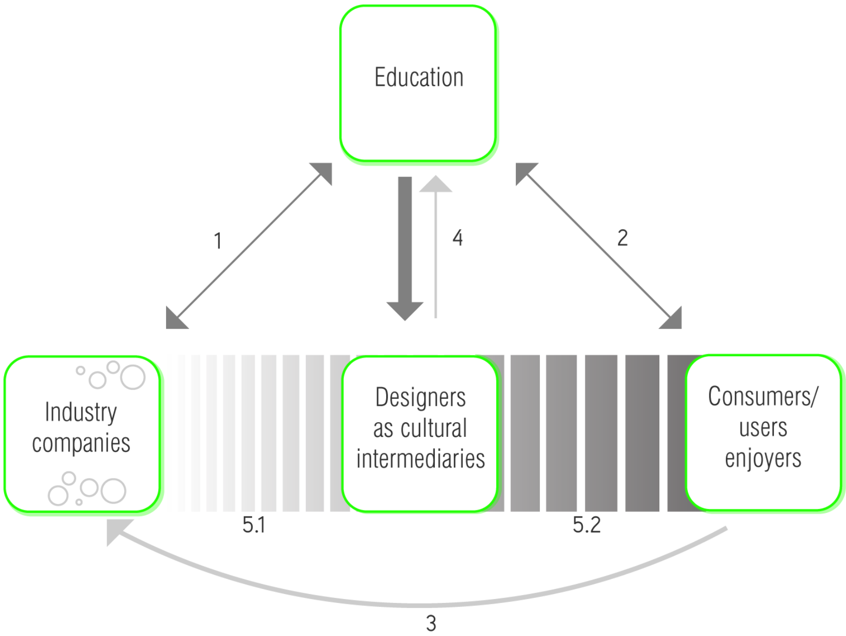


Fig.1 | Diagram of the relationship between industry, design education, designers and consumers; Almendra 2007

with 1 and 2 characterize the relationship between Industry/Education and Education/Consumers that are not optimized since we observed that, on one side, there was a reduced interaction between them and, on the other side, the knowledge flows between parts derived not from direct and real-time observation but rather were the result of indirect readings or supported by indirect information sources.

The use of lines with different shades – light grey, medium grey and black – serves the purpose of identifying knowledge that is directly acquired from the "real world" (light grey) and knowledge that results from the education learning as a reflection of an interpretation of that "real world"(medium grey). The gradation of grey to black identifies a type of knowledge that is the synthesis of the two types of knowledge just mentioned and which characterizes the actions undertaken by designers.

Path 3 indicates the relationship between Industry and Markets, which varies among different sectors. There are sectors that have solid relationships with markets. That is due to permanent follow-up actions and an undying attempt of anticipation actions undertaken by the industry that faces consumer's needs and desires (it is the case of the energy sector); there is also sector with fragile relationship with markets and those are mostly the ones integrating manufacturing industries.

Path 4 identifies the relationship between Education and Designers which occurs in two distinct moments: a) the moment of designer's educational formation, which is built upon explicit knowledge and which lacks an updated perspective of the practice of the "labour world," as well as displays a clear distant look of the market and the users; b) the moment professional designers go "back to school", a return related not only with the fact that most of the teachers are recruited in the labour-market but also because in several occasions professional designers are invited to participate in pedagogical activities promoted by the education institutions.

Finally, we have path 5, which is the fundamental axis that structures products existence and that is fostered by Industry perceiving designers as artefact creators and cultural intermediaries, for materialization of consumer's needs and desires. Here I choose to interpret the designer's role as taking place in between the industry-consumers relationship, given its role of mediation and intermediation in the process. This intermediary role conveys responsibilities and high capabilities because it is imperative to match interests of various natures in harmonious ways. It is supposed that a real value creation will occur to both interlocutors – industry and consumers – and it will be a designer's job, as an expert, to make it possible. The fact that there are two moments in this relationship (5.1 and 5.2) is to some extent justified because I believe that through design intervention a firm's output presents effective value-added products to final consumers.

Regarding the relationship between Designers and Industry, the assumption of Design as 'a company's strategic resource' is a reality according to the last 15 years of design management literature (see Design Management Institute articles of this period). However, as William Faust (2000, p.34) pointed out:

"Design is in the middle, between companies and customers. As it should be (…) the only people who value design at this level are the designers. While design has gained some respect over the last decade with mainstream business leaders, it is still the most undervalued and most misunderstood discipline in corporate business. (…) So how to explain this sorry state? (…) designers don't speak the language of business …"

In fact, there are clear problems with a correct integration of the activity and its professionals inside Portuguese companies and part of these difficulties are due to educational inefficiencies on the behalf of designers.

The Portuguese design practice has been studied for the past 15 years by CPD[4] that regularly publishes their results under the name "The Design Observatory". The last national survey among designers and industrial companies, launched in 2002 (CPD, 2003, pp. 30-31) revealed among other things that:

> Even though having a background education in product/industrial design, 40% of the designer's representative sample develops graphic design.

> The labour opportunities depend more on market request rather than on education background.

The fact that product/industrial designer's labour market is less dynamic is related with endogenous and structural characteristics of Portuguese Industries.

The deficit of knowledge in Portuguese society in general about what design is, the deficient regulation of the activity and the absence in the industrial world of knowledge of how to integrate design in production and communication strategies of the company are aforesaid as the most important problems that affect design development.

1.2.2 Focusing on the conceptual phase of Design processes

In this study we decided to restrict the investigation to the conceptual phase of Design processes. This restriction had to do with constraints related to the time and resources available to produce this work.

The choice of this particular moment of the design process was not without purpose, but it has been

4. CPD – Centro Português de Design

supported by the evidence of several author's studies (Restrepo, Goldsmith; Christiaans; Cross; Dorst; Lawson) such as Rehman and Yan ((2007, p.170) that define it as being a phase in which information processing and decision-making is very intensive as a consequence of the generation and evaluation of alternative ideas. It is also pointed out by the authors that "the importance of conceptual design to the overall success of the product is crucial as once a final concept is chosen, the majority of the design decisions relating to the product behaviour, cost and quality has been fixed as the subsequent product life-cycle activities (manufacturing, assembly, use and recycle/dispose) are implicitly determined by the concept. Moreover, detail design and manufacture cannot make up for a poor or inadequate conceptual design."

It is also a phase where according to Stoll (1999, p.38) decisions have a critical importance since they have a tremendous impact on the total cost of the product. That is particular visible in Figure 2.

Also Nicholls (1990, pp.5-15) has shown that up to 85% of the life-cycle costs of a product can be committed at the end of the conceptual design phase, when only about 5% of the actual life-cycle costs have been spent.

IMPROVING EARLY DESIGN DECISIONS

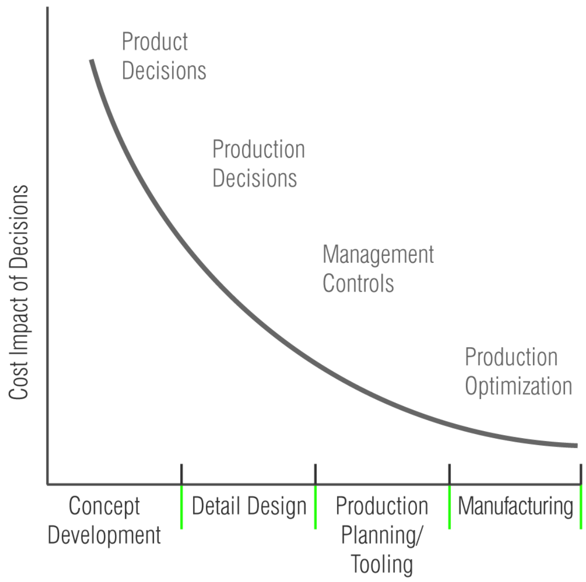


Fig.2 | Cost impact of decisions over the product life cycle (Stoll, 1999, p. 39)

Normally, a concept at this stage is evaluated and selected on the basis of the desired functional requirements only, neglecting the impact of concept selection on subsequent life-cycle phases like manufacturing, use, maintenance, and disposal, as well as on the user satisfaction of the product.

Also important to the adoption of this stage as a central one was the fact that it is the phase that is most studied, under different perspectives and about several issues and that provided us with richness of information that was important to the development of this approach. In this way, it is possible to compare results and also contribute for a better knowledge of this complex and very dynamic stage of Design processes.

2. RESEARCH AIMS

The main goals of the current research are:

> The achievement of a description of design processes among design students and professional designers in order to build up a "common language" regarding strategic adequacy and overall quality

> The development of descriptive models and tools that can support the understanding of design process management in terms of its critical variables.

> The suggestion of new tools and teaching methods that will better serve companies' expectations about design's profession and practice.

> The promotion of a more effective interaction between design education and industrial Portuguese companies.

In terms of specific goals, the aspirations are:

> Characterize in a rigorous way the conceptual phase of design processes in order to identify possible strategies to improve its quality of results

> Identify the key parameters of design processes concerning its strategic adequacy and overall quality;

> Describe the role some determinants of design processes have in its outcomes.

3. THE RESEARCH QUESTION

This is an exploratory study that tries to accurately describe and critically analyse the design process during the conceptual phase. The research problem regards the common lack of efficiency and effectiveness of the product design process. This might often result in badly designed final products. One of the initial statements presented in the doctoral proposal suggested that the reduced efficiency was mainly due to a bad management of the creative process, especially with respect to time management, its total quality management, and strategic adequacy. With the development of the study it was possible to refine both the research question and the hypotheses and to come up with the one presented below.

"Is it possible to describe design processes in such a way that we can understand what variables play a key role in its strategic adequacy and overall quality?"

This research question gave origin to the development of subsequent questions such as the ones listed underneath.

> What are the determinant variables in the conceptual phase of the design process in terms of strategic adequacy and overall quality?

> Will the construction of a descriptive model (with determinants) of the design process contribute to the deeper understanding of it? And if so, will it serve as an adequate pedagogical tool to improve Design Processes, for both professional designers and design students?

> Which variables in a Design Process can better be controlled in pedagogical terms?

4. STRUCTURE OF THE THESIS

This thesis is structured in four Parts that account for seven Chapters.

There are some pre–text elements that precede the general development of the study. It is the case of the

Dedication (pag. iii), the Acknowledgements, (pgs. v-vii) the Epigraph (pg. ix), the Abstract (pgs. x-xi), the Indexes (pgs. xv-xxviii) and the List of Acronyms and Abbreviations (xxix).

Part one initiates the thesis text. It is named *Presentation of Research* and includes Chapter I named *Introduction*. This Chapter designs the "big picture" of the research defining its limits, its drivers and aims and its structure. Chapter one (from page 1 to page 11) informs the reader about the research and problem conceptualization, the research aims, the research question and sub questions.

Part two, called *Research Supporting Theory and Methods*, includes Chapters II and III that are respectively called *Theoretical Framework* and *Methodology and Methods*. Chapter II (from page 12 to page 103) addresses the paradigms that support the research consolidating the concepts addressed in the research question. It includes therefore a critical approach to design processes and to the central concepts of strategic adequacy and quality. At the end of the chapter and resulting from the literature critics the research hypothesis are formulated. Chapter III (from page 104 to page 122) offers a comprehensive description and analysis of the methodology and methods used in this study.

Part three, entitled *Exploring Design Processes* comprises Chapter IV and Chapter V that are respectively termed Accessing/Experimenting/Describing Design Processes and *Discussion*. Chapter IV (from page 123 to page 308) is a keen description of all the actions undertaken in order to describe design processes according to the defined research question and hypotheses. It includes the depiction of all the work done throughout the seven interventions that include surveys, exercises and experiments. Chapter V (from page 309 to page 315) presents the discussion of the findings and tries to critically interpret it.

Part four, labelled *Conclusions and Recommendations* incorporates Chapter VI and VII each of one accounting for one of the two issues announced in this Part. Chapter VI (from page 316 to page 322) reports to the conclusions taken at the end of the study and Chapter VII (page 323 to page 327) displays a number of recommendations raised up along the research and that emerge as natural consequences of the previously presented conclusions.

Finally there are presented the Post-Text elements such as *Bibliographic References* (from page 329 to page 339); *Bibliography* (from page 341 to page 363); *Appendix A* (from page 365 to page 368); other *Appendix* (DVD).

BIBLIOGRAPHIC REFERENCES

CROSS, N. 2006. *Designerly ways of knowing*, London, Springer.

CE 2004. Manufuture: a Vision for 2020. Assuring the future of manufacturing in Europe. Report of the High Level Group. Luxembourg: Office for Official Publications of the European Communities.

European Community. 2006. MEMO/06/190. http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/190&format=HTML&aged=0&language=EN&guiLanguage=fr (Accessed in May 2007).

Faculdade de Arquitectura da Universidade Técnica de Lisboa. Relatório de Avaliação Interna. 2005.

FAUST, W. 2000. Building and fostering long-term client relationships. *Design Management Review*, 11(2), 33-42.

Centro Português de Design. 2003. Cadernos de Design. Anuário. Ano Seis, 17/18.

REHMAN, F., YAN, X. 2007. Supporting early design decision-making using design context knowledge. *Journal of Design Research*, 6(1-2), 169-189.

STOLL, H. 1999. *Product Design Methods and Practices*, New York, Marcel Dekker, Inc.

NICHOLLS, K. 1990. Engineering changes under control. *Journal of Engineering Design*, 1(1), 5-15.

Part two: research supporting theory and methodology and methods

CHAPTER II – THEORETHICAL FRAMEWORK

In this chapter, the fundamental analysis of the literature related with the operational concepts integrating the research question will be presented. It is important then to characterize: (1) the Design process with a special focus on design as a decision making process (2) and also the concepts of (3) strategic adequacy and (4) overall quality of the outcomes of design processes.

1. DESIGN PROCESSES

1.1. Supporting Theoretical Approach

As supporting theoretical paradigms approached in this research there are those of Donald Schön – The Reflection in Action Theory and of Herbert Simon – the Rational Problem Solving one. The first one is based on a constructionist[5] view of human perception and thought processes and is supported by *tacit knowledge*[6], a concept of Michael Polanyi (1966, p.4) that defended "we know more than we can tell". The second one has its roots in the positivistic epistemology[7] that claims being objective knowledge of reality the only possible source of knowledge. Both paradigms contributed to the understanding of Design processes, its nature and structure.

Also Terence Love (2005) came within reach of this dual possibility of looking at design especially in what concerns design research. In his view there are two opposing perspectives that create a fundamental epistemological problem in design research. The perspectives are in his words (2005; p. 1): "a) Belief that design research will lead to the activity of design being completely understood; b) Belief that research into design will ultimately be limited because design activity is dependent on human creativity and human creativity cannot be deterministically modelled in the manner of simple physical research."

According to Love (2005, p. 2) "(…) empiricism and interpretivistic exploration regard each other's central assumptions as invalid. Empirical scientific research specifically excludes subjective reporting as reliable evidence. Interpretive approaches deny that the scientific empirical approach

5. See Glossary
6. See Glossary
7. See Glossary

addresses the central target of design research – the human internal creative design activities."

Furthermore, Love (2005, p. 5) proposes that the resolution between the two positions requires a meta-perspective that focuses on the human aspects of design, because together these provide the only necessary and sufficient condition. That hypothesis was tackled by him and also Coyne and Snodgrass (1991) through a constructivist[8] approach - that basically proposes that individuals construct their knowledge on the base of their experiences, their memories and prior conceptualizations as well as their social interactions.

This kind of approach allowed them to enter an interpretative exploration of the way individuals constructed their knowledge of past and future designs. However, this attempt made also evident that it had a reduced usefulness since it was impossible to fix, as Love (2005, p. 5) recognized later, a "(…) clear picture of the relationship between 'knowledge', 'knowledge construction' and 'the activity of designing'." All these concepts are indeed ill-defined until now.

Under these circumstances, Love re-centred his research in understanding why the internal processes such as cognition, emotion creativity and intuition are in place in humans. His vision is that only with an ethological[9] meta-perspective it is possible to identify "many of the core aspects of design ability that are grounded in these animal aspects of human functioning" (2005, p. 6).

This perspective supposes an evolutionary vision of the human development and according to the author the main reason to take this viewpoint is that the majority of human activities are outside the conscious control. Having that knowledge to view humans as animals can bring new insights to design knowledge being that dependant of studies emerging from the area of cognitive neuroscience. In fact the role of neuroscience is underlined by Love (2005, p. 7) since:

"(…) it addresses the causal physiological processes that explain how and why humans construct knowledge, and make emotion and value laden judgements. It thus provides the conceptual bridge between previous constructivist integrating

8. See Glossary

9. "Ethology is the study of animal behaviour, and applying an ethological perspective requires that humans are studied as animals rather than from a biased human-centric perspective. Applying the perspectives of ethology to humans offers the basis for gaining insights that researchers are otherwise blinded by the wall of human-centric literature "(Love, 2005, p. 5)

approaches and the application of ethological approaches to humans. In addition, it provides a bridge linking ethology with anthropology and ethnography: important design research perspectives. For ethology, cognitive neuro-science provides an understanding of why and how the physiological substrates needed by design, creative activity and other associated activities are actualized. It also provides an understanding of on one hand, the physiological foundations on which human culture is developed, and, on the other, understanding of how culturally-related behaviours shape humans' physiologically defined envelope of action possibilities."

Besides the ethological approach, Love (2005; p.7-8) proposes systems approaches to deal in a structured way with the complexity of Design. His defense of systems approaches is related mainly with the possibilities it offers concerning: a) the fact that they are "well suited to representing understandings from ethological and evolutionary perspectives. The combination of ethology, evolutionary analysis and systems perspectives provides a means of modelling and representing human collaboration and cooperation processes in the arena of organisational behaviours associated with design."; b) the alignment they have with findings from cognitive neuroscience that have shown that "physiology systems always contain and depend on elements of prior systems – a sort of recursive physiology of systems for which complex systems analysis offers a particularly appropriate way of simultaneously representing what is, and enabling modelling such that emergent properties are revealed."

Although Love's perspective is fascinating we could not find basis to put forward a research based upon his approach. Therefore, in this study of design processes we rely mostly upon the work of Dorst (1997, pp.168-169) who has demonstrated that "both paradigms (the rational solving problem and the reflexive practice one) deliver relevant descriptions of design-as-experienced (…)" and that "the properties and limitations of each of the two paradigms are such that they could be used in combination (…)" (p.168).

So, we find it relevant to shortly present the two paradigms in its fundamental characteristics and differences.

1.1.1 The rational Solving Problem paradigm

Herbert Simon[10] (1996 3rd edition; first edition 1969) proposed at the beginning of the seventies a theory known as the "Rational Problem Solving" that was and still is central to the design methodology field. In his vision Design was seen as a rational solving problem process that should be address, as proposed by Newell and Simon (1972) and synthesized by Dorst (2004, p. 3), taking into account the following four central propositions:

> Fewer are the general characteristics of the Human Information Processing system that are invariant over task and the problem solver;

> These characteristics are sufficient to determine the *task environment* as a *problem space*, occurring *problem solving* in that space;

> The structure of *task environment* determines the possible structures of the *problem space*;

> The structure of *problem space* determines the possible programs that might be used in problem solving;

To validate the vision Simon has about design is to accept that the solution of the design problem takes place inside the *problem space* that is structured by the *task environment* structure that itself determines the programs or strategies that can be used in designing.

The *problem space* is a person's internal (mental) representation of a problem, and the place where problem-solving activity takes place. The *problem space* is seen as consisting of knowledge states, and problem solving proceeds by a selective search within the problem space using rules of thumb (heuristics) to guide the search.

The *task environment* is the physical and social environment in which problem solving takes place. The reason for this distinction is that individual behaviour influences problem solving; this influence is greater the less structured the task is.

According to Simon's thought experts, both human and mechanical, do much of their problem solving not by searching selectively, but instead by recognizing

10. Herbert Simon, winner of the 1978 Nobel Prize in Economics, the A.M. Turing Award and the National Medal of Science and many other awards for his work in cognitive psychology and computer science, died on February 9, 2001, at the age of 84. His research ranged from computer science to psychology, administration and economics. The thread of continuity through all of his work was his interest in human decision-making and problem-solving processes and the implications of these processes for social institutions. He made extensive use of the computer as tool for both simulating human thinking and augmenting it with artificial intelligence. Dr. Simon was widely considered to be a founder of the field of artificial intelligence. (Biography; Carnegie Mellon University)

the significant cues in situations analogous to those experienced before. It is their assets of experience that makes them 'experts'. Simon also proposed three types of problem-solving methods and among them the heuristics that is a central concept to our study.

Simon (1996) stated that heuristics[11] exploits the information in the *task environment* as that *task environment* is represented internally in the processor by the *problem space*.

In the heuristic search there is a dependence of the search process upon the nature of the object being sought in the *problem space* and the progress being made toward it. This dependence functions as a feedback that guides the search process with controlling information acquired in the process of the search itself, as the search explores the internalized task environment. This method explains how complex problems are solved with both human and mechanical bounded rationality.

However, Herbert Simon himself recognized later (1973, pp.181-201) that his theory is hardly applicable to design problems since these problems are almost always *ill-structured*[12] ones. An *ill-structured problem* (sometimes also called ill-defined) is what Rittell and Webber (1973, pp. 155-169) named, in the context of problems of social policy, *wicked problem*. In their concept framing they define this type of problems as the ones that lack a clear problem definition and can occur in any domain involving stakeholders with differing perspectives.

Ritchey (2007, pp. 2-3) established ten defining characteristics of this type of problems:

> There is no definitive formulation of a wicked problem.

> Wicked problems have no stopping rule.

> Solutions to wicked problems are not true-or-false, but better or worse.

> There is no immediate and no ultimate test of a solution to a wicked problem.

> Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.

11. See Glossary
12. See Glossary

> Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

> Every wicked problem is essentially unique.

> Every wicked problem can be considered to be a symptom of another problem.

> The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.

> The planner has no right to be wrong (planners are liable for the consequences of the actions they generate).

So, in general terms, *wicked problems* or *ill-defined* or *ill-structured* ones are problems: a) where the solution depends on how the problem is framed and vice-versa, that is to say that the problem definition depends on the solution); b) where stakeholders have different views of the problem and different frames to understand it; c) where the constraints of the problem and the resources to solve it change over time.

This way, an *ill-defined problem* can be assumed as a problem that is never solved in a definitive way.

In face of the fact that his theory fitted mainly the *well-structured problems* Simon (1973; pp. 181-204) proposed then that *ill-structured problems* should be framed by what he defined as an *immediate problem space* (see Figure 3) that could be accessed through a *noticing* and *evoking mechanism*. The general idea was that *ill-structured problems,* if decomposed in sub-problems, could be accessed as *well-structured problems*, and being so his theory was again applicable.

Though, unfortunately he did not explain how this mechanism would work and how someone could access and control it.

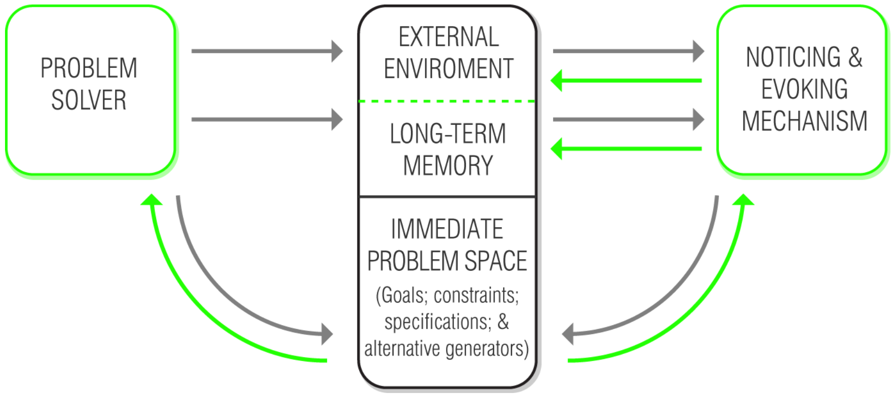


Fig.3 | Schematic diagram of a system for ill structured problems. It shows the alternation between a problem solver working on a well structured problem, and a recognition system continually modifying the problem space.
(Source: Simon, 1973, p. 192)

1.1.2 – The "Reflection-in-Action" paradigm

Donald Schön,[13] who had an educational background in Philosophy, fifteen years after Simon's proposal has come up with the formulation of a new paradigm that described Design as an activity that is structured upon a reflexive practice. His theory was a clear reaction to the *Rational Problem Solving* paradigm and it finds its roots in Schön's conviction that Simon's theory supported a deficient and equivocal Design education. Schön defended that in the professions where it existed design activity this one was underestimated and its nature was misunderstood. In his work (1983; 1987) he demonstrated that in professional school's curricula, which had design as a core activity, the design knowledge was defined in terms of design processes in generic terms and making a dominant use of *declarative knowledge*.[14]

In direct confrontation with Simon's proposal Schön (1983, pp. 39-40) argues:

"From the perspective of Technical Rationality, professional practice is a process of problem solving. Problems of choice or decision are solved through the selection, from available means, of the one best suited to established ends. But with this emphasis on problem solving, we ignore problem setting, the process by which we define the decision to be made, the ends to be achieved, the means which may be chosen. In

13. Donald Alan Schön (1930-1997) trained as a philosopher, but it was his concern with the development of reflective practice and learning systems within organizations and communities for which he is remembered. His most important achievements and focus were on three areas: learning systems (and learning societies and institutions); double-loop and organizational learning (arising out of his collaboration with Chris Argyris); and the relationship of reflection-in-action to professional activity.

14. See Glossary

real-world practice, problems do not present themselves to the practitioner as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain. In order to convert a problematic situation to a problem, a practitioner must do a certain kind of work. He must make sense of an uncertain situation that initially makes no sense."

Schön pursues his reasoning saying that "Technical Rationality depends on agreement about ends. When ends are fixed and clear, then the decision to act can present itself as an instrumental problem."(1983, p. 41)

Knowledge acquisition is a key issue in Schön's theory. In Schön's (1973, p. 49) words "Knowing is ordinarily tacit, implicit in our patterns of action and in our feel for the stuff with which we are dealing. It seems right to say that our knowing is in our action. Similarly, the workaday life of the professional depends on tacit knowing-in-action."

Knowing-in-action is for Schön (1973, p. 54) the characteristic mode of ordinary practical knowledge that leads to the concept of *reflection-in-action*.

Reflection-in-action is the reflection that occurs while the action is being developed. Schön (1973, p.56) defends that this type of reflection "(…) hinges on the experience of surprise. When intuitive, spontaneous performance yields nothing more than the results expected for it, then we tend not to think about it. But when intuitive performance leads to surprises (…) we may respond by reflecting-in-action. (…) in such processes reflection tends to focus interactively on the outcomes of action, the action itself and the intuitive knowing implicit in the action."

Schön's understanding of Design processes is best summarized in his own words:

"A Designer makes things. Sometimes he makes product; more often, he makes a representation - a plan, program, or image of an artefact to be constructed by others. He works in particular situations, uses particular materials, and employs a distinctive medium and language. Typically, his making process is complex. There are more variables - kinds of possible moves, norms, and interrelationships of these - than can be presented in a finite model. Because of this complexity, the designer's moves tend, happily or unhappily, to produce consequences other than those intended. When this happens, the designer may take account of the unintended changes he has made in the situation by forming new appreciations and understandings and by making new moves. He shapes the situation, in accordance with his initial appreciation of it, the situation "talks back," and he responds to the situation's back-talk. In a good process of design, this conversation with the situation is reflective. In answer to the situation's backtalk the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves."

However, as pointed out by Dorst (2004, p.5) "Schön's failure to link the theories of reflective practice to a model of design tasks means that descriptions of design activities within this paradigm can not benefit from any structure that might be present in the design task. If anywhere, the structure of the design problem should be found in the frame a designer uses. It is a pity that Schön never addressed the questions how frames are made, and what the properties of a good frame would be."

1.1.3 – Conciliating the two paradigms

Both paradigms previously described have been intensely explored in the last twenty years, particularly as a basis to gain better knowledge regarding design problems, its structure and its possible categorization in a taxonomy. This was also the case of the work of Kees Dorst (1997; 2001; 2003; 2004) that considered the use of these two approaches to be fundamental to better describe and study design processes.

Although being based in two epistemological opposite sides of the spectrum (Coyne, 1995; Varela 1991) the Positivism[15] (base for the Rational Problem Solving paradigm) and the Phenomenology[16] (base for the reflexive practice paradigm) Dorst (2004, pp. 5-7) puts forward that the work of Gadamer (1986) in the hermeneutics domain offers the possibility of bridging this epistemological gap.

15. See Glossary
16. See Glossary

The fundamental concept that will allow that bridging is interpretation. Interpretation is seen by Gadamer (Dorst, 2004 *Apud* Gadamer 1996) as being simultaneously "'revealing of what the thing itself already points to' and 'an attribution of value to something'". The first condition of interpretation can be seen as 'objective interpretation' being the second one what is called 'subjective interpretation'.

How is then seen interpretation in the context of Design processes?

Empirical evidence resultant from Dorst (1997, pp. 83-150) work showed that are a few factors to consider in what he called the "designer's interpretative behaviour" namely:

> The design project's goals and decisions tend to describe and present to all stakeholders with precision in order to reduce implicit data and 'subjective' interpretation;

> The "subjective interpretation" is determinant when we have to deal with *ill-defined* problems in order to give sense to it.

> When a design project gives or demands freedom of choice on designer's part he depends upon its own perceptions and interpretation of the problem. In this case the design activity is better described in terms of a *reflection-in-action* activity.

> Designers spend considerable amount of time at the beginning of a project trying to define the type of problem they deal with. They do it in terms of constraints of the problem that impose itself to the freedom of defining personal goals. Some designers reveal to be more comfortable with an 'objective' approach to problems others with a 'subjective' one."

In effect through interpretation that can be both 'objective' and 'subjective' it is possible to better access to design activities. Dorst (1997) has observed that the type of dominant interpretation varies not only throughout the different phases of design activities but also in terms of design situations. Ultimately the decision upon the need of using 'objective' or 'subjective' interpretation throughout the design activity depends upon the designer itself.

But if interpretation in this hermeneutical view of design can bridge both paradigms it still remains important for design process's comprehension the non objective structure of design problems.

At this respect Dorst and Cross (2001) advanced the description of undetermined problem solving through the empirical study of design as *situated problem solving*.[17] In their approach design processes are characterized by the co-evolution of the design problem and the design solution. This view is supported by the assumption that design problems can not be fixed through the imposition of a frame. In fact, design in the words of the authors:

"seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces' - problem space and solution space. In creative design, the designer is seeking to generate a matching problem-solution pair, through a 'co-evolution' of the problem and the solution. Our observations confirm that creative design involves a period of exploration in which problem and solution spaces are evolving and are unstable until (temporarily) fixed by an emergent bridge which identifies a problem solution pairing." (2001, p.435).

In this co-evolving process it is central the role of understanding and the way it arises.

Again it is important to consider, as proposed by Snodgrass and Coyne (1997), the hermeneutical circle[18]. As the authors (1997, p.76) define it "the hermeneutical circle has to do with the circular relation of the whole and its parts in any event of interpretation. We cannot understand the meaning of a part of a language event until we grasp the meaning of the whole; and we cannot understand the meaning of the whole until we grasp the meaning of the parts."

Understanding thus involves a process of projection that Heidegger[19] (1962) named as "fore structures of understanding". What Heidegger proposed was that each interpretation event includes a pre-given perspective of the matter that a person places in a certain context.

17. The concept of situated problem solving assumes that 'the design problem' as such does not exist as an objective entity in the world. Instead there is "an amalgamate of problems that arise from the challenge described in design brief. Being so (…) there is never a complete representation of the design problem in the head of the designer". (Dorst 2004, p.8). In sum situated problem solving means that the problem cannot be separated from the context and the dialogue the designer engages in with the situation.

18. The analysis of hermeneutics made by Snodgrass and Coyne derives mainly from Martin Heidegger and Hans-Georg Gadamer. See Martin Heidegger, *Being* and *Time*, trans. John Macquarrie and Edward Robinson, London, Basil Blackwell, 1962; Hans-Georg Gadamer, *Truth and Method*, London, Sheed and Ward, 1975; *idem, Reason in the Age of Science*, trans. Frederick G. Lawrence, Cambridge, Mass., MIT Press, 1981; *idem, Philosophical Hermeneutics*, trans. and ed. David E. Linge, Berkeley, University of California Press, 1976; *idem*, "Hermeneutics and Social Science," *Cultural Hermeneutics* 2 (1975): 307-16;

19. Heidegger terms these three fore-structures "forehaving" *(Vorhabe)*, "fore-sight" or "fore-seeing" *(Vorsicht)*, and "fore-conception" or "fore-hypothesis" *(Vorgriff)*. *Vorhabe* includes all the culturally acquired skills and practices we employ in acts of interpretation; these cultural practices are constitutive of our being, and thus determine what we find intelligible. *Vorsicht* includes all the resources of a common descriptive language, the vocabulary or conceptual scheme we bring to the act of interpretation, and which determines what we count as real and what are relevant aspects of what we interpret. *Vorgriff* is a hypothesis we have concerning the thing being interpreted; it is the "conceptual reservoir" that we hold in advance and bring to the interpretive act. See Heidegger, *Being and Time,* p. 193;

This vision is what Snodgrass and Coyne (1997, p.78) described as a process where "every revision of the fore-project is capable of projecting before itself a new project of meaning, that rival projects can emerge side by side until it becomes clearer what the unity of meaning is, that interpretation begins with fore-conceptions that are replaced by more suitable ones. This constant process of new projection is the movement of understanding and interpretation."

These "fore-structures" were also approached by Gadamer (1997) that has termed it "prejudices". He aimed to rescue the term from its pejorative connotations rehabilitating it as a prejudging legitimate moment. This prejudgement or pre-assumptions in Gadamer's view can either be, as referred by Snodgrass and Coyne (1997, p. 78), "(…)enabling or disabling, depending on the way in which they are opened up to hermeneutical understanding. Interpretation, then, is 'the working out of possibilities projected in understanding' (Gadamer *apud* Snodgrass and Coyne) that is, it is the working out of how something figures in the context in which it stands".

This pre-understanding is clearly present as a central concept in Schon's work (1983; 1987). Actually, reflexive practice approach to design refers undoubtedly to the working of the *hermeneutical circle*. In it the designers project the meaning of the whole and work out the implications of this projection by referring it back to the parts. Consequently, the design is recurrently re-determined by an anticipatory movement of the pre-understanding; understanding occurs than by a process of constant review.

This hermeneutical approach to design made Snodgrass and Coyne (1997, p. 92) conclude that:

"Designing is primarily an interpretative activity. It is an activity that pertains to understanding a design situation rather than to having knowledge of formulae, theorems and algorithms. Designing is a hermeneutical rather than an epistemological event. (…) In the hermeneutical event theory cannot be divorced from practice. The theory, such as it is, only comes into consciousness, is only clarified, disclosed, in the process of its application. Theory and practice coalesce in the act of interpretation; general principles are revealed as what they are, are revealed to be what they are, come to be understood in their being, in the unfolding of their application in the event".

In the sequence of this short theoretical general approach to Design processes it is useful to concentrate in it in depth. That implies addressing the design process in its structural components with a special focus on those that are key subjects of this study.

1.2 Accessing Design Processes

The study of design processes is one field of Design Research that for the past four decades consistently has produced more information and reflection among the design scientific community. Design processes are seen, for the purposes of this study, as problem solving activities that can be considered in the light of cognitive science in the way Christiaans and Restrepo (2004, p. 1) defined it: " (…) as an information processing activity, being the problem solvers assumed as information processing systems."

However, as Christiaans and Restrepo (2004, p. 1) pointed out " (…) because of the very nature of design problems, there is very often very little information about the problem, even less information about the goal (solution) and absolutely no information about the transformation function. This means that design problems require a lot of structuring."

So, in the face of the previously presented it is clear that it is necessary to consider, at least, the design problem; the solution; the transformation function and all its agents.

Problem structuring and solution structuring have been studied intensely in the past twenty years in various areas of Design Knowledge. It is the case of design engineering where some of the models produced propose that first engineers make the analysis of the problem and in sequence they synthesize a solution (Jones, 1992; Pahl and Beitz, 1984, Roozenburg and Eekels, 1991, 1995; Cross, 2000).

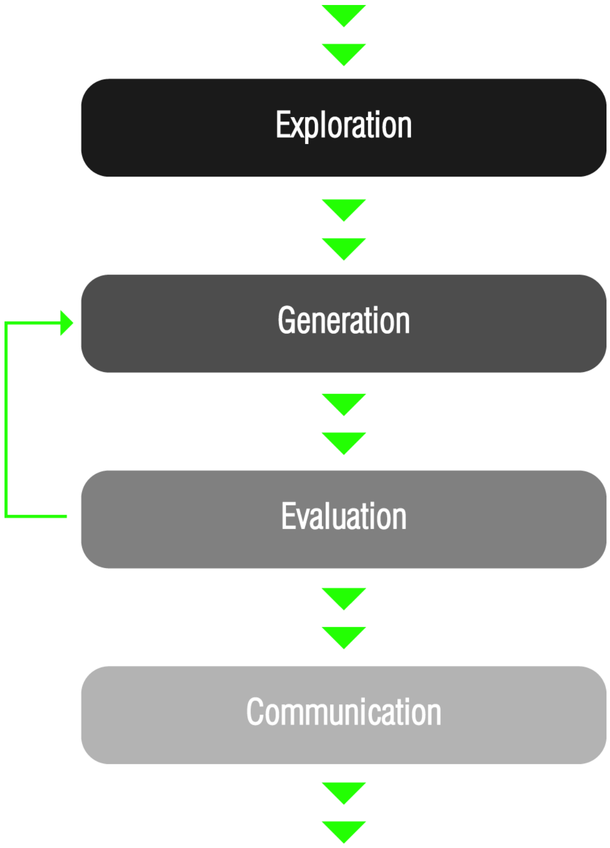


Fig.4 | Four stage design process after Cross, 2000; source: Dubberly, 2004, p. 30.

Some of the models produced by these authors are the expression of these findings. It is the case of the models of Cross presented in Figures 4 and 5. Together they illustrate the design process in its stages and in terms of the designer's *modus operandi.*

Figure 4 is a simple descriptive model of the design process that assumes the main four activities performed by the designer. It starts with the exploration of the ill-defined problem space; the solution arises from the generation of a concept that is after subject of evaluation against the goals, constraints and criteria of the design brief. The end point of the process is the communication of the solution (a stage that was first proposed by Archer in 1963).

Figure 5 focus on the design strategy used to solve the problem. According to Cross the overall aim of the designer's strategy is to converge on a final detailed solution. Within the process of reaching that final solution there will occur moment of necessary (deliberate or

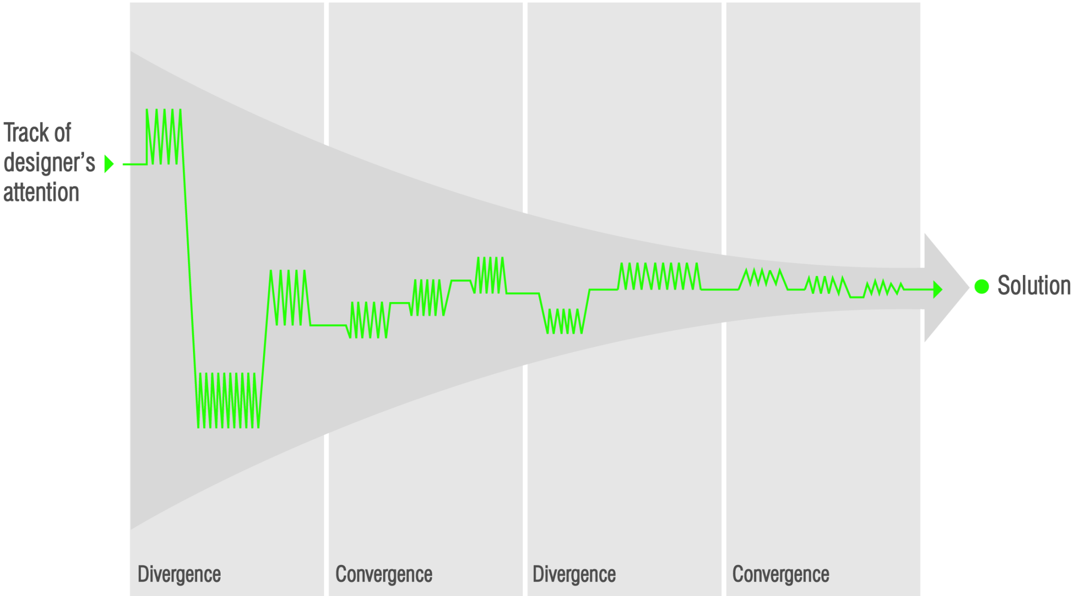


Fig.5 | Dynamics of divergence and convergence in design process after Cross, 2000; source: Dubberly, 2004, p. 25.

unconscious) divergence to widen the search seeking new ideas, information and different perspectives.

The model proposed by Pahl and Beitz (1984) that is shown in Figure 6 is a sequential process that includes iteration as a way of upgrading and improving the final solution. It corresponds to the vision of design processes being a general sequence of analysis and synthesis where iteration takes place with the main intention of refining the solution.

In the case of software design it is also suggested by Guindon (1990a; 1990b) that the designer first negotiates the structure of the problem and only after develops the solution. For that purpose the designer often use simulation that acts as a mechanism for problem understanding and structuring (problem domain scenarios) that can lead to the inference of new constraints or requirements.

Furthermore the author states to exist evidence of a"(…) mixture of applying retrieved software system design schemas[20] and discovering parts of the design decompositions, compounded with the inference of new requirements and evaluation criteria resulting in problem restructuring, (that) contribute to the opportunistic design behaviours[21] (…)"(Guindon, 1990 b, p. 297).

20. Software design schemas provide a means for abstracting software designs into broadly reusable components that can be assembled and refined into new software designs; It can provide designers with sets or sequences of operators to produce the design solution. The specialized design schemas can vary from simple rules to complex schemas that define the overall high-level decomposition for a class of systems. Software system schemas can be abstracted from previously developed software systems with similar structures but in different problem domains. The software system schemas do not necessarily impose a strict order in which to develop each of the subsystems, since they can be independent of each others. The software design schemas can induce top-down processing, and as a consequence, contributed to a systematic design process (Guindon, 1990b, p.300)

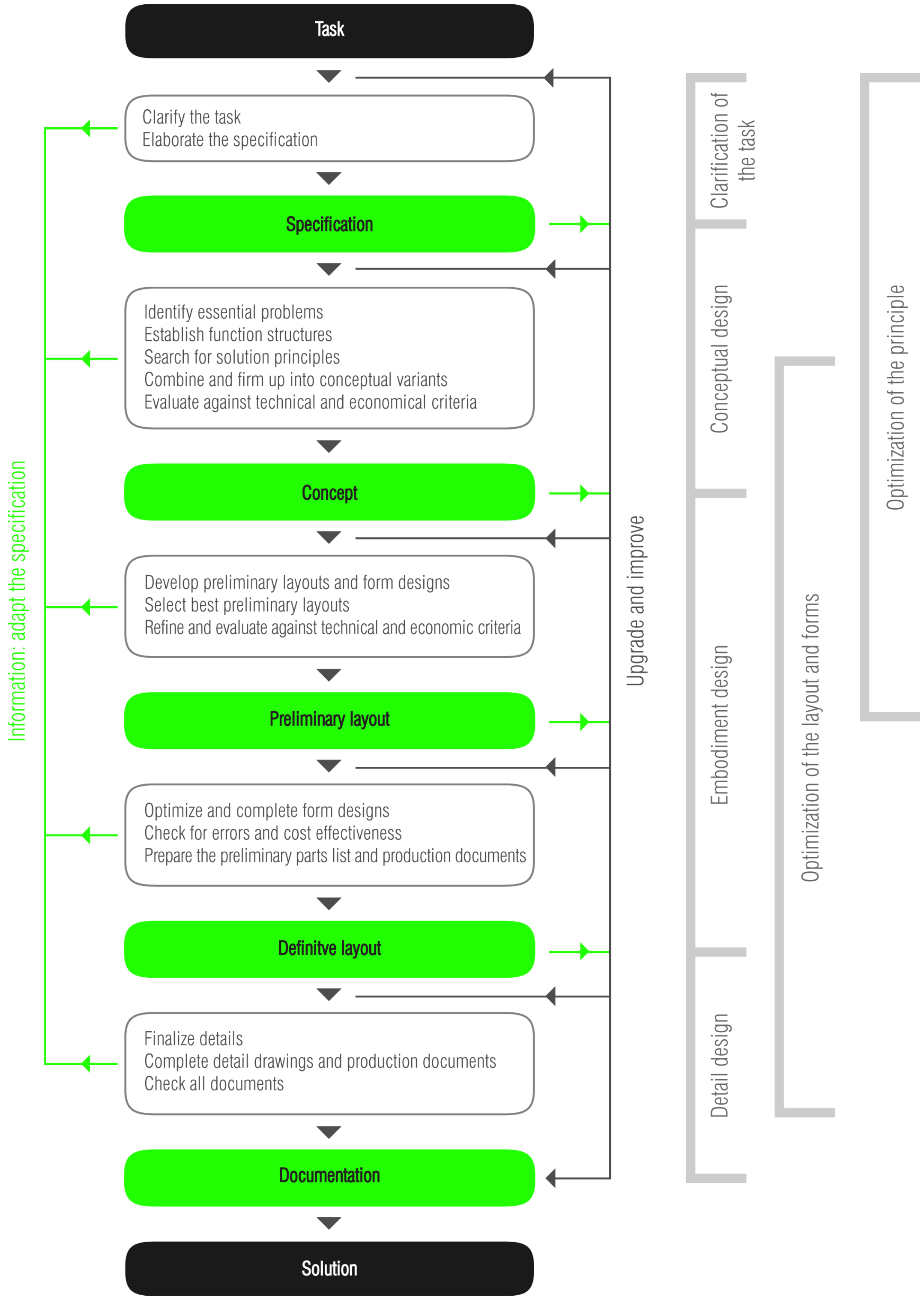


Fig.6 | Design process – Gerhard Pahl and Wolfgang Beitz (1984)

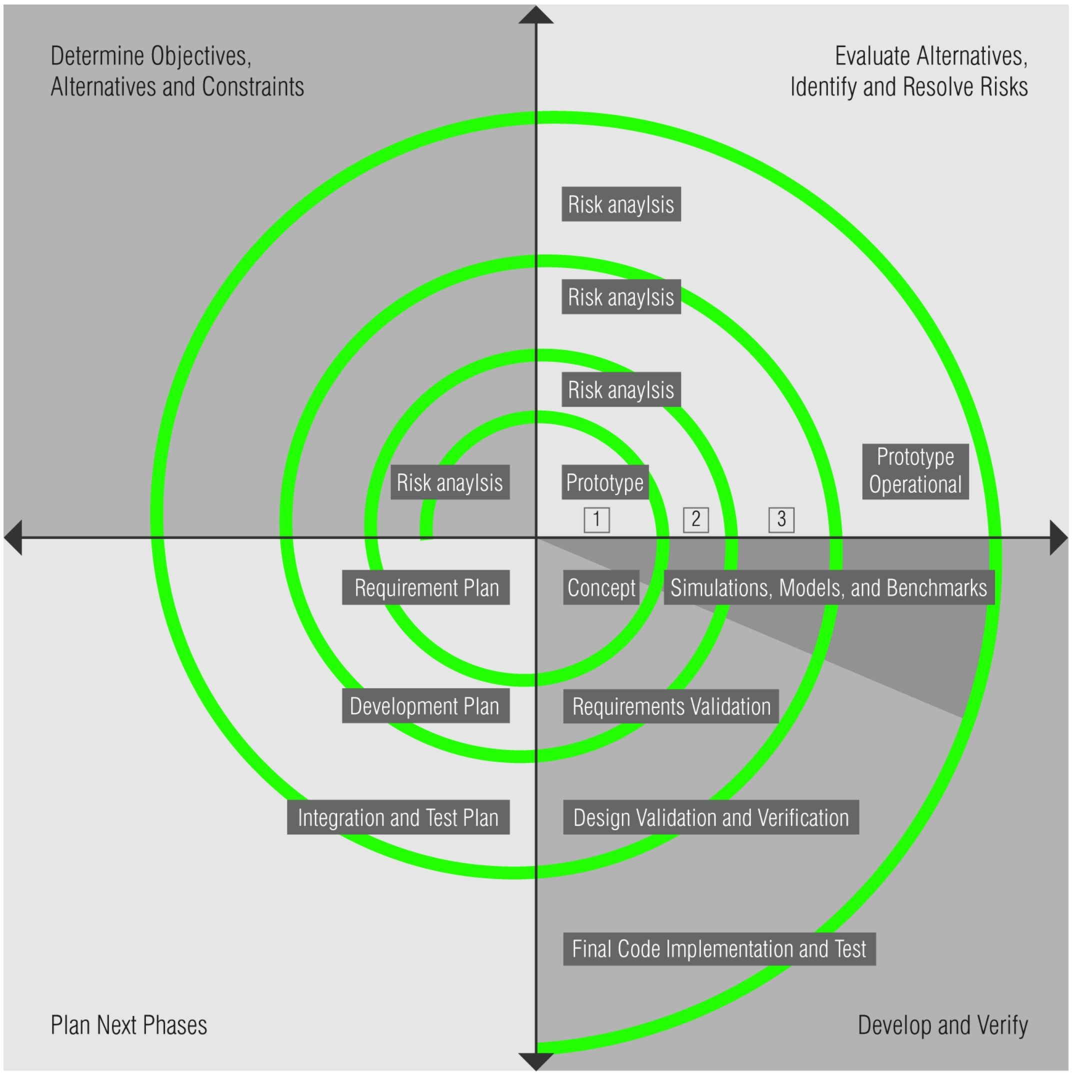


Fig.7 | Spiral model of the Design process (Barry Boehm, 1986). Source: Dubberly, 2004, p. 122)

It is then the case to consider design as a guided search where only the most promising search paths can be pursued. As Guindon explains it "Design solutions are satisfactory, as opposed to optimal, because it is too expensive or impractical to generate all the alternative design solutions and because no objective metrics usually exist to evaluate the alternative solutions" (Guindon, 1990 b, p. 297).

An example of a model produced in this area is the one of Barry Boehm (1986) that is presented in Figure 7, where it is visible the use of simulation, modelling and prototyping as a way to address the problem's complexity and reduce the risk of failure.

The model of Boehm (Figure 7) assumes that software design processes are similar to repeated cycles where risk

21. Opportunistic behaviour of designer's along their processes means a "deviation from a structured plan or methodical process into the 'opportunistic' pursuit of issues or partial solutions that catch the designer's attention" (Cross, 2006, p. 87). This behaviour was observed by several researchers (Visser, 1990; Guindon, 1990; Ball and Ormerod, 1995)

assessment is a key element. The radial dimension of the model represents the cumulative costs (this particular aspect is relevant as it will be discussed in the strategic adequacy sub-chapter) when finishing the steps. The angular dimension represents the progress made in completing each cycle. Each loop of the spiral from x-axis clockwise through 360º represents one phase. One phase is split roughly into four sectors of major activities: a) objective setting; b) risk assessment and reduction; c) development and validation; d) planning the next phases.

In terms of industrial design processes the sequence of empirical studies of Christiaans (1992), Christiaans and Restrepo (2001) and Restrepo and Christiaans (2003) made it possible to derive that: a) problem structuring occurs mainly at the beginning of the process but it reoccurs along its progression; b) designers approach the design assignments using two different strategies: a problem oriented and a solution oriented one.

In reality the work of Lawson (1979, 1990) dedicated to the observation of problem-solving behaviour on the part of scientists and designers (architects) suggested differences in the two approaches: scientists solve by analysis, being generally problem-focused and designers solve by synthesis being in general solution focused. This behaviour however was found to be presumably learned since it is not displayed when comparing initiate students with senior ones.

In 1980 Lawson made a comparison between the creative process (Kneller, 1965) and the design process. Figure 8 presents his reflection and it is visible the focus on solution after a first stage of recognition that a problem exists. The period of 'first insight' of creative process involves in design process the recognition and analysis of the problem; The next phase of 'preparation' involves a conscious effort to develop an idea for solving that problem in the Design process; The period of 'incubation' is one where the designer is unwittingly reorganizing and re-examining the previously deliberate thoughts; It is followed by the 'illumination' phase where there occurs the sudden emergence of an idea. Once the

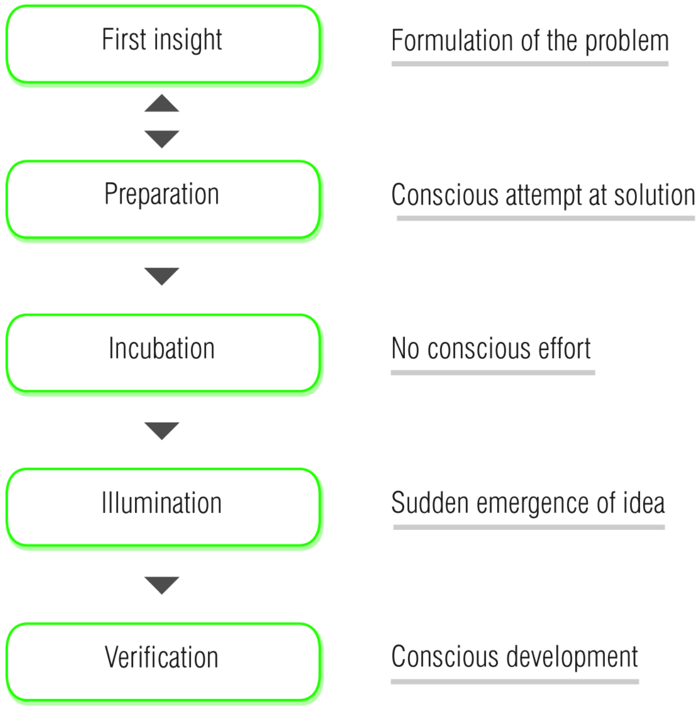


Fig.8 | Creative vs Design process, after Lawson (1980). Source: Dubberly, 2004, p. 42.

idea emerges there is a final moment of 'verification' that implies a conscious development and test of that idea towards the final solution.

It is also to underline that Lawson's work (1979) is not consistent with the experiments conducted by Christiaans and Restrepo (2001; 2003) where a homogeneous group of designers, both in terms of experience and education, displayed both the problem oriented and the solution oriented types of behaviour in an idiosyncratic way.

Moreover, the work of Thomas and Carroll (1979) had already anticipated that designers seem to display a combination of the two mentioned strategies. The authors observed conduct where problems are assumed by designers as being *ill-defined* (even if they are well-defined) and where the adopted strategy is one in which problem's constraints and goals are changed along the process.

A further insight was brought to the subject when Lloyd and Scott (1994) in a protocol study they made with

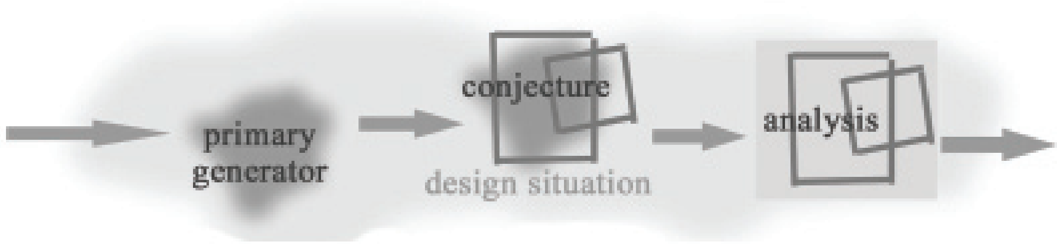


Fig.9 | Model of Jane Darke design process (adapted from Irina Solovyova, 2003, p. 4)

experienced engineers established that the use of the two strategies was related with the level and type of previous experience. Designers more experienced in the type of problem undertaken would be inclined to display a generative reasoning focusing more on solutions and the ones with less experience would show a deductive reasoning and focus in particular on problem analysis.

Also relevant to this matter is the finding of Jane Darke (1979) of the existence of a 'primary generator', that is to say, a pre-solution that the designer generate before start talking about the problem. This concept was developed as an integrated element of a design process model that is presented in Figure 9.

The model of Darke (1979) presents a three step process that is initiated with the 'primary generator' that is a concept or objective that helps to generate the solution (Darke, 1979). These 'primary generators' can be images (as referred by the author) but also, as pointed out by Restrepo and Christiaans (2003, p. 7) "could also be abstract relations describing the design situation. In our empirical studies, we called the representation of these first interpretations "early representations". These early representations have a great influence on how the process continues."

Also Rowe (1998; first edition 1987) in his studies of architectural design found out that there is a substantial influence exerted by initial design ideas that designers tend to make work.

It becomes clear until now that design processes, in spite of the specific domain of knowledge that is addressed, have in common the phases of researching, analysis,

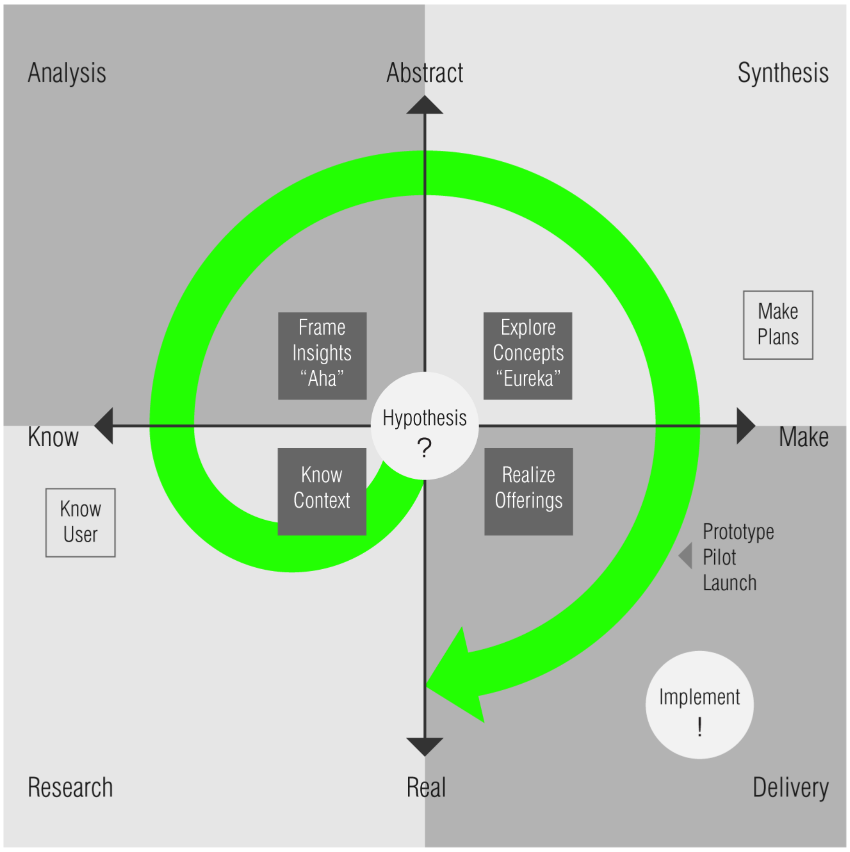


Fig.10 | Innovation planning (process), Vijay Kumar, 2003. Source: Dubberly, 2004, p. 125.

synthesis and delivery (or communication). That is also the case of the model of Kumar (2004) shown in Figure 10 that was designed as an Innovation planning process and that is worth to mention.

In effect the aim of design processes is not just to find a solution for the problem in hands; it is to find the best solution and that is by all means related with an innovative outcome. (Utterbach et al, 2006; Cagan and Vogel, 2002; Stamm, 2003).

The model proposes ‘modes of planning’ instead of phases and emphasizes the iterative and interrelated nature of design process. It display for each of the modes tools and methods to be used in order to advance in the process. The process is seen by Vijay as a continuous loop from knowing, through framing that leads to exploring that gives occasion to the final realization. This occurs in a process understanding that is framed by the axes – know/make and the one of abstract/real that determine the space where the transformation function will take place.

1.2.1 – A proposed design process model - a cognitive approach

Significant to the comprehension of Design processes and in particular to the assessment of the transformation function is the concept (already explained in previous pages) proposed by Dorst and Cross (2001, p.11) that states that between input and output is where we find problem and solution co-evolving.

This space where 'transformation function' occurs was, for the purpose of this research, initially defined in relation with the activities performed by designers, seen as contexts of knowledge management and decision making. Later it was refined due to the incorporation of findings resultant from the undertaken experiments and resulted in the final decision making model (presented in Chapter IV).

Furthermore it is central to the understanding of our approach to Design processes analysis the already mentioned findings of Christiaans and Restrepo (2001; 2003) that designers made use of two different strategies when facing a design brief: either they are problem-oriented, or solution-oriented.

Based upon the premises presented above it was developed a design process's model of analysis to support the execution of the first experiment.

Figure 11 illustrates the first model of design process developed by the researcher that assumed design process as a knowledge management process addressed in terms of the activities performed by the designers along it.

It is a model designed to support the analysis of verbal Protocols. The framework incorporates the possibility of designer's use of different strategies in their processes (problem-oriented and solution-oriented) as observed in several studies. A new category was added, the process-oriented one that further ahead in this research was renamed integration – oriented (integration driven) and that has to do with the approach some designers have that is intimately related with the concept of co-evolution of problem and solution (Dorst and Cross, 2001).

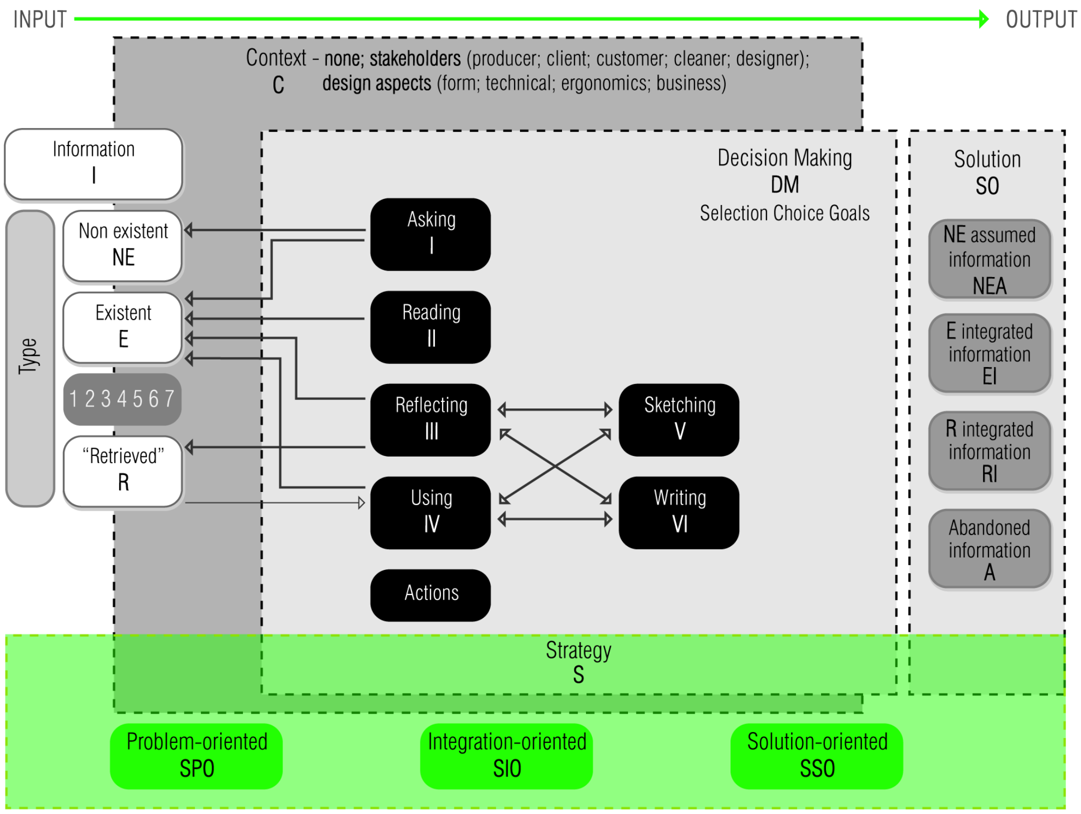


Fig.11 | Design Process model I [action related] (Almendra, 2007)

The model describes design processes as having as a start point the input of information that can be of different types: a) non existent (the one designers search/ask but it is not available); b) existent (the one who is searched and available) and c) retrieved (the one designers get from his/her memory storage).

The output of Design process is assumed to be a solution where it is possible to trace back the contribution of: a) non existent/assumed information; b) existent information that was integrated partially or as a whole; c) retrieved information that was equated in terms of the final solutions; d) abandoned or even forgotten information that also have a say to the final outcome.

In between input and output there is the space of transformation that is supported by a context that is accessed and put in action through decision making. This occurs while the designer develops several activities related with knowledge management which were identified as: a) asking; b) reading; c) reflecting; d) sketching; e) writing and f) using (modelling).

The context includes all the stakeholders: the designer, the clients, the producer, the user, the customer.

Decision making occurs along the process feeding the 'design moves'[22] and the generation and selection of alternatives that will give origin to the final solution.

After using the model as the basis of analysis of the first experiment (that was the main reason of the creation of this model) it become apparent to the researcher that decision making was one of the determinants of design processes that was central to the strategic adequacy and overall quality of its outcomes. Therefore, a particular effort was made to deepen the knowledge and to explore decision making in design processes.

SUMMARY OF DESIGN PROCESSES

The approach done to Design Process was supported by the critical assessment of both the paradigms of the *Rational Problem Solving* from Herbert Simon and the *Reflection-in-Action* one from Donald Schön.

That analysis made us to face as the correct approach to Design Process the one of Kees Dorst (1997) that proposed to use both paradigms in combination.

The conciliation of both paradigms is made by the assumption of the role of interpretation (as Gadamer defends it) in Design Process. That assumption places Design as an hermeneutical process and the study of design as 'situated problem solving' (see footnote 17).

It goes from this that Design Processes are processes where problem and solution co-evolve (Cross and Dorst, 2001) and must be understood by means of the 'hermeneutical circle' (Snodgrass and Coyne, 1997).

Furthermore it is useful to access Design Process in the way it is conceptualized. Therefore, the study of several Design Process models puts in evidence the way several authors consider the problem and solution structuring.

The analysis of models coming from different Design domains illustrate several aspects of design process that

22. Goldschmidt (1996, p. 72) defined a 'design move' as " (…) a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move".

must be taken into account. They are: the divergence/convergence modus operandi; the iteration in design process; the framing and enabling mental and practical operations; the role of creativity and innovation in design processes.

BIBLIOGRAPHIC REFERENCES

CAGAN, J., VOGEL, C. 2002. *Creating Breakthrough products - innovation from product planning to program approval*, FT Press.

CHRISTIAANS, H. 1992. *Creativity in Design: The role of domain knowledge in designing*, Utrecht, Lemma.

CHRISTIAANS, H., RESTREPO, J. 2001. Information Processing in Design: a theoretical and empirical perspective. In: ACHTEN, H., DE VRIES, B., HENNESSEY, J. (ed.) *Design Research in the Netherlands 2000*. Eindhoven: Eindhoven University of Technology, pp.63-73.

CHRISTIAANS, H., RESTREPO, J. 2004. Problem structuring and information access in design. *Journal of Design Research,* 4(2).

COYNE, R. 1995. *Designing information technology in the postmodern age*, Cambridge MA, The MIT Press.

COYNE, R., SNODGRASS, A. 1991. Is designing mysterious? Challenging the dual knowledge thesis. *Design Studies*, 12(3), pp.124-131.

DARKE, J. 1979. The primary generator and the design process. *Design Studies*, 1(1), 36-44.

DORST, C. 2003. *Understanding Design*, Amsterdam, BIS Publishers.

DORST, C., CROSS, N. 2001. Creativity in the design process: co-evolution of problem-solution. *Design Studies*, 22(5), pp.425-437.

DORST, K. 1997. *Describing Design: A Comparison of Paradigms*, Delft, The Netherlands, Delft University of Technology.

DORST, K. 2004. On the problem of design problems - problem solving and design expertise. *Journal of Design Research,* 4(2).

DUBBERLY, H. (ed.) 2004. *How do You Design?*, San Francisco: Dubberly Design Office.

GADAMER, H.-G. 1986. *The relevance of the beautiful and other essays*, Cambridge, Cambridge University Press.

GOLDSCHMIDT,G.1996. The Designer as a team of one. *In*: CROSS, N., CHRISTIAANS, H., DORST, C. (ed.) *Analysing Design Activity*. New York: Wiley.

GUINDON, R. 1990. Designing the design process: exploiting opportunistic thoughts. *Human Computer Interaction*, 5(2), pp.305-344.

JONES, J. 1992 *Design Methods*, New York, John Wiley & Sons Inc.

LAWSON, B. 1979. Cognitive strategies in architectural design. *Ergonomics*, 22(1), pp.59-68.

LAWSON, B. 1990. *How designers think: the design process demystified* London, Butterworth.

LLOYD, P., SCOTT, P. 1994. Discovering the design problem. *Design Studies*, 15(2), pp.125-140.

LOVE, T. 2005. A unified basis for design research and theory. *International Design Congress - IASDR 2005: New Design Paradigms.* Douliou, Taiwan: International Association of Societies of Design Research, Taiwan.

NEWELL, A., SIMON, A. 1972. *Human Problem Solving*, New York, Prentice-Hall.

PAHL, G., BEITZ, W. 1984. *Engineering Design*, London, The Design Council.

POLANYI, M. 1983 (1st ed. 1966). *The Tacit Dimension,* Gloucester Peter Smith, Mass.

RESTREPO, J., CHRISTIAANS, H. 2003a. Design Requirements: Conditioners or Conditioned? *ICED03 - International Conference on Engineering Design*. Stockholm.

RESTREPO, J., CHRISTIAANS, H. 2003b. Problem Structuring and Information Access in Design. *Paper accepted for the Design Thinking Research Symposium 6: 'Expertise in design'.* Australia.

RITCHEY, T. 2007. Wicked Problems: Structuring Social Messes with Morphological Analysis. *Swedish Morphological Society* [Online]. Available:http://www.swemorph.com/wp.html [Accessed 24 November 2007].

RITTEL, H., WEBBER, M. 1973. Dilemmas in a general theory of planning. *Policy Science*, 4, pp.155-169.

ROOZENBURG, N., CROSS, N. Year. Models of the design process - integrating across the disciplines. *In*: HUBKA, V., ed. Proceedings of ICED 91, 1991 Zürich. Heurista.

ROOZENBURG, N., EEKELS, J. 1995. *Product Design: Fundamentals and Methods*, Chichester, John Wiley & Sons, Inc.

ROWE, P. 1998. *Design Thinking*, Cambridge and London, The MIT Press.

SCHÖN, D. 1983. *The Reflective Practitioner: How Professionals Think in Action*, New York, Basic Books.

SCHÖN, D. 1987. *Educating the Reflective Practitioner,* San Francisco, Jossey-Bass – A Wiley Imprint.

SIMON, H. 1973. The ill structure of ill-structured problems. *Artificial Intelligence*, 4, pp.181-204.

SIMON, H. 1996. *Sciences of the Artificial*, Cambridge, The MIT Press.

SNODGRASS, A., COYNE, R. 1997. Is Designing hermeneutical? *Architectural Theory Review, Journal of the Department of Architecture*, 2 (1), 65-97.

THOMAS, J., CARROLL, J. 1979. The psychological study of design. *Design Studies*, 1(1), pp.5-11.

UTTERBACH, J. ALVAREZ, E. EKMAN, S. SANDERSON, S. TETHER, B. VERGANTI, R. 2006. Chapter one: What makes products great? In UTTERBACH, J. (ED.) *Design Inspired Innovation*. Singapore, World Scientific Publishing Co. Pte. Ltd.

VARELA, F., THOMPSON, E., ROSCH, E. 1991. *The Embodied Mind*, Cambridge MA, The MIT Press.

VON STAMM, B., 2003. *Managing Innovation, Design and Creativity,* London, John Wiley & Sons Ltd.

2. DESIGN PROCESSES AS DECISION MAKING PROCESSES

Decision making is a field of study that is constantly addressed in all domain knowledge areas being the focal driver of those studies the cognitive assessment of how decision making occurs. As Longueville et al (2003) noticed in recent years a number of proposals have been advanced for the study of decision-making processes in knowledge areas such as management, cognition, engineering design, and artificial intelligence etcetera.

As Simon et al (1986) also acknowledged decision making has many applications in different fields, from economics to business, statistics and government. The prescriptive theory of rationality of subjective expected utility (SEU)[23] as well as the theory of games[24] are good examples of it.

Although it is possible to find different categorization regarding the nature of the approaches done to decision making processes it is assumed as Sarma (1994) proposes three main streams: a) Descriptive, that uses models and theories to describe and explain human decision-making behaviour by studying human beliefs and preferences as they are; b) 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 c) 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 one that is important to refer (since this thesis aims to be a descriptive study): the naturalistic decision making (NDM), a descriptive approach, that in the words of Endsley at all (2007, p.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 (1986, 1989, 1993) and is seen by Endsley at all (2007, p.3) as rejecting some previous research on design theory mainly normative instead of descriptive being that the cause of the failure in capturing critical aspects of how people decide mainly when dealing with "(…) ill-structures problems, uncertainty, time stress, risk, multiple and changing goals, multiple individuals

25. SEU is "a sophisticated mathematical model of choice that lies at the foundation of most contemporary economics, theoretical statistics, and operations research. SEU theory defines the conditions of perfect utility-maximizing rationality in a world of certainty or in a world in which the probability distributions of all relevant variables can be provided by the decision makers. (In spirit, it might be compared with a theory of ideal gases or of frictionless bodies sliding down inclined planes in a vacuum.) SEU theory deals only with decision making; it has nothing to say about how to frame problems, set goals, or develop new alternatives." (Simon et al, 1986, p. 2)

24. Game theory attempts to mathematically capture behavior in *strategic situations*, in which an individual's success in making choices depends on the choices of others. While initially developed to analyze competitions in which one individual does better at another's expense (zero sum games), it has been expanded to treat a wide class of interactions, which are classified according to several criteria. Today, "game theory is a sort of umbrella or 'unified field' theory for the rational side of social science, where 'social' is interpreted broadly, to include human as well as non-human players (computers, animals, plants)" (Aumann 1987).

(…)". More recently NDM expanded its analysis to macro cognition incorporating the work of Klein, Ross, Moon and Hollnagel (2003) that had focus on the behaviour of experts providing a research that includes processes such as attention management, mental simulation, mental model development, uncertainty management and course of action generation.

Klein et al (2003) work describes 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.

In addition, Jin and Chusilp (2005) claimed that design concepts are created and elaborated after mental iterations of idea generation and evaluation. They defined these iterations as the repetition of cognitive activities occurring in designers' thinking processes. When engaged in design, designers seem to generate questions and select directions within an internal dialogue. Understanding the design process is then to assess the mental activities of the designer relative to their context variables.

Psychological research in decision making has demonstrated that judgment applied under uncertainty often relies on simplified heuristics that is to say as Cox (1987, p. 665) defined it. "Competencies as reasoning processes that do not guarantee a solution or a useful transformation but derive their validity from the usefulness of their results". Being so, it is expected that within the decision making process, designers make use of specific cognitive heuristics to resolve the uncertainty in the problem space in order to explore and generate creative solutions.

Also to consider the suggestion made by Christensen and Schunn (2009) regarding the need of studying the relationship between the cues designers are using, the creative cognitive processes employed and their functions for understanding what leads to creative outcomes.

In that respect it is also useful to our study the work of Finke, Ward, & Smith (1992) that assessed creative processes and proposed they should be analyzed according to two categories: generative and exploratory one. While analogical transfer; association; retrieval; and synthesis are regarded as generative processes, contextual shifting; functional inference; and hypothesis testing are considered to be exploratory processes. In its view in a design process a cue can promote one type of generative process and that might constrain another exploratory one. However, this two fold model of creative cognitive processes it is still insufficient to a thorough detailed understanding of these processes and their function and relationship with other key aspects of design processes such as knowledge management and decision making.

Finally it is central to bring up the defense of the descriptive approach, in the way Longueville et al. (2003) defines it as an approach aiming at modeling in order to study, understand, represent and re-use existing decision-making processes.

In our opinion, the most relevant contribution lays in the possibility it opens to analyze the relationship between the decision-making process and the quality and strategic adequacy of the result. The reason is our belief that product development should solve a profit-maximization problem (Herrmann, 2004). In controlled protocol studies one can only simulate part of this product development process, the conceptual stage of the product. But even within these constraints this process shows something of the product development organization in terms of a sequence of steps that transform customer requirements into a satisfactory product design; and of the information flow governed by one or a team of decision-makers who make both design decisions and development decisions under time and budget constraints. It is a decision production system (Herrmann, 2002).

Most academic studies over the last decades, however, lack this perspective of understanding how detailed design decisions affect profitability.

It is the case of John Gero's FBS (function-behavior-structure) model of designing, first presented in 1990 and developed with his collaborators of the Key Centre of Design Computing and Cognition at the University of Sydney (Gero and Kannengiesser, 2006). In this model, recently discussed in Design Studies (Vermaas and Dorst, 2007), decision-making is not addressed directly but in a diffused complex way.

In site of the fact that the model is both prescriptive and descriptive and that the authors claim to be unique in its versatility - as opposed to the limitations of all the models used until now, such as those developed in the sequence of Delft Protocol Workshop (Cross et al, 1996) – it lacks the ability to make possible a 'satisfying' (in terms of usefulness for designers, companies and education) empirical analysis of how and why the decision-making process leads to a certain quality of the result.

However it is possible to find models (Jones, 1970; Pugh, 1990; Ertas and Jones, 1996; Vanguard Group, 1999; Sun Product Lifecycle (PLC) n.d.; Sun Sigma, n.d.) where the outcome of a design process integrates the quality of results measured in financial/profit terms. The majority of these models come from the consultancies and firms territory and to approach it is to devise also possibilities of assessing the understanding of Design processes on both parts (Education and Business).

Among the models that introduce the issue of profitability there are the ones proposed by Jones (1970) and Vredenburg (2003) that are clear examples of the previously said. Figure 12 presents the model of Jones (1970) where value analysis with a special focus on costs plays a key role.

In fact the way value analysis is seen by Jones makes it similar to a design method that aims to "increase the rate at which designing and manufacturing organizations learn to reduce the cost of a product" (Jones, 1992, p. 106).

Moreover, the model of Vredenburg (2003) that is shown on Figure 13, assumes the necessity of linking the design process with the business achievements possible through it. In this case, being a more recent model, other dimensions are explored, namely the User Centered Design (UCD) and the Integrated Product Development (IPD) hereby explored in the context of the IBM firm.

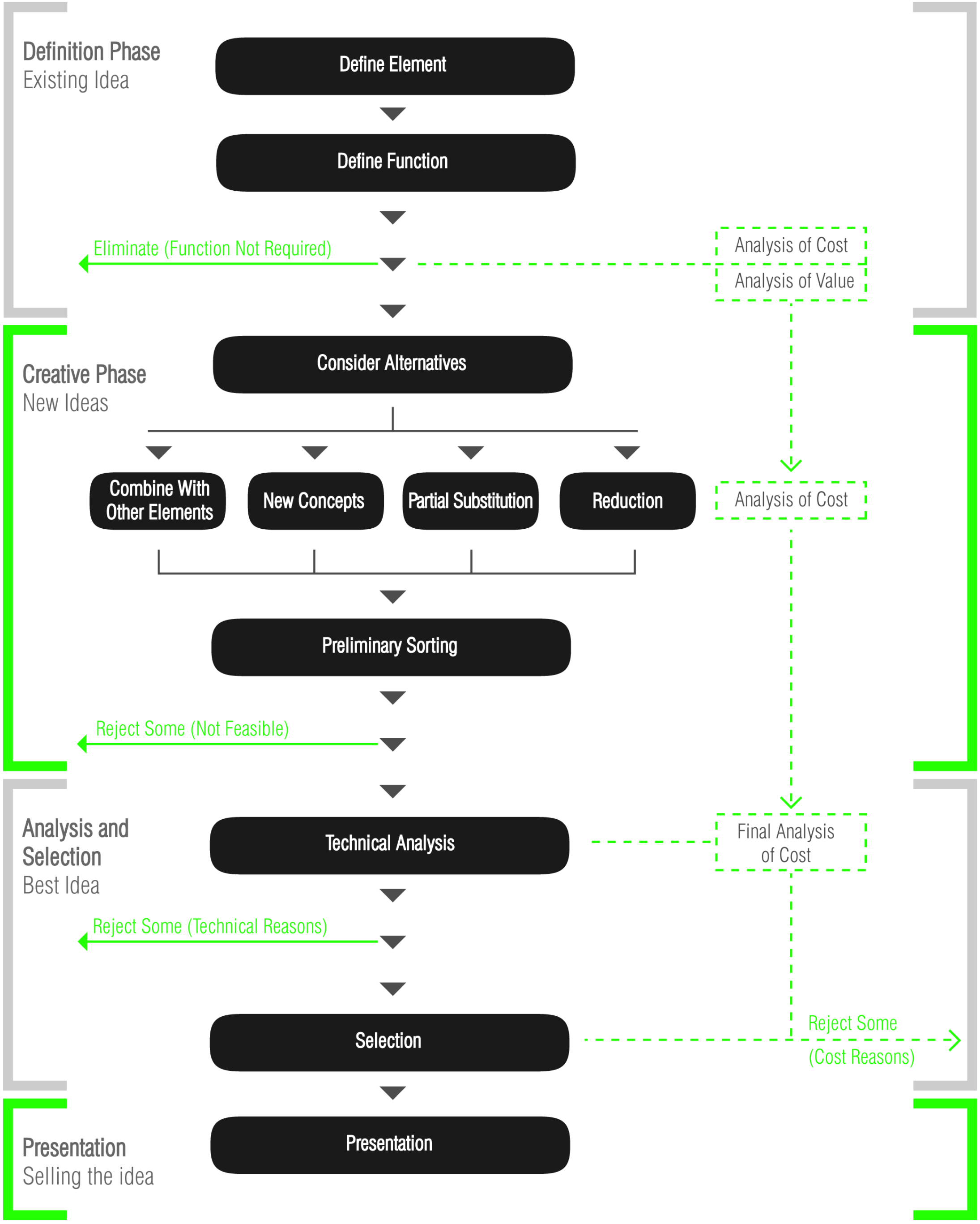


Fig.12 | Value Analysis / Design Process (John Chris Jones, 1992, pg. 109; first edition 1970)

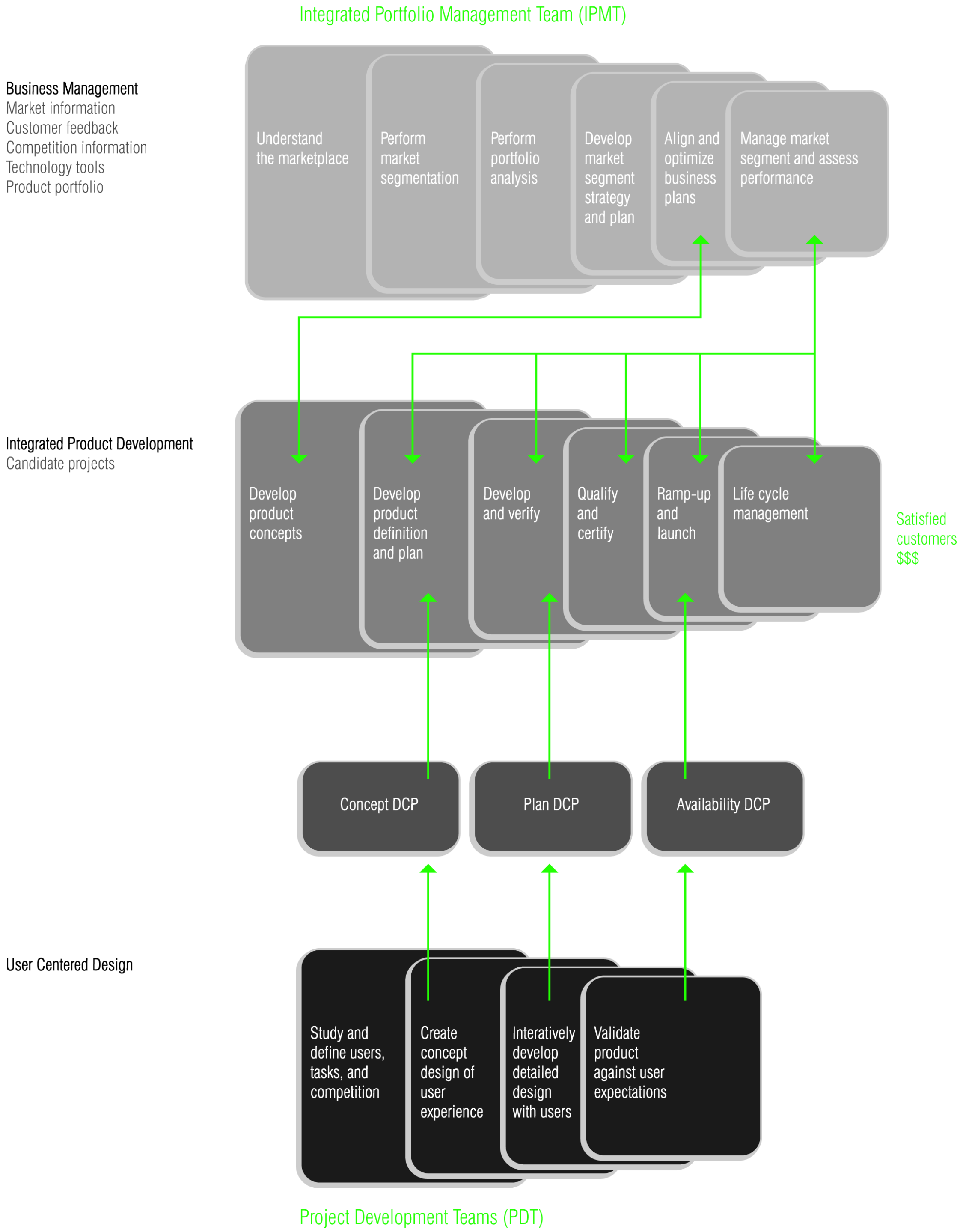


Fig.13 | Design Process – relationship among UCD, IPD and Business Management in IBM (Vredenburg, 2003); Source: Dubberly, 2004, p. 77)

The model of Vredenburg points up of how UCD integrates the IBM's integrated product development and its overall business management process.

Vredenburg (apud Dubberly, 2004, p.77) noted:

"Developing a new process and further enhancing it is only one component, albeit an important one, in the overall strategy of building ease of use into the total user experience at IBM. Organizations need to be enabled to carry out new processes and be provided with leadership and guidance while executing them. UCD is a core enabling process in the overall integrated product development process, which is the business checkpoint mechanism used for all funding and project milestone reviews within IBM. Having UCD and UE (User engineering) included directly in the corporate-wide IPD process ensures that decisions made about an offering will be required to take UCD and UE information into account".

From the words of Vredenburg (2003) it is to retain the idea that decision making at an operational level can derive in a very effective way from the corporate wide decision processes.[25]

That rises up the allusion to the studies undertaken by Krabuanrat and Phelps (1998) that tackle the use of heuristics in analysis of strategic management decisions. As the authors (p. 83) observed "being the success of a firm's strategy dependent on the interaction of the external environment, the firm's internal strengths, and the decisions it makes it is on the last ones that firms can exert its complete control and promote more immediate changes in order to adapt to changes in others".

However, at this stage of the present study the focus is on the operational level of decision making in design processes.

At that level, as Alexander proposes (1982, p. 281) "(…)if we regard decision-making as a process of choosing between alternative problem solutions which are already there, the question of their origin becomes secondary. At most, the solutions have to be found by means of alternative search mechanisms - systematic, heuristic ("rule-of thumb") or intuitive."

These alternative search mechanisms to support decision making is rather important in accessing decision making processes.

25. This topic will be further explored in the sub-section of strategic adequacy presented ahead in this thesis.

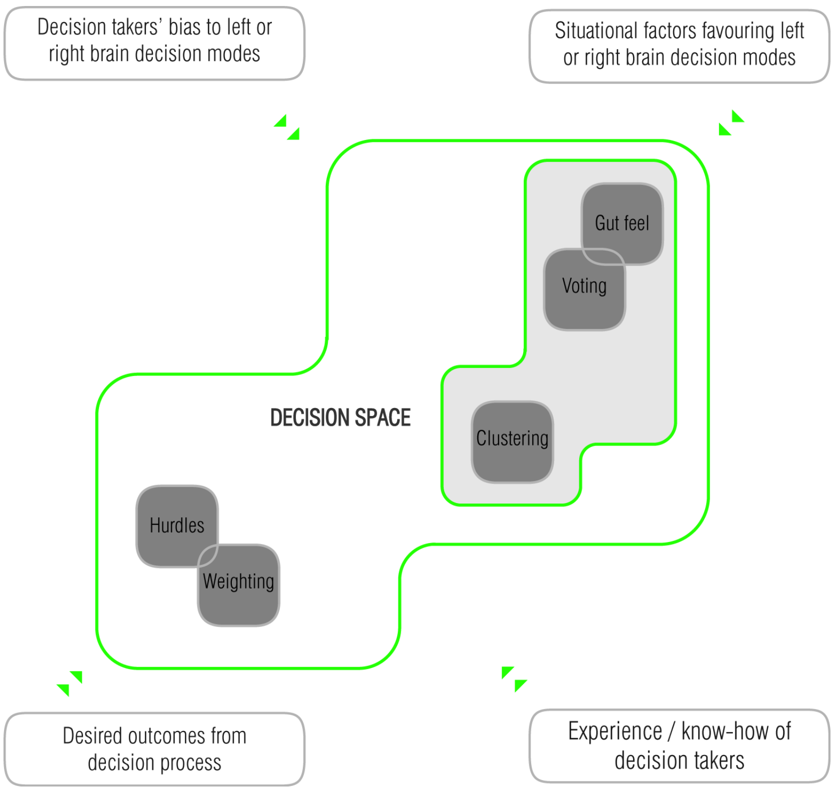


Fig.14 | Contingent Variables Influencing the Decision Process in Selecting "Closing-down" Techniques. Rickards, 1986, p. 16.

26. Closing down procedures are related with the reduction of idea generation which prevent the process to get out of balance. As Rickards (p. 12) explains it "In non-technical terms, any behaviour by a system (including the application of a problem-solving technique) which opens up possibilities requires a balancing stage for closing down the numbers of possibilities. As some techniques have several opening-up stages, each of them will have a mechanism for closing-down, before the next stage is introduced. The various circumstances of the situation influence the type of closing-down mechanisms (…). Among the closing down approaches after idea generation there are five identified by Rickards as being the most used. They are: a) Voting; b) clustering; c) hurdles; d) weighting methods; e) gut feel.

Related with it is the work done by Rickards (1987) that has developed a contingency model for explaining the decision making processes associated with closing-down procedures[26].

Figure 14 presents the model of Rickards. In there it is possible to distinguish a decision space that is influenced by situational factors such as the nature and reliability of data, time pressure etcetera. Then it is also to consider the experience and know-how of the decision takers, and their own biases towards left- or right-brain modes of decision making.

Finally there are the desired outcomes that rise up some questions as the ones presented by Rickards: "(…) is there an over-riding requirement such as maintaining group consensus, or getting a rapid mechanism for eliminating least useful options?" (Rickards, 1986, pp. 15-16).

Inside the decision space there are five identified techniques that are widely used to support the closing-down of the processes in terms of decision making. They are: a) voting; b) clustering; c) hurdles; d) weighting and e) gut feel.

Regarding the voting technique this one presents clear frailties especially when people are faced with ambiguous categories to vote in. However it is a good way as Rickards (1987, p. 12) states it " (…) of identifying commitment and ownership of some problem. In the nominal-group version of brainstorming (Delbecq et al, 1975), representatives of subgroupings generate sets of "blocks and barriers" to some complex problem. Each representative then ranks the blocks so that differences of perception between groups emerge. Not surprisingly, voting "works" best where personal commitment is an important consideration in the decision-making process."

In what concerns clustering[27] it is used to promote the systematization of ideas and the disclosure of its relationship that will bring light to the problem and hopefully to decision making. The technique of morphological analysis is a form of clustering in which system's dimensions are arranged to throw light on the inter-relationships.

Regarding the hurdles technique this one is used also when a large number of ideas, at different stages of development need to be scrutinized. Then a hurdle is created with differing degrees of severity. However, unlike clustering this technique as Rickards (1986, p. 13) points out

"(…) brings about a culling. Sometimes the need to cull is more important than the need to preserve the variety within a smaller number of broad dimensions. This is the case when a management wants to allocate resources to ideas or strategies. In setting up hurdles, the trick is to impose cheap screens that filter out a lot of the ideas early on. Later the hurdles of payback times, strategic fit, etc, can come in. In new product development it is typical for ideas to arrive over a period of time. When sufficient ideas are collected they are entered for a race across the hurdles set them. A simple set of hurdles might be to allow ideas to pass the first hurdle if they reveal some evidence of a market need. Then the next hurdle might be to convert ideas into prototype or demonstration products in a given time. Those failing this hurdle are put with

27. Clustering mean the assembling of components or ideas within some set into a smaller number of groupings, which can then be explored for interrelationships. Jones and Sims (1985) used the term mapping for a similar process.

ideas arriving to take place in the next race over the hurdles."

The weighting techniques are very common and take place when a group of ideas is assessed against a set of criteria, each of has an allocated importance or weight (Kepner and Tregoe, 1965). After the ideas are scored and ranked. However, as Rickards (1986, p. 13) states this technique presents the real danger of "(…) forcing weighting systems on "fuzzy" sets of ideas for which the weighting system was never intended."

Finally the technique of gut feel. Here it is useful to bring up the concept of 'hedonic response' , a psychological state prior to the moment of discovery that Gordon (1961) identified while applying a synectic method of creative problem solving. The idea is that you know before you know how you know. The synectics technique encourages the use of gut feel as a "promising" new way of looking at the problem. Rickards (1986, p. 13) appreciation of this technique is useful and is best synthesized on his own words:

"From observations in many synectics sessions, it seems to me that the client's choice of a problem-statement or idea depends on the willingness of that person to "go at risk". If the climate is not supportive, the choice will be more conservative; if the problem is an important one, again the choice is close to existing experience. The situation is analogous with that of a personal development discussion. The counsellor recognises that the "best" idea is the one that the client needs, even if it is not possible to justify within a rational framework. The difficulties with relying on gut feel arise when others do not share the feeling — as often happens in industrial situations."

2.1 Factors Influencing the Decision Process

The Decision making in design processes is in our view, and after the conclusion of some of the experiments, dependent essentially 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.

From those broad categories it is possible to isolate some factors that influence the decision-making along design process affecting its development and outcome. Among them it can be discriminate: a) knowledge management with a special focus on the information content and the way subjects value it and use it along the process b) the idea generation along the process; c) sketching as a means of searching the solution space; d) the expertise/ knowledge of the subject (that includes capitalized knowledge reuse i.e. the reuse of any knowledge capitalized from the same project or other projects, e) the individual and/or group dynamics.

2.1.1 Knowledge management – information access and use

As appointed by Beheshti (1993) and Wang et al (2008) design knowledge can improve the quality of design decisions by supporting designers to make better decisions thus achieving the improvement of the design efficiency.

To be so, as Wang et al (2008) puts it "(…) there is an overwhelming need to provide design decision with enough knowledge support throughout the design process."

There exist several assessments to both engineering (Vincenti,1990; Zhang, 1998; Ahmed, Bracewell, and Kim, 2005) and industrial design (Teixeira, 2007; Restrepo, 2004; Christiaans, 1992) knowledge.

Considering the case of engineering design approach it is of use to mention the classification of Vincenti (1990) that includes six categories such as fundamental design concepts, criteria & specification, theoretical tools, quantitative data, practical considerations and design instrumentalities. However, and unlike Zhang (1998) it does not include 'design process' that is a fundamental area of knowledge.

The classification shown in Figure 15 belongs to Zhang (1998; *apud* Wang et al, p. 128).

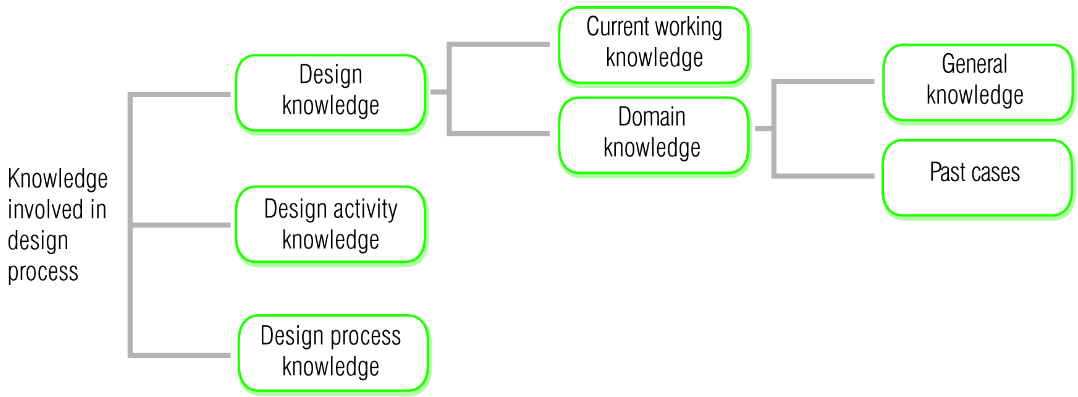


Fig.15 | Design Knowledge (source: Zhang, 1998 in Wang et al, 2008)

The diagram proposed by Zhang (Figure 15) recognizes the existence of domain knowledge of different natures and coming from diverse sources. All of it contributes to decision making and influences its course and outcomes.

Furthermore Ahmed et al (2005) also addressed product design knowledge and categorized it according to two dimensions that are presented in Table 1. In the first one the knowledge is separated into process-related and product-related knowledge. In the second dimension, the knowledge is split into stored externally Information and stored internally in human memory (including explicit knowledge, implicit knowledge, and tacit knowledge).

In terms of industrial design Christiaans (1992, pp. 67-68) in his study with learner reports from design students, proposed an assessment matrix system that relates three natures of knowledge with four types of it. The natures of knowledge are:

a) Basic knowledge (that include knowledge and skills that are supplied by other domains, experiences suggesting 'learning about yourself', knowledge about the working conditions);

b) Design knowledge (knowledge and skills involved in the design task);

c) General process knowledge (knowledge that is abstracted from the design task as metacognitive knowledge – evaluation, knowledge related to the process; knowledge of techniques for optimizing the process).

	Stored externally	Stored internally in human memory		
	Information	Explicit knowledge	Implicit knowledge	Tacit knowledge
Process	Descriptions of the design process (e.g. information)	Explanations about the process (e.g. rationale)	Understanding about the process (e.g. strategies)	Intuition about the process (e.g. insights)
Product	Descriptions of the product (e.g. information)	Explanations about the product (e.g. rationale)	Understanding about the product (e.g. relationship)	Intuition about the product (e.g. insights)

Table 1 | Classes of Knowledge and Information (source: Ahmed, 2005, p. 3)

The types of knowledge that were identified by keywords are:

a) Declarative knowledge – *keyword*: "I learnt *that*…"(the one that is stated by the subject, a value statement);

b) Procedural knowledge – *keyword*: "I learnt *how*… "(that presupposes that insight or understanding of the procedure is evident);

c) Situational knowledge – *keyword*: "I learn *when* …" or "if…*then*…" (it is a type of knowledge that asks not only for the keyword but also for an action).

d) Strategic knowledge; *keyword*: "*Before* I…" or "*First*, I start with…" (it occurs when a sequence of activities is planned in time).

Also Teixeira (2007, p. 14) conducted research where it was possible to identify evidence that "(…)enable the validation of the hypothesis that design knowledge is seldom applied by organizational knowledge to identify new business opportunities, but also identified new opportunities to leverage design knowledge contribution to organizational knowledge."

This contribution is rather important since it is central to identify how design knowledge relates with organizational knowledge given that both are involved in the decision making processes especially at its macro level analysis.

Figure 16 shows Teixeira (2007, pp. 15-16) diagram that is put forward by the author as it follows:

"The opportunity identified in this study presents an intriguing new research avenue that focuses on exploring

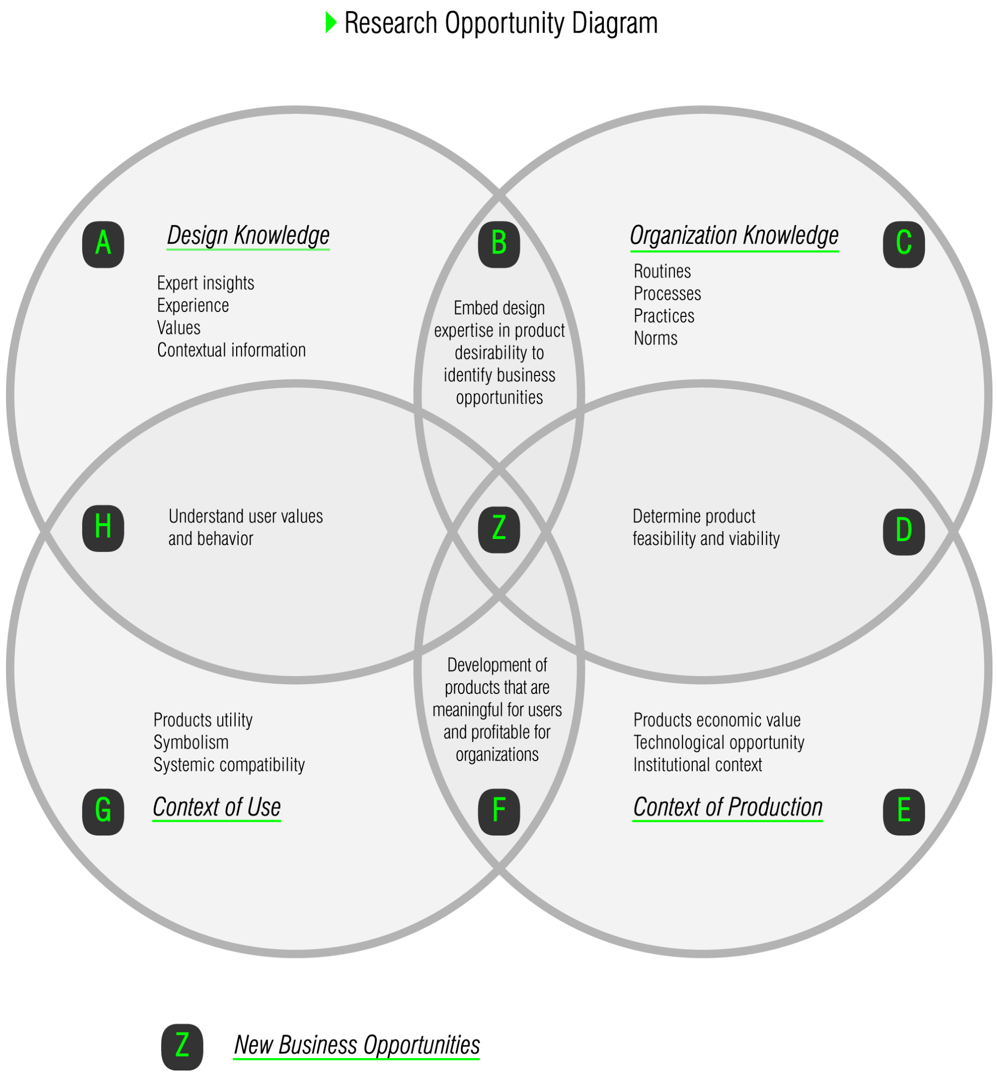
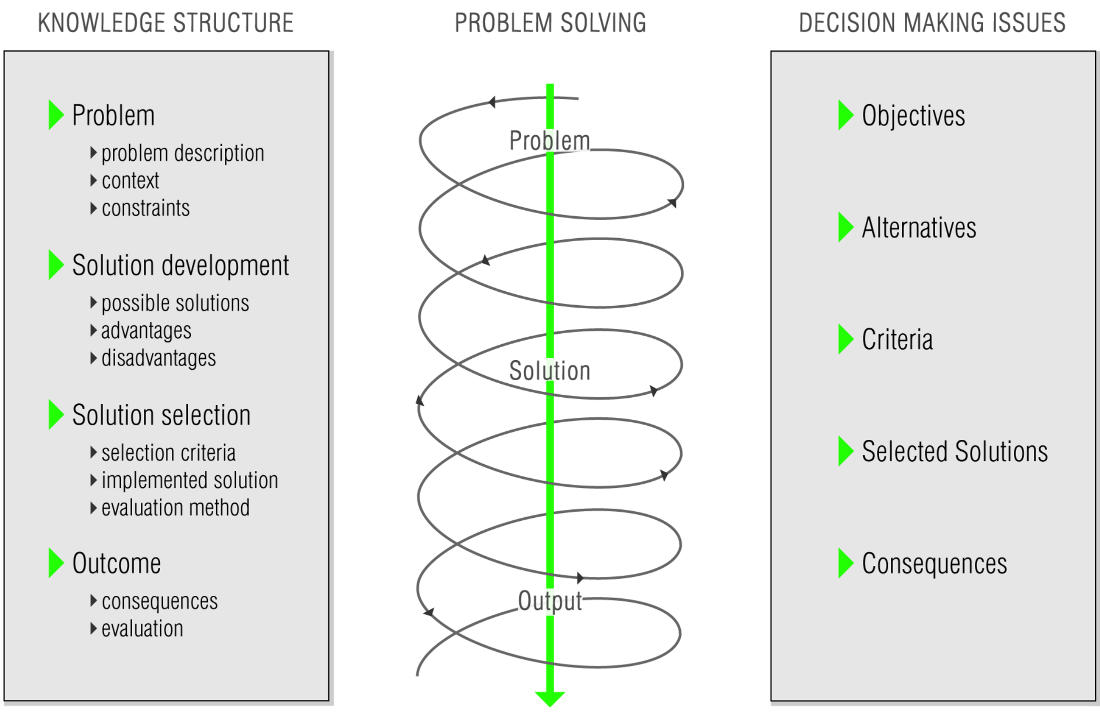


Fig.16 | Design Knowledge and Organization knowledge integration – a space for new business opportunities. Source: Teixeira, 2007, p. 15

the mechanism in which the unique expertise of design knowledge to understand user values and behavior (H) can influence organizational knowledge (B) in its identification of business opportunities (Z). As a starting point for future research, the exploration of designers' unique expertise in understanding user values and behavior can be used to overlap the context of use (G) with the context of production (E) to identify innovative business opportunities for organizations (Z). The proposal is to explore ideas of how the creation and delivery of meaningful and therefore valuable products for the user can generate economic value for organizations (F). It also highlights the need for a deep understanding of how organizations apply their knowledge to identify new business opportunities (C) and define a clear proposal of how designer insights, experience, values and information (A) can be



embedded into existing organizational routines, processes, practices, and norms (C) to enhance its knowledge (B) in identifying new business opportunities (Z), developing new products, improving existing ones to add or create new value for organizations and users (F)."

Additionally Qiu et al. (2007, p.53) defend that "(…) 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 17.

Fig.17 | Utilising knowledge to support decision making for solving problem. Source: Adapted from Haque et al (2000).

Figure 17 shows how knowledge is structured to help in problem definition, solution development and solution selection according to Haque et al (2000) and Kreitner and Kinicki, (2004) suggestion. 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.

As Wang et al (2008, p.131) recognize: "(…) contemporary design process becomes increasingly knowledge-intensive and collaborative". Under these circumstances to support design processes in terms of knowledge becomes critical not only in respect with its appropriateness and availability in time but also in terms of its delivery among all stakeholders involved in the process. Marsh (1997) found out that the proportion of designers' time captivated by information acquirement activities to be 20-30% being the majority of information got from personal contacts, who in 78% of cases retrieved it from memory. (Wang et al, 2008, p.131 *apud* Marsh, 1997).

This information is relevant given that part of the structuring of design problems is made through the use of information that is taken to the process not only to provide problem structuring but also to allow problem solving.

Regarding information access and use, as appointed by Song, Dong and Agogino (2002) the choices made by designers depend on their comprehension of the problem and its context as well as on their ability to structure both. That structuring is intimately connected with the obtainment of appropriate information regarding both problem and its context. Furthermore it is essential to have access to that information. There are numerous issues conditioning the accessibility of an information source, like awareness of the source, value of the results, format, level of detail, etc. (Choi and Rasmussen, 2002; Fidel and Green, 2004).

Restrepo and Christiaans (2003) also identified in their studies that there are differences between the information gathered and used in problem structuring and in problem solving. In the first case the information by and large refers to the context and stakeholders and implies a more active interpretation before use; in the second one is related with more concrete and operational issues such as materials, technical and constructive data.

The information used along the design process can be, as previously stated, of different natures. Eastman (2001) identified two main information origins: a) the use of information gathered through gained knowledge and experience on the part of the designer and b) information from external sources of information that can have different natures and types. However, as noted by Ullman et al (1988) there is also the information generated or inferred throughout the design process.

Equally pertinent is the identification of the sources of information used by designers that depend upon the activity being performed. Fidel and Green (2004) (and also the findings of the survey made in this research) reveal that specific data about materials and properties is searched mostly in books and manuals while when negotiating the structure of the problem a person is the preferred consultant since a person can translate knowledge in terms that fit the doubts of the asking designer.

As Restrepo and Christiaans (2004, pp. 10-11) state "Access to information will be improved if the information provided is deemed by the user as relevant, for relevance is not a property of the information itself, but an attribute endowed by the user in a certain situation".

2.1.2 Idea Generation and Creativity

Idea generation occurs along design processes and it somehow moulds its course of action. When talking about idea generation, creativity is an issue to attend to (Goldschmidt, 2005). In fact, it is not to say that all ideas generated along design processes are creative because they are not; but it is expected that at least some of them are thus contributing to a better outcome. In fact the general belief that the generation of a large amount of ideas correlates with better quality of outcomes was found to be false (Goldschmidt, 2005, p.603). Analyzing the table proposed by Howard et al (2008) that is presented as Table 2 it is possible to clearly see that idea generation integrates the creative design processes.

Table 2 | Comparing creative design processes. Source: Howard et al, 2008, p.165

MODELS	ANALYSIS PHASE	GENERATION PHASE	EVALUATION PHASE	COMMUNICATION / IMPLEMENTATION PHASE
Helmholtz (1826)	Saturation	Incubation / Illumination	X	X
Dewey (1910)	A felt difficulty / Definition and location of difficulty	Develop some possible solutions	Implications of solutions through reasoning	Experience collaboration of conjectural solution
Wallas (1926)	Preparation	Incubation / Illumination	Verification	X
Kris (1952)	X	Inspiration	Elaboration	Communication
Polya (1957)	Understanding the problem / Devising a plan	Carrying out the plan	Looking Back	X
Guilford (1957)	X	Divergence	Convergence	X
Buhl (1960)	Recognition / Definition / Preparation / Analysis	Synthesis	Evaluation	Presentation
Osborn (1963)	Fact-finding	Idea-finding	Solution-finding	X
Parnes (1967)	Problem, challenge, opportunity / Fact-finding / Problem-finding	Idea-finding	Solution-finding	Acceptance -finding / Action
Jones (1970)	Divergent Search for data / Understand the problem	Transformation Pattern finding / Flashes of insight	Convergent Judgement	X
Stein (1974)	X / Fact-finding	Hypothesis formulation	Hypothesis testing	Communication of results
Parnes (1981)	Mess finding / / Problem-finding	Idea-finding	Solution-finding	Acceptance--finding
Amabile (1983)	Problem or task presentation / Preparation	Response generation	Response validation	Outcome
Barron and Harrington (1981)	X	Conception / Gestation / Parturition	X	Bring up the baby
Isaksen et al. (1994)	Constructing opportunities / Exploring data / Framing problem	Generating ideas	Developing solutions	Building acceptance / Appraising tasks / Designing process
Courger et al. (1993)	Opportunity, delineation, problem definition / Compiling information	Generating ideas	Evaluating, prioritising ideas	Developing an implementation plan
Shneiderman (2000)	Collect Relate	Create		Donate (communicate)
Basadur et al. (2000)	Problem finding / Fact finding / Problem defn. Diverge - converge at each stage	Idea finding	Evaluate and select	Plan / Acceptance / Action
Kryssanov et al. (2001)	Functional requirements / Structural requirements	Functional solutions / Analogies, metaphors	Reinterpretation	X

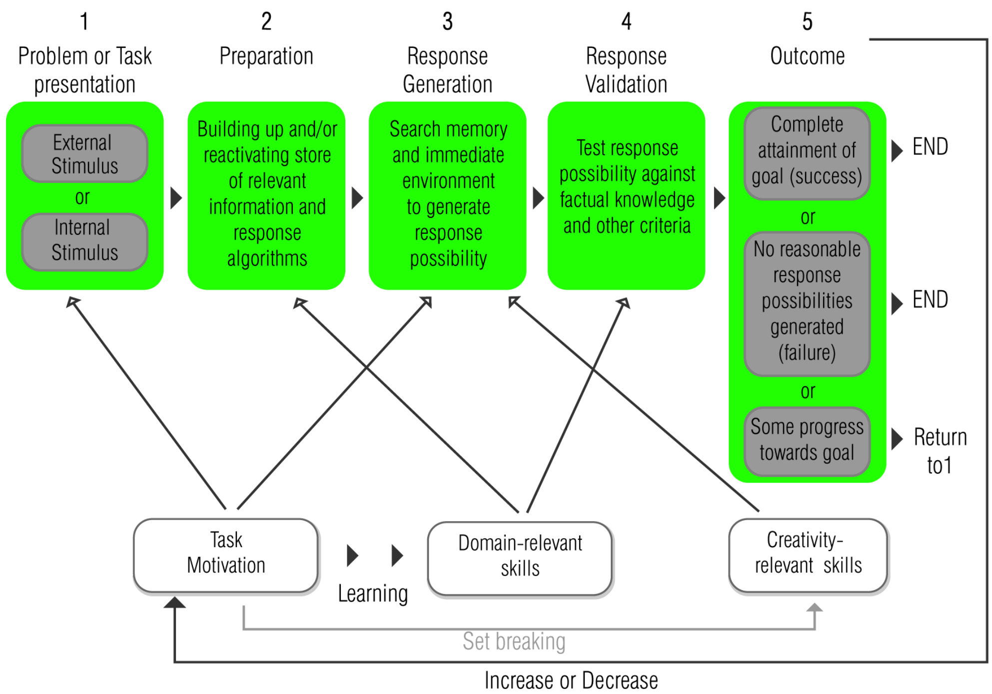


Fig.18 | Model of Creativity (Amabile, 1983)

A brief analysis of Table 2 shows that phases in the generation column are not precisely synonymous. That has do to with the fact that it is observable a tendency over time of a general shift from describing the creative processes as subconscious cognitive stages (Helmholtz 1826; Wallas 1926; Kris, 1952) to activity-based stages (Jones, 1970; Parnes 1981; Amabile, 1983).

In the face that the two concepts are so intimately linked it is useful to try to first explain them.

Design ideation or idea generation "(…) can be seen as a matter of generating, developing and communicating ideas, where 'idea' is understood as a basic element of thought that can be either visual, concrete or abstract" (Jonson, 2005, p.613).

Creativity on the other hand as Christiaans (1992) mentions can not be assumed as an universal concept since it depends upon domain specific elements (as Amabile stated in 1983), the commitment of the creator, previous knowledge being also culturally defined.

Amabile's model of creativity presented in Figure 18 highlights most of the issues addressed with the exception of the cultural determinants that constrain not only problem structuring but also the generation of ideas, the development of solutions and the overall process of decision making.

Even without a precise and complete definition of creativity thus assuming creativity as a 'relative' concept it is possible to say that it is a mental and social process that involves the generation of new/novel ideas or concepts. As Christiaans (1992) advanced, probably at the design specific domain, unlike for example the art domain, the products of creative thought must guarantee both originality and appropriateness.

Regarding idea generation Jin and Chusilp (2005, p. 30) stated that they "(…) include in generate activity not only memory retrieval but also perceptual stimulation that can act in response to iteration and stimulate designer's ideation." In fact the authors aiming primarily to understand iteration in design processes made it through an idea generation approach focusing on the contents and ideas flowing during iteration[28] process.

In reality there exists substantial evidence (Goldschmidt, 1991; Lawson, 1994; Suwa and Tversky, 1997; Suwa et al, 2000; Tovey et al, 2003) to put forward that the production of design ideas emerge to depend greatly on the interaction with conceptual sketches, i.e. the ones done along design process while having what Schön (1983) described as a "conversation with the drawing".

It is then evident the relationship between idea generation and sketching (further discussed) since it is a mean to achieve it. As van der Lugt (2001, p. 49) underlines through sketching it is possible to stimulate a re-interpretive cycle of idea generation process either in the mode of thinking (where you can move from general descriptions to specific depiction), talking (when you communicate your ideas you stimulate its development and allow re-interpretation) or storing (that provides accessibility to earlier ideas that can lead to a better integrated idea generation process).

Not only sketching influences idea generation. The visual stimuli is also an important variable in idea generation as Malaga (2000) found out in an experiment where participants had to generate ideas having the stimuli

28. Jin and Chusilp (2005, p. 25) "classify iteration into two primary types: iteration of design tasks and iteration of cognitive activities. For the first type, iteration is recognized as repeating design tasks in a design project, which is often carried out by a team of designers. For the second type, iteration is recognized as repeating cognitive activities in a single designer's mind when he/she is performing design tasks."

of word, picture and combined word picture where the use of picture stimuli elicited more creative ideas than the other two stimuli.

Focusing now on the creative process it is central to state that it is a rather complex one that is subject of widespread research.

Solovyova (2003, p.1) hypothesized in her studies "(…) that the level of creativity of design solutions is associated with thematic impulses triggered during the design process via memories of emotional experiences." According to her those memories trigger emotions that influence decision-making and also the formation of belief and value system of a designer.

Also Downing (2000) stated that designers use the knowledge and emotional impact enclosed in their memorable experiences in order to support them in the creative design process.

On the other hand there is to refer the work of Chua and Iyengar (2008, p.164) that equates creativity as a matter of choice[29] being prior experience and task instruction boundary conditions for the effects of choice on creativity. Through two experiments, they found that "(…) only individuals with high prior experience in the task domain and given explicit instruction to be creative produced more creative outcomes when given more choice. When either of these two conditions is not met (i.e., low prior experience or given non-creativity instruction), more choice did not lead to more creative performance".

Kim and Kim (2007, p.1) conducted several experiments exploring the relationship between creativity and the dynamics of teams. In their words they tried "to explore subjective perception on creativity in relation to personal creativity modes; (…) compare creativity of conceptual design teams of two groups." (…) The result shows that the teams in experimental group acquired higher score than those in control group without teamwork practice activity. Also we conducted detailed team interaction analysis of protocol data for a diverse team composed of various creativity modes and a uniform team composed of the same creativity mode. The analysis result of team interactions indicates that personal creativity modes could affect the way design teams interact."

29. Greenberg (1992) found that subjects who had choice in selecting which problems to work on in a given task situation produced more creative outputs. The main psychological mechanism that underlies these findings is that choice confers self determination and intrinsic motivation — key ingredients for creative performance (Amabile, 1983, 1990).

2.1.3 Sketching

Sketching influences decision-making in the way that it allows subjects to engage two types of reasoning as identified by Goldschmidt (1991, p. 131), one based on analogical or metaphorical thought, dealing with extracting new meaning from a sketch, that she describes as 'seeing as' and another type, the 'seeing that' that deals with design consequences of this newly acquired meaning of the sketch. This role of sketching as being "(…) not merely an act of representation of a pre-formulated image (but) in the context (…) more often than not, a search for such an image" (p.131) reinforces the importance sketching has in the decision-making process being evident the role of 'reflection while sketching'.

It is also important to consider the already mentioned work of Van der Lugt (2001) that establishes sketching as affecting the idea generation process (that is subject of an accurate scrutiny by decision-making process) in the way that: a) thinking sketches stimulates a re-interpretive cycle in the idea generation process (by means of its indeterminacy) b) talking sketches stimulates re-interpretation in the idea generation process; c) storing sketches stimulates the use of earlier ideas by enhancing their accessibility.

Sketches also appear to be critical for adjusting and refining ideas, generating concepts and assisting problem solving (Do et al, 2000).

Thus, sketching makes design thinking easier by 'seeing it' and 'storing it'. In other words, "(…) sketching puts much less load on the cognitive processes needed to design". (Bilda, 2006, p.607).

However, there is evidence that particularly in expert designers of sketching not being fundamental in the early phases of conceptual designing (Bilda et al, 2006, p. 587).

To summarize it is of use the words of Goldschmidt (2006, p. 553):

"(…) research suggests that (a) Designers, like others, can use mental imagery to manipulate shapes and forms and recombine them in meaningful and even creative ways in an activity that is most relevant to designing. (b) Sketching is useful (i.e., leads to more creative results) to those who due to experience are proficient users of sketching in design problem solving, in certain types of spatial manipulations of simple forms. It is postulated that the advantage results from the self-generated sketches becoming displays that are particularly rich in useful cues. (c) Domain specific design experience controls performance and qualifies the benefit from sketching in problem solving. (d) Visual displays in the work environment act as stimuli and possibly as prompts in design problem solving."

2.1.4 Expertise

Many studies have been conducted on expertise in diverse domains ranging from chess to physics and arts, and from novices to experts. The central aspects that define expertise seem to be: (1) quantitative and qualitative training, (2) motivation, and (3) acquiring complex mechanisms for controlling, executing and monitoring their performance. As one of the most experienced authors in the field of expertise Ericsson (2005) claims: 'The acquisition of reproducible superior performance on domain-specific tasks goes beyond accumulating knowledge. The development of high levels of skill requires the acquisition of representations that allow efficient control and execution of performance as well as mechanisms that support planning, reasoning and evaluation that mediate further improvement and maintenance of high levels of performance' (p. 238).

Ericsson and Lehmann (1996) found out that superior performance of experts is normally domain-specific and it is not transferable across domains.

Also Cross (2006) during the last 15 years studied the design processes and in it the role of expertise normally along with other parameters like designing, design strategies etcetera. Cross (p. 27) stated that "conventional wisdom about the nature of expertise in problem-solving seems often to be contradicted by the behaviour of expert designers. "

In order to understand design expertise Cross has done studies (besides the ones with less experienced designers or students) with expert designers. Cross (2006, p. 74) observed that expert designers display among them similar strategic aspects such as: "a) taking a broad 'system approach' to the problem rather than accepting narrow problem criteria; b) 'framing' the problem in a distinctive and sometimes rather personal way; and c) designing from 'first principles'[30]. These aspects were suggested by other researchers (Jones, 1970; Schön, 1983) but make known separately and never all together like in Cross's case.

Moreover the Delft protocol study (Cross, Christiaans and Dorst, 1996) brings light to the expertise analysis in design processes. Expertise was one of the research questions studied by comparing novices and final year design students. The most striking findings in this study were that the creativity of the solution was not dependent on the level of expertise, while the information-seeking behaviour definitely was.

In establishing relationship between expertise and decision making it is important to allude to Morrow et al (2003, p.1) that stated that "Experts excel on domain-relevant tasks in part because their knowledge supports comprehension and decision making. (…)More familiar situations that readily map onto knowledge structures may be easily recognized, so that decisions about appropriate responses are quickly made. However, such strategies may be less likely to occur for less familiar (or more anomalous) situations, where experts must engage in more effortful processes to identify problems and generate solutions (Klein, 1993; Patel and Arocha, 2001)."

2.1.5 Individual versus Group Dynamics

Deciding individually is different from group decisions, and it influences the outcomes of design processes.

That can be perceived if we attain to Visser (2009, pp. 203-204) that defends that:

"(…) there is no reason to suppose that cooperation modifies the nature of the basic cognitive activities and operations implemented in design (i.e., generation, transformation, and

30. Designing from 'first principles is usually advocate has a way to generate good and or creative designs (French,1985) In the definition of Roozenberg (1993) it is the abductive leap of reasoning from function to form that is regarded as the kernel of design.

evaluation of representations). (…) Because cooperation proceeds through interaction, it introduces, however, specific activities and influences designers' representational structures (both on socio cognitive and emotional levels. Some examples of such activities are coordination, operative synchronisation, construction of inter designer compatible representations, conflict resolution, and management of representations that differ between design partners through confrontation, articulation, and integration. Activities involving argumentation that is, in our view, activities aiming to modify the representations held by one's interlocutors obviously play a particularly important role. The construction of inter designer compatible representations (Visser, 2006), their existence beside designers' private representations, and their management introduce factors that may add complexity to collective design situations compared to individual design."

Goldschmidt (1996) approached the study of the differences between the performance of a team of designers and an individual one. In synthesis she found out that "(…) the team participants do not resemble different aspects of the individual designer, but rather that the individual designer is a unitary system that resembles the team."(p.90)

Also Günther et al (1996, p.117) analysed the some topic and allude to the fact that "(…) working together in a group gives another dimension to the use of designer's abilities. The way in which a group discusses, solves conflicts and makes decisions may increase or decrease the performance of its members. Thus the prerequisites[31] of the group are of great influence on the process and its result."

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.

Cross and Cross (1996) also addressed the study of teamwork in design processes. Their observation was based upon the following aspects: "a) roles and relationships; planning and acting; information gathering and sharing; problem analyzing and understanding, concept

31. Prerequisites are considered by the author as previous knowledge and skills that the designer has and that might influence the process and the result.

generation and adoption and conflict avoiding and resolving" (p.291). The main conclusion of their work is consistent with the view of Günther et al view since they found out that "(…) teamwork is a social process, and therefore social interactions, roles and relationships cannot be ignored in the analysis of design activity performed by teams. (…) many aspects of the design teams activity are influenced by social process factor. (…) personal commitments to particular concepts lead to social process actions such as expressing commitment and persuading others" (p. 316).

At this respect also Brereton et al (1996, p. 339) reveal that "The content of the evolving design depends heavily upon negotiation strategies and other more subtle and ubiquitous social processes that shape design work." (…) Depending on their level of commitment and other team member's alignment they adopt appropriate strategies of persuasion. "

According to Huitt (1992) 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.

Furthermore, Kleinsmann and Valkenburg (2008, p. 369) researched the barriers and enablers for the creation of shared understanding during a co-design process in industry. This knowledge is important "since it influences both the effectiveness and quality of the design process". To accomplish their research the authors defined three organizational levels: the actor, the project and the company level and clustered the barriers and enablers according to its content.

In their words (p. 369) "The results show that the clusters of barriers and enablers all concerned a different type of interface. Within each interface barriers and enablers on the three different organizational levels exist. This means that the effectiveness of creating shared understanding is not only dependent on face-to-face communication, but also on project management and project organization."

SUMMARY OF DESIGN PROCESSES AS A DECISION MAKING PROCESSES

To approach Design Process as a decisional process was thought to make it easier to make converge the understanding of it from both the managerial and the designer's point of view.

The nature of the study that was done is a descriptive one meaning that we seek to explain human decision making behaviour by studying human beliefs and preferences.

The critical analysis of literature regarding design process in general and also as a decision making process allowed us to identify several aspects that influence the process all along. Among those aspects we focused upon: 1) Knowledge management and information access and use; 2) Idea generation and creativity; 3) Sketching; 4) Expertise and 5) Individual versus group dynamics.

These will be aspects to be addressed and studied in detail in the experiments that were developed in this research.

BIBLIOGRAPHIC REFERENCES

AHMED, S., BRACEWELL, R. KIM, S. 2005. Engineering Knowledge Management. *A Symposium in Honour of Ken Wallace.* Cambridge, UK.

ALEXANDER, E. 1982. Design in the decision-making process. *Policy Sciences*, 14, pp.279-292.

AMABILE, T. 1983. The social psychology of creativity: a componential conceptualization. *Journal of Personality and Social Psychology*, 45(2), pp.357-376.

BEHESHTI, R. 1993. Design decisions and uncertainty. *Design Studies*, 14(1), pp.85-95.

BILDA, Z., GERO, J., PURCELL, T. 2006. To sketch or not to sketch? That is the question. *Design Studies,* 27(5), pp.587-613.

BRERETON M., C., D., MABOGUNJE, A., LEIFER, L. 1996. Collaboration in design teams: how social interaction shapes the product. In: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity*. New York: John Wiley & Sons,pp.319-340.

CHOI, Y., RASMUSSEN, E. 2002. Users' relevance criteria in image retrieval in American history. *Information Processing and Management*, 38,pp.695-726.

CHRISTENSEN, B., SCHUNN, C. 2009. Putting Blinkers on a Blind Man. Providing Cognitive Support for Creative Processes with Environmental Cues. In: MARKMAN, A. (ed.) *Tools for Innovation*. Oxford University Press.

CHRISTIAANS, H. 1992. *Creativity in Design: The role of domain knowledge in designing*, Utrecht, Lemma.

CHUA, R., IYENGAR, S. 2008. Effects of experience, instruction, and choice on creativity. *Journal of Creative Behavior*, 42(3), pp.164-180.

COX, V. Year. An Application of Cognitive Science to Understand Problem Solving Activity for Well Structure Problems: Cognition, Algorithms, Metacognition and Heuristics. In: Proceedings of Frontiers in Educational Annual Conference, 1987. pp. 664-669.

CROSS, N. 2006. *Designerly ways of knowing*, London, Springer.

CROSS, N., CHRISTIAANS, H., DORST, C. (EDS) 1996. *Analysing Design Activity*, Chichester, Wiley.

CROSS, N., CROSS, A. 1996. Observations of teamwork and social processes in design. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity*. New York: John Wiley & Sons, pp.291-317.

DELBECQ, A., VAN DE VEN, A., GUSTAFSON, D. (ed.) 1975. *Group Techniques for Program Planning: a Guide to Nominal Group and Delphi Processes*, Glenview, Illinois.: Scott Foresman.

DO, E., GROSS, M., NEIMAN, B., ZIMRING, C. 2000. Intentions in and relations among design drawings. *Design Studies*, 21(5), pp.483-503.

DOWNING, F. 2000. *Remembrance and the Design of Place*, College Station, Texas, A&M University Press.

DUBBERLY, H. (ed.) 2004. *How do You Design?*, San Francisco: Dubberly Design Office.

EASTMAN, C. 2001. New Directions in Design Cognition: Studies on Representation and Recall. *In*: C.M. EASTMAN, W. M., MC CRACKEN, W.C. NEWSTETTER (EDS) (ed.) *Design Knowing and Learning: Cognition in Design Education*. Amsterdam: Elsevier, pp.79-103.

ENDSLEY, M., HOFFMAN, R., KABER, D., ROTH, E. 2007. Cognitive engineering and decision making: an overview and future course. *Journal of Cognitive Engineering and Decision Making*, 1(1), pp.1-21.

ERICSSON, K. 2005. Recent advances in expertise research: a commentary on the contributions to the special issue. *Applied Cognitive Psychology*, 19, pp.233-241.

ERICSSON, K., LEHMANN, A. 1996. Experts and exceptional performance: evidence on maximal adaptations on task constraints. *Annual Review of Psychology*, 47, pp.273-305.

FIDEL, R., GREEN, M. 2004. The many faces of accessibility. *Journal of Information Processing and Management*, 40(3), pp.563-581.

FINKE, R., WARD, T., SMITH, S. 1992. *Creative Cognition: Theory, Research and Applications*., Cambridge, MIT Press.

GERO, J. S., KANNENGIESSER, U. 2006. A Function-Behaviour-Structure ontology of processes. *In*: GERO, J. (ed.) *A Function-Behaviour-Structure ontology of processes.* New York: Springer, pp.407-422.

GOLDSCHMIDT, G. 1991. The dialects of sketching. *Creativity Research Journal*, 4(2), pp.123-143.

GOLDSCHMIDT, G. 1996. The Designer as a team of one. *In*: CROSS, N., CHRISTIAANS, H., DORST, C. (ed.) *Analysing Design Activity*. New York: Wiley , pp.65-92.

GOLDSCHMIDT, G. 2005. How good are good ideas? Correlates of design creativity. *Design Studies*, 26, pp.593-611.

GOLDSCHMIDT, G., SMOLKOV, M. 2006. Variances in the impact of visual stimuli on design problem solving performance. *Design Studies*, 27, pp.549-569.

GORDON, W. 1961. *Synectics: the Development of Creative Capacity.*, New York, Harper and Row.

GUNTER, J., FRANKENBERGER, E.; AUER, P. 1996. Investigation of Individual and team design processes. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity.* New York: John Wiley & Sons, pp.117-131.

HAQUE, B., BELECHEANU, R., BARSON, R., PAWAR, K. 2000. Towards the application of case based reasoning to decision-making in concurrent product development (concurrent engineering). *Knowledge-Based Systems*, 13(2/3), pp.101-112.

HERRMANN, J. 2004. Decomposition in Product Development - Technical Report 2004-6. College Park: Institute for Systems Research, University of Maryland.

HERRMANN, J., SCHMIDT, L. 2002. Viewing product development as a decision production system. *In*: Proceedings of DETC 2002, ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September, 29 - October, 2, Montreal, Canada.

HOWARD, T., CULLEY, S., DEKONINCK, E. 2008. Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, 29, pp.160-180.

HUITT, W. 1992. Problem solving and decision making: Consideration of individual differences using the Myers-Briggs Type Indicator. *Journal of Psychological Type*, 24, pp.33-44.

JIN, Y., CHUSILP, P. 2005. Study of mental iteration in different design situations. *Design Studies*, 27(1), pp.25-55.

JONES, J. 1992 *Design Methods*, New York, John Wiley & Sons Inc.

JONSON, B. 2005. Design Ideation: the conceptual sketch in the digital age. *Design Studies*, 26(6), pp.613-624.

KEPNER, C., TREGOE, B. 1965. *The Rational manager: a systematic approach to problem solving and decision making*, New York, McGraw-Hill.

KIM, M., KIM, Y. 2007. Perceived Creativity and Design Team interaction. *IASDR07*. The Hong Kong Polytechnic University.

KLEIN, G. 1989. Recognition-primed decisions. *In*: ROUSE, W. (ed.) *Advances in man-machine systems research*. Greenwich: JAI Press, pp.47-92.

KLEIN, G. 1993. A recognition-primed decision (RPD) model of rapid decision making. *In*: KLEIN, G., ORASANU, J., CALDERWOOD, R., ZSAMBOK, C. (ed.) *Decision making in action: Models and methods* Norwood, NJ: Ablex, pp.138-147.

KLEIN, G., CALDERWOOD, R., CLINTON-CIROCCO, A. Year. Rapid decision making on the fire ground. *In*: Proceedings of the Human Factors Society, 1986 CA. Human Factors and Ergonomics Society, pp.576-580.

KLEIN, G., ROSS, K., MOON, B., KLEIN, D., HOLLNAGEL, E. 2003. Macrocognition. I*EEE Intelligent Systems*, 18(3), pp.81-85.

KLEINSMANN, M., VALKENBURG, R. 2008. Barriers and enablers for creating shared understanding in co-design projects. *Design Studies*, 29, pp.369-386.

KRABUANRAT, K., PHELPS, R. 1998. Heuristics and rationality in strategic decision making: an exploratory study. *Journal of Business Research*, 41, pp.83-93.

KREITNER, R., KINICKI, A. 2004. *Organizational Behavior*, New York, McGraw-Hill.

LAWSON, B. 1994. *Design in mind,* Oxford, Architectural Press.

LONGUEVILLE, B., LE CARDINAL, J., BOCQUET, J., DANEAU, P. 2003. Towards a project memory for innovative product design: a decision-making process model. *International Conference on Engineering Design (ICED03)*. Stockholm.

MALAGA, R. 2000. The effect of stimulus modes and associative distance in individual creativity support systems *Design Support Systems*, 29, pp.125-141.

MARSH, J., 1997. The Capture and Utilisation of Experience in Engineering Design, PhD Thesis, Cambridge University.

MORROW, D., MILLER, L., RIDOLFO,. H., KELLY, R., FISHER, U., STINE-MORROW, E. 2003. The influence of pilot expertise on comprehension and decision making. *12th International Symposium on Aviation Psychology*. Dayton.

PATEL, V, AROCHA, J., 2001. The nature of constraints on collaborative decision-making in health care settings. In SALAS, E., KLEIN G. (Eds.), *Linking expertise and naturalistic decision making*. Mahwah, NJ, Erlbaum.

QIU, Y.-F., CHUI, Y-P., HELANDER, M. 2007. A cognitive approach to understanding knowledge-based virtual team decision making in product design. *International Journal of Intelligent Enterprise*, 1(1), pp.45-64.

RESTREPO, J., CHRISTIAANS, H. 2003. Design Requirements: Conditioners or Conditioned? *ICED03 - International Conference on Engineering Design*. Stockholm.

RESTREPO, J., CHRISTIAANS, H. 2003. Problem Structuring and Information Access in Design. *Paper accepted for the Design Thinking Research Symposium 6: 'Expertise in design'*. Australia.

RICKARDS, T. 1987. "Closing Down": a classification of creative decision making aids. *Journal of Managerial Psychology,* 2(3), pp.11-16

SARMA, V. 1994. Decision Making in Complex Systems. *Systems Practice*, 7(4), pp.399-407.

SIMON, H., DANTZIG, G., HOGARTH, R., PIOTT,C., RAIFFA, H., SCHELLING, T., SHEPSLE, K., THAIER, R., TVERSKY, A., WINTER, S. 1986. Report on the Research Briefing Panel on Decision Making and Problem Solving. Washington DC: National Academy of Sciences.

SOLOVYOVA, I. 2003. Conjecture and Emotion: An Investigation of the Relationship Between Design Thinking and Emotional Content. *DTRS6 - Design Thinking Research Symposium 6 , Creativity and Cognition Studios*. Sidney, Australia: University of Technology.

SONG, S., DONG, E., AGOGINO, A. 2002. Modeling information needs in engineering databases using tacit knowledge. *Journal of Computing and Information Science in Engineering*, 2, pp.199-207.

SUWA, M., GERO, J., PURCELL, T. 2000. Unexpected discoveries and S-invention of design requirements: important vehicles for a design process. *Design Studies*, 21(6), pp.539-567.

SUWA, M., TVERSKY, B. 1997. What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4), pp.385-403.

TEIXEIRA, J. 2007. Applying Design Knowledge to Create Innovative Business Opportunities. Available: trex.id.iit.edu/papers/design_knowledge.pdf [Accessed February 2009].

TOVEY, M., PORTER, S., NEWMAN, R. 2003. Sketching, concept development and automotive design *Design Studies*, 24(2), pp.135-153.

ULLMAN, D., DIETTRICH, T., STAUFFER, L. 1988. A model of the mechanical engineering process based on empirical data. *AI EDAM,* 2(1), pp.33-52.

VAN DER LUGT, R. 2001. Sketching in design idea generation meetings. TU Delft, Faculty of Industrial Design Engineering.

VERMAAS,P., DORST, K. 2007. On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology. *Design Studies*, 28(2), pp.133-157.

VINCENTI, W. 1990. *What Engineers Know and How They Know It?,* Baltimore, John Hopkins University Press.

VISSER, W. 2009. Design: one, but in different forms. *Design Studies,* 30(3), pp.187-223.

WANG, K. R., L., TONG, S., EYNARD, B., MATTA, N. 2008. Design Knowledge for Decision-Making Process in a DFX Product Design Approach. *In*: YAN, X., ION, W., EYNARD, B. (ed.) *Global Design to Gain Competitive Edge: an Holistic and Collaborative Approach Based on Computational Tools*. London: Springer, pp.127-136.

ZHANG, Y. 1998. *Computer-Based Modelling and Management for Current Working Knowledge Evolution Support*. PhD Thesis, Strathclyde University.

3. DESIGN AS A STRATEGIC RESOURCE – THE STRATEGIC ADEQUACY OF DESIGN PROCESSES

The strategic adequacy of the design process's outcomes was elected as one of the key issues to be addressed in this study. As described in the 'glossary' this concept was to be evaluated in all experiments by all the jury members and had the following definition: "the extent to which the concept integrates and aligns the formal, technical and constructive aspects with business aspects i.e. the extent to which the product is able to assume a correct market positioning, contributing for brand consolidation and company's reputation."

To assume strategic adequacy of the design outcomes in the previously stated way is implicitly to presuppose design as a strategic resource in business. Therefore it is vital to access the way Design assumes a strategic role in business as well as the way business has made use of it until now.

Behind every object created by a designer lie several design decisions concerning not only the appearance, but also ergonomics, efficient use of materials, ease of manufacture, user friendliness etc. That means that as Walsh (2000, p. 75) mentions it "someone makes a series of decisions that result in a product of a particular function, cost and appearance, any of which may contribute to its commercial success. (…) Design is therefore an important activity for manufacturing firms and an important topic for economic and sociological analysis while the management of design is a vital aspect of corporate strategy."

The recognition of Design as a strategic resource is not a recent avenue. Fifteen years ago, Kotler and Rath (1984) noticed that "Design is a powerful but neglected strategic tool". In reality, several other studies undertaken in the ninety's (Borja de Mozota, 1985; Roy et al, 1986, 1998; Potter et al, 1991; Walsh, 1995; Svengren, 1995; Riedel et al, 1996; Sentence and Clarke, 1997; Borja de Mozota, 2000; Hertenstein, Platt and Brown, 2001; Nieminen et al, 2005; Walton, 2003; Design Council, 2004, 2005) have achieved results proving that Design improves the performance of the firms affecting positively several economic indicators such as sales, profit, turnover, product cost as well as qualitative indicators such as customer satisfaction.

Although sometimes design investments can pay back, as both Roy and Potter demonstrated (1993), vast evidence suggests that the potential of design is most often wasted by business (Walsh, et al. 1992; Potter et al, 1991.

Furthermore, the expectations of firms differ as it was observed by Walsh (2000) that discovered that the most striking difference was the one between the contribution of the industrial designer and the engineer/engineering designer. There are firms that see design as primarily about appearance and might only employ industrial designers, while there are others that see design as mainly about performance and might only employ design engineers. At this respect it is important to consider Moody (1984) explanation of the distinctions between 'industrial design' and 'engineering design'. He (1984, p. 62) says that: "Industrial design seeks to rectify the omissions of engineering; it is a conscious attempt to bring form and visual order to engineering hardware where the technology does not of itself provide these features". He details his reasoning arguing that:

"(…)when form does not automatically follow function, industrial design tries to relate the hardware to the dimensions, instinctive responses and emotional needs of the user. Through the conscious control of form, configuration, overall appearance and detailing, industrial design is capable of conveying to the user the abstract characteristics of a product – for example, robustness, precision … It can arrange for controls to be comfortable, pleasant and easy to operate. It is capable of imbuing a product with a distinctive ambience, style and feeling of good quality that equates with the personal taste of the user. In these various ways ,therefore, industrial design makes a contribution to innovation that produces a more rounded-out effect, meeting the needs (explicit, unconscious, or possibly only assumed) of the user." (p.62)

Still, in what concerns design's "meaning", as Walsh (2000) observed in her studies, it helps to mention that there are enormous variations in what firms, managers and people in general mean by "design". It can be defined for only one element of design such as fitness to use or performance or visual appearance or in some cases all three.

In the words of Walsh:

"Designers also have different perspective on design: some see their work in terms of creativity, other in terms of problem solving or even in terms of art. The marketing managers may see the work of designers as differentiating their products from those of competitors (…). To consumers the function of design may be the creation of new stiles and images (...) or the improvement of products so that they are easier to use, long-lasting (…). Strategic management may see the function of design as adding value, increasing production efficiency in use of materials and energy, and generating increased profits". (2000, p.76)

Also the study developed by De.:SID[32], that the researcher integrates, launched a survey were among other issues it were addressed the perceptions managers have about the nature and use of Design. The outcomes will be discussed in Chapter IV.

3.1 Firm's Strategic options Towards Design

Despite the strategic importance of design to the firms, the diffuseness of design makes it difficult to use strategically. This diffuseness of design, argue Dumas and Whitefield (1989, p. 51), is both "conceptual and organizational. It is conceptual in relating to issues such as: what design disciplines does a firm need? Or even: what does the firm means by design? It is organizational in that design is an activity without well-defined organizational boundaries."

In addition it was found that a variable mixture of in-house and consultant designers was employed by firms (Walsh 2000). This happens mainly for three reasons: there is a general lack of in-house skill or lack of a particular skill and also some firms, as a matter of principle or company strategy, employ consultants in order to have a flow of fresh ideas.

32. De.:SID is the acronymous of a research project entitled: "Design as Company's strategic resource: a study of the impacts of Design", that was funded by the Foundation for the Science and Technology (FCT) and hosted by FAUTL during 36 months from 3 September 2007 until August 2010.

Walsh also found a wide variety of attitudes and strategies towards design. "Firms (including firms in the same sector and of similar size) vary enormously in the extent of time, effort, money and professional expertise they believe should be accorded to design and the extent to which design is carried out by professional staff, (employed in-house or retained as consultants). Sometimes firms take design very seriously and allocate resources accordingly" (Walsh 2000, p. 76).

Furthermore there is a wide variation in the location of design in firms (Walsh 2000) – sometimes firms have a specialist design and development department, others have it as a part of R&D, where it is captured by the term research, design and development; It may be defined as part of the production department; It can be the responsibility of marketing department or, in some cases, design is split up between departments.

Another fact that contributes to this situation is the widespread phenomenon of "silent design" (Gorb and Dumas, 1987) that is related to a firm's commitment to design. 'Silent Design' is the process in which marketing, production and other staff contributes to design decisions, or do design and development work part time. They may be highly qualified in, and committed to design, but their managerial responsibilities make it impossible to devote much time to design. It is very common and very often creates difficulties to the correct integration of Design in the firms.

That is also the situation in Portugal as it is documented in Chapter IV (De.:SID survey).

The particular features of the institutionalization of design and its location with respect to the boundaries of the firm is partly explained by the combination of similarities and differences between design and R&D and design and Innovation. "Design is an activity more widespread than R&D in any particular firm; since it makes a contribution to marketing and production as well as to new product development" (Walsh 2000).

It is then important to consider here the existent organization structures. From the perspective of design management, Owens (2000, p. 58) argues:

"designed products derive from long chains of decisions, and that different decisions made at critical points in the process result in differences in the designed products. (…) This suggests that a design can be understood in terms of the decision-making process used to arrive at it, not only in terms of the aesthetic, market, or technological factors commonly assumed to drive designs. For products designed in groups, this means the organizing structures used to facilitate coordination during the design process have a substantive effect on the content of design".

In fact, one of the primary intents of organizing structures is the control of how decisions are made. Being so, it should be taken into account the implications of different types of organizing structures used to manage design practice.

The general business trend since the nineties indicates a progress towards flat, low-hierarchical organizational structures that are based upon self managing teams (Dumaine, 1990; Katzenbach and Smith, 1993) that empower members to assert their own expertise when needed. These structureless models make decision making in groups more complex, especially when it comes to relevant design decisions – such as the innovative definition of a product – that most often lay on subjective arguments based on incomplete information, ill-defined judgments and personally-held values.

In such low hierarchical structures the role of leadership assumes a particular value. Relevant work regarding this topic is the one developed by Birgit Jevnaker (2000) based on case-studies observation, literature analysis, research studies and interviews. She sustains that design must be championed, being that role "an education process that works best if it comes from a variety of internal and external sources" (p. 26). Jevnaker (2000) gathered evidence that "Design Management is also about leadership and human interaction" (p.26), being leadership significant when design becomes a more prominent component of management.

In fact, behind the best cases of design management - such as the work of Peter Behrens in AEG or the case of

Charles Eames at American Herman Miller – it happened that individuals "acted as persistent design promoters, providing the design leadership essential to connect and support design expertise to the particular corporate wisdom and core competencies in place (…) Design championing is a dyadic process rather then one excellent person, and it is fuelled by more than one entrepreneurial persona"(Jevnaker, 2000, p. 28).

The design-capable organizations, in the words of Jevnaker, depend upon many organizing activities that enable them to nurture constructive design developments in firms.

Table 3 presented below is elucidative of the actions underlying design capabilities.

Organizing Design Capability	Leadership Action involved
Design Resourcing Capability	Starting up design or development initiatives; Assessing best suitable design and business expertise; Resourcing money, time, projects and facilities without detrimental overload of capacity.
Design Combinative Capability	Configuring design resources; Tapping and connecting to firm-specific resources, strategic assets, or otherwise distinctive resources; Creating interaction of design resources and the firm's core competent people.
Design Learning Capability	Communicating design with ethos repeatedly to multiple stakeholders; Exposing and testing design within a reciprocal and acknowledge design relationship; Inaugurating design experiences to key stakeholders; Debriefing design building memory;
Design Innovation Capability	Adopting new knowledge and ideas; Fostering creative design developments; Nurturing open exchange and taking advantage of creative abrasion.
Design Strategic Capability	Providing a strategic focus while allowing out-of-the box discovery; Anchoring design developments in business strategy and strategists; Implementing strategy stretch.
Design Advantage - Protecting Capability	Protecting new designs by patents, licensing, pattern protection; Capturing design-based value and sharing risks through legal agreements, royalties and relational contracting; Sustaining design capabilities through design alliancing, R & D partnering.

Table 3 | Relationship between Design Capacities and Leadership Activities. Source: Birgit H. Jevnaker (2000, p. 29)

Observing Table 3 it is clear that design intervention is broad and anchored on business strategy, thereby being indispensable the validation of design as a strategic area of the business that must be correctly valued and explored.

In fact Kristensen (1998, p.219) noticed that "design was still an embryonic field since it was not clear under what circumstances a successful and differentiated design approach could be adopted or generated by business firms".

In addition to that, from research studies such as the one of Dougherty (1992, p. 200), it is possible to assess "how design integration can be impeded in manifold ways by divisional structures and routines, as well as by the dominance of a core group of expertise or by interpretive barriers."

Furthermore Nevado et al (2008, p. 9) suggest that "Designers represent the competences best placed within the company to act as a mobilizing force for projects for the development, monitoring and implementation of new ideas. The responses of companies to appeals from the market are many and touch on different areas of knowledge. Therefore it is necessary for somebody to know how to coordinate all of this knowledge of different specialties and different strategic involvement and make the intangible into something tangible."

The reality is that, nowadays, business management is confronted with complex and rapidly changing opportunities and threats within a global and digitalized economy. So, as Jevnaker (2000,p. 33) states "in face of the exposed how can leaders foster a design leadership that may help gain and sustain a competitive advantage? (…) in such a competitive context it is important to facilitate not only the introduction of a professional design approach in firms, but also to identify how creative leadership can foster a more dynamic design capability – that is, an ability to sense and respond in a timely way to new opportunities that can create and capture new values".

Jevnaker (2000, p. 34) also proposes that, in practice, that dynamic capability can be fostered if the leadership assumes four key aspects that are summarized in Figure 19.

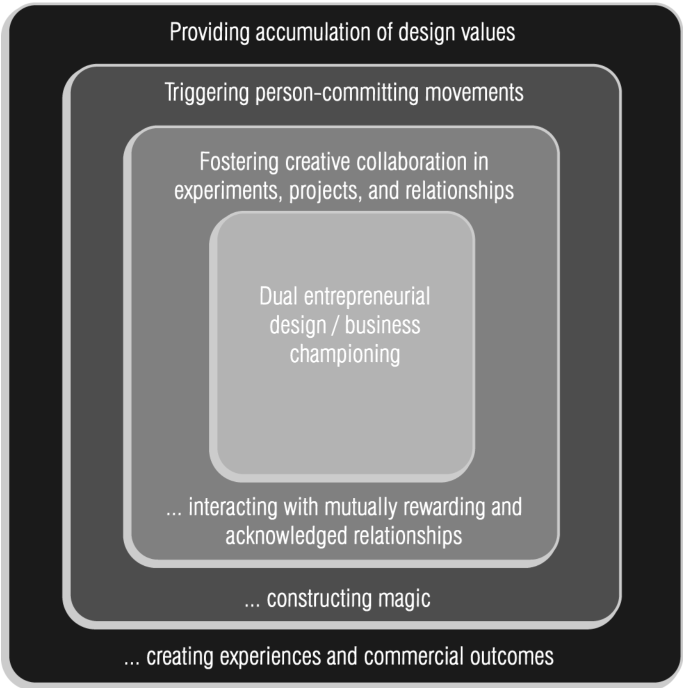


Fig.19 | Four leadership process-related aspects identified as key in design championing. Source: Jevnaker, 2000, p. 34

Dual Entrepreneurial Design/Business Championing – The importance of a design ambassador to lever design within a firm is one of the first lessons learned by the analysis of all the design-related literature. It implies courageous moves by both sides (the managerial and the design one) being difficult to point out which side is most essential in terms of the creation of the new design relationship. In addition, says Jevnaker (2000, p. 34), "we need the dual champion-related terms to appreciate the skillful opportunity finding and the vital advocacy of the best available design directions."

Fostering creative collaboration in experiments, projects and relationships – dedicate and keep resources in design development tactic. Once initiated the process of reciprocal and collaborative actions the start of a long-term design relationship is established. (For example IDEO invites new clients into brainstorming session of a five-day "deep-dive" workshop in addition to regular presentations and interim meetings).

Triggering person-committing movements – this third point refers to "the combined element of skilful action and charismatic engagement" (p. 34). (One example of that is what happened with the hired industrial designer Roy

Tandberg, from the Tvengsberg consultancy, when he wanted to set up his own design business. At that moment, the technical director of Tomra invited him. This suggestion leads to Tomra's internal but partly independent, design consultant, a hybrid solution that leads to a triggering dynamic between internal and partly external resources).

Providing an accumulation of design values – Jevnaker (2000) notices that "as demonstrated by IBM, continued design investments by firms and designers can accumulate visible outcomes, as well as experiential and tacit knowledge. The latter can be distributed on three continents and when combined, can create momentum".

These studies and reflections reveal the vital and specific importance of human capital to overall design integration.

3.2 Design Processes inside the Firms

Design processes inside the firms can be seen as Mozota (2003) proposes, at three level, the strategic one, the tactical (management) and the operational one (see table 4). Design processes get facilitated through the company's enablers. Walton (2003, apud Nieminen et al, 2005, p.29) defines the term "'Enabler' as 'something with suitable power, means, opportunity and authority to achieve a specific result of action'."

Enablers concern design usage in companies that have not a particular way of being organized. Enablers depend

Table 4 | Operational, Tactic and Strategic Levels of Design (source Mozota p.259).

Design ACTION	Design FUNCTION	Design VISION
The Differentiating Value of Design	The Coordinating Value of Design	The Transforming Value of Design
Design is an economic competency that changes the primary activities in the value chain.	Design is an management competency that changes in the support activities in the value chain.	Design is a core competency that changes the value chain of the sector and the vision of the industry.
"3" Brand marketing Production Communication	"3" Structure Technology management Innovation management	"3" Strategy Knowledge management Networking management
Operational Design Management	Functional Design Management	Strategic Design Management

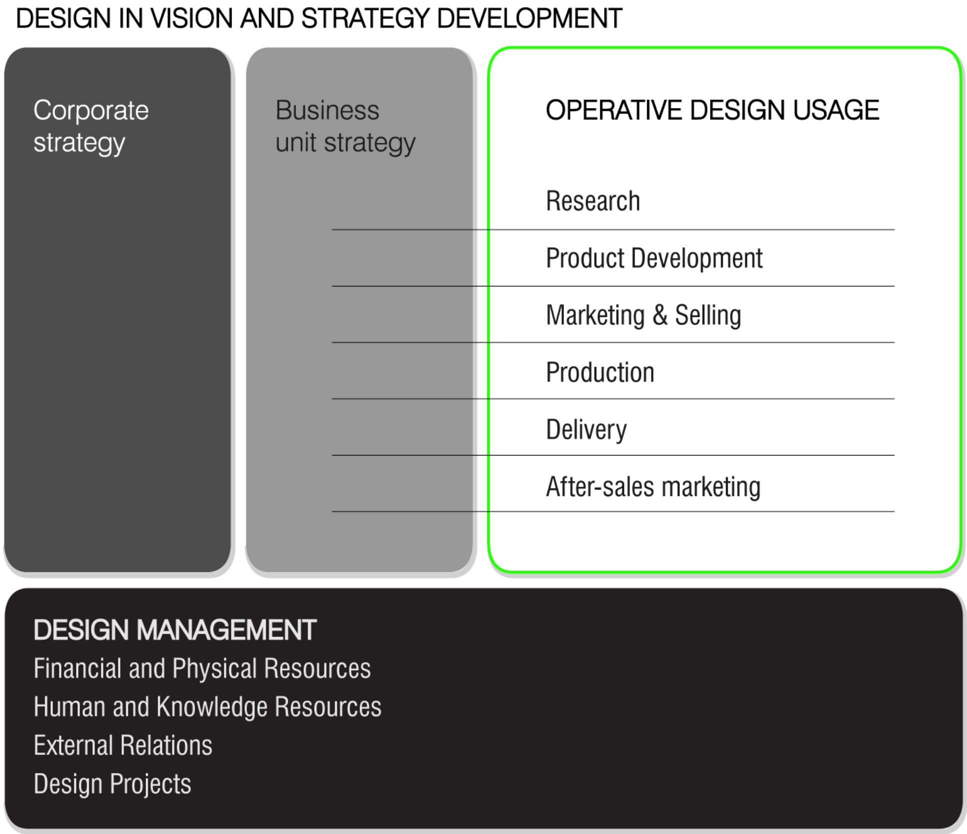


Fig.20 | Enablers in the Evaluation Model for Strategic Impacts of Design. Source: Nieminen et al, 2005, p. 30

in a very close way upon the company's drivers. The drivers of a company are its characteristics and factors in business environment that affect both the organization and the content of design strategies. According to Nieminen et al (2005) study the most important drivers for design usage are the maturity and velocity of the industry, customer type, and the size of the company.

At the three different stages there are specific decision-making levels of design along with different designer's participation in decision making and furthermore distinct expected results.
Figure 20 presents the evaluation model of strategic impacts of design developed by Nieminen et al (2005, p. 30) that focus on the enablers at the three referred levels.

As it can be observed in Figure 20 the type and complexity of design decision making depends upon several relevant factors and areas of knowledge that interact with it at different stages.

Organizing the design process inside a company is therefore challenging. As Cooper and Press (1995) referred the extent to which design is seen as an individual creative activity or as a corporate planning process depends upon company characteristics such as company size, the complexity of its production system and the nature of both the corporate and national cultures.

In addition, as Nieminen et al (2005, p. 30) pointed out:

"external drivers have an impact; for instance, in high-velocity industries, companies need to be able to react fast to new trends (product features, colour, etc.) and develop matching products. Therefore, there is an immense need for organizing the design process – the time for experimentation is limited and the focus is on the exploitation of accumulated design knowledge. Moreover, production constraints affect the organization of the design process: a high-technology product requires tight co-operation with other functional departments, and the designer cannot work in isolation. Fluent cross-functional communication is important in any case."

Nieminen et al (2005) considerations bring out the mediation role of design since it must cooperate with other functional areas inside the firms. That relationship can be either formal or informal, the separation of tasks can be precise or loosely defined and the work can be organized either sequentially or members of different functions can be organized in project teams.

Under these circumstances the role and impact of design activity in business is diverse and the designer's responsibilities and their role in decision making are a crucial issue.

According to Nieminen et al (2005, p. 45) "The right timing by effective scheduling of decision-making procedure minimizes the need for time-consuming corrective actions in the idea-to-markets process. The company's reactivity under risky conditions is extremely important: for the competitiveness and risks, it is better if the company can make the decisions later in the process. Strategic planning and a well-timed decision-making procedure reduce delaying corrections and renewals."

3.3 Strategic adequacy and decision making

The understanding of what strategic design usage means was reflected by Nieminen et al (2005, p. 74) that questioned it in this way: "Does it mean that design usage should be increased, planned in the longer horizon, or that designers participate in strategic decision-making?".

To ensure the strategic design usage it is central that the three different levels of design intervention are coherently linked. As Nieminem et al (2005, p.75) put forward "It is vital that the operative level has direct contacts with strategic decision making to assure that set decisions remain and that information arising in the operative level will be utilized in strategy development. In addition, there has to be design competence both at strategic and operative levels in order to assure that design usage supports the company's strategic goals."

Furthermore, as stressed by several representatives of the case companies' operative levels (Nieminen et al, 2005, p. 75) it is very important to have "adequate, competent design resources to support internal argumentation in decision making during the whole project."

Also pertinent to the strategic design usage is the designer's influence in the vision and strategic development that was designed by Nieminen et al (2005, p. 75) as it is presented in Figure 21.

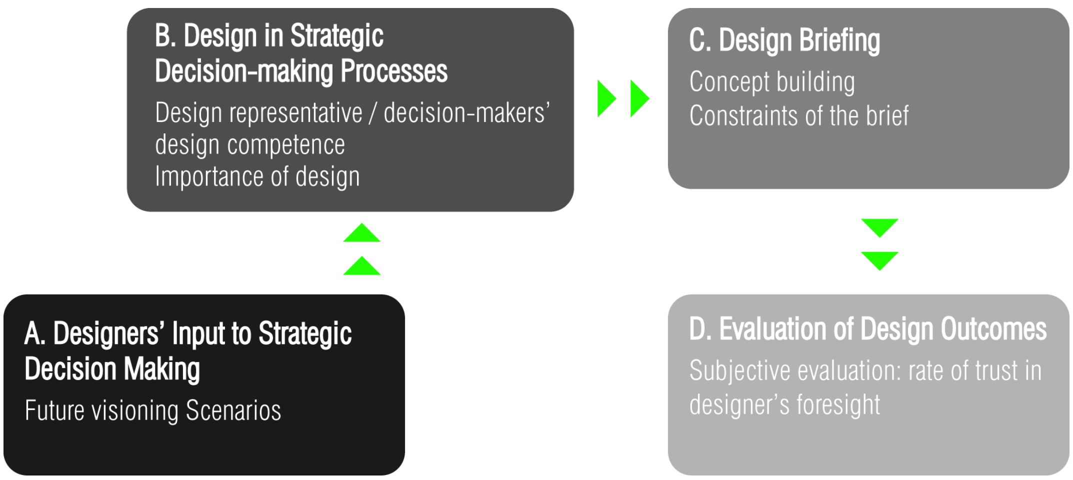


Fig.21 |Designers' possibilities to influence strategy development. Source: Nieminen et al, 2005, p.75.

Figure 21 presents four different levels of design influence in strategic terms. They are:

A - Possible design inputs to strategic decision making, namely by means of future visions and scenarios. This is a possibility of design information to support strategic decision making. As found out in Nieminen et al (2005) study it is crucial to have a direct flow of information and market research conducted from the design perspective;

B – Participation in strategic decision making, because as stressed by Nieminen et al (2005, p. 75) " When there is no design representative in strategic decision making but the company relies on the design competence of the management, there is a risk that design decisions are prolonged and the significance of design is not adequately stressed. Centralizing the design authority brings order but heterogenic evaluation has also benefits – discussions and conflicts may also be fruitful and increase management's design competence and commitment."

C - Influencing the design briefing, by means of creating concepts based on a slackly defined design brief, the strategy is 'emergent' instead of intentionally controlled; In Nieminen et al study the case companies considered the design brief and evaluation as the most important ways of improving the design usage. "The case companies emphasized the role of design in creating a concrete and unambiguous interpretation to strengthen and fasten the decision-making process." (Nieminen et al, 2005, p. 75)

D - Influencing design evaluation, given that design evaluation includes many subjective issues, being essential that the company decides the degree of trust it places in a designer's foresight. Besides, as Nieminen et al (2005, p.76) stated "Leaving the designer outside the design evaluation is contradictory to the initial choice of investing in design. If design solutions are not justified, there is a risk that they may be neglected. The research showed that when a designer is able to justify design solutions based on the given goals and constraints, decision-making becomes easier."

Affecting also the degree of participation in strategy and vision development decision making is the role

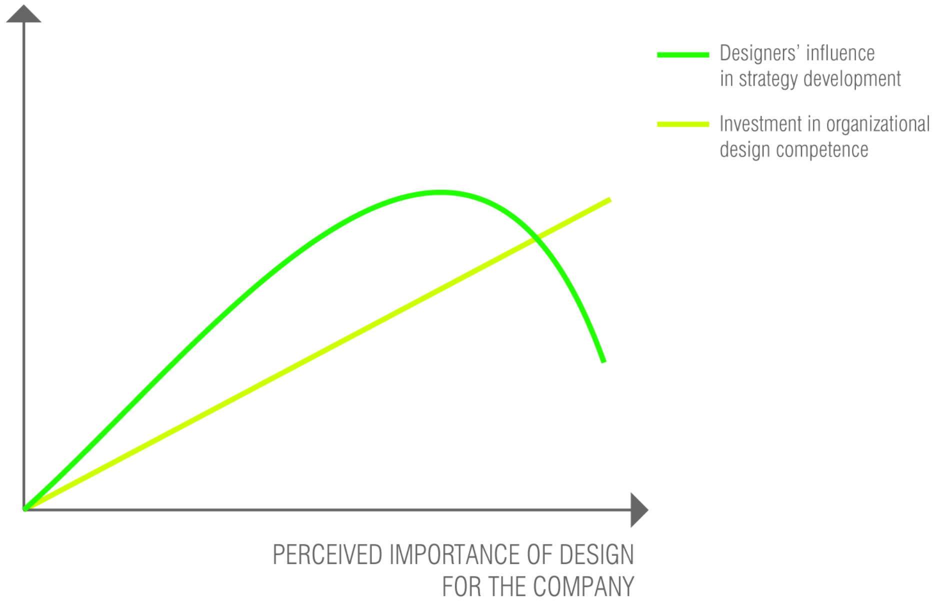


Figure 22 | Designers' influence in strategy development in the case companies. Source: Nieminen, 2005, p.76

of design as a competitive edge. Nieminen et al (2005, p.76) reinforce this idea stating: "the greater the design's significance was perceived, the better were designers' chances to influence, especially in briefing and evaluation of design".

Figure 22 illustrates how designers' influence on strategy development increases in parallel with the perceived importance of design in the company up to a point where design is of such grand significance that the requests of organizational design competence begin to outshine the designers' influence.

Michel (2007, p.34), that developed a diagnostic tool to help leaders to understand the decision making culture and routines in their organizations, recognizes that "(…) CEOs[33] really want to know where specifically their systems are already supporting at scale the development of good judgment, creativity, discipline and rigor of thought, and where specific changes and investments need to be made."

In the view of Michael (2007, p. 34) "Formal decision-making practices are a competitive advantage. They can not walk away, and they can not be copied easily (…)". Furthermore as acknowledged by Hammond et al (1999) decision-making can not be measured directly. Being formalized it gets effortless to do it since criteria can be established and information can be accessed easily.

33. See Acronymous

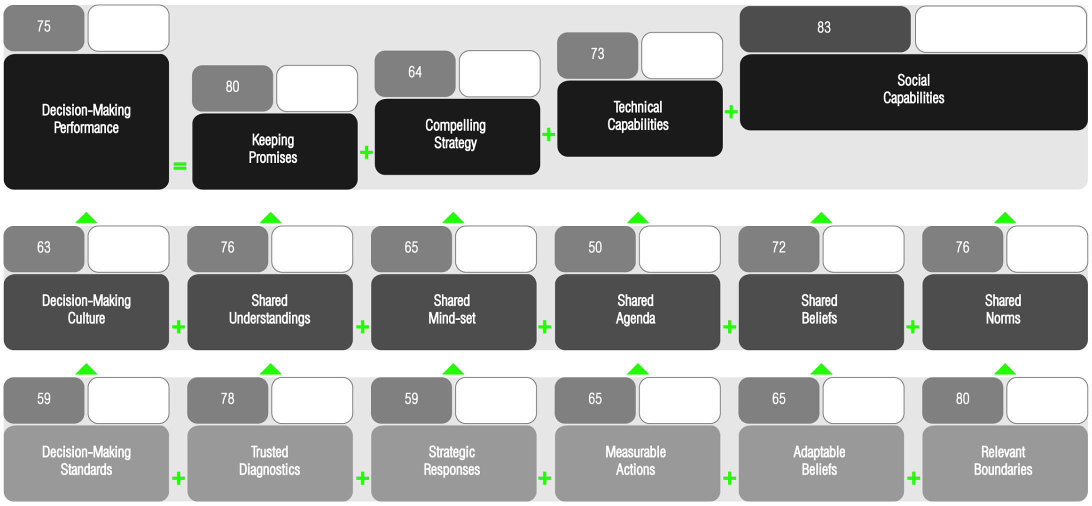


Fig.23 | Decision making Balance Scorecard (Michel, 2007, p.37)

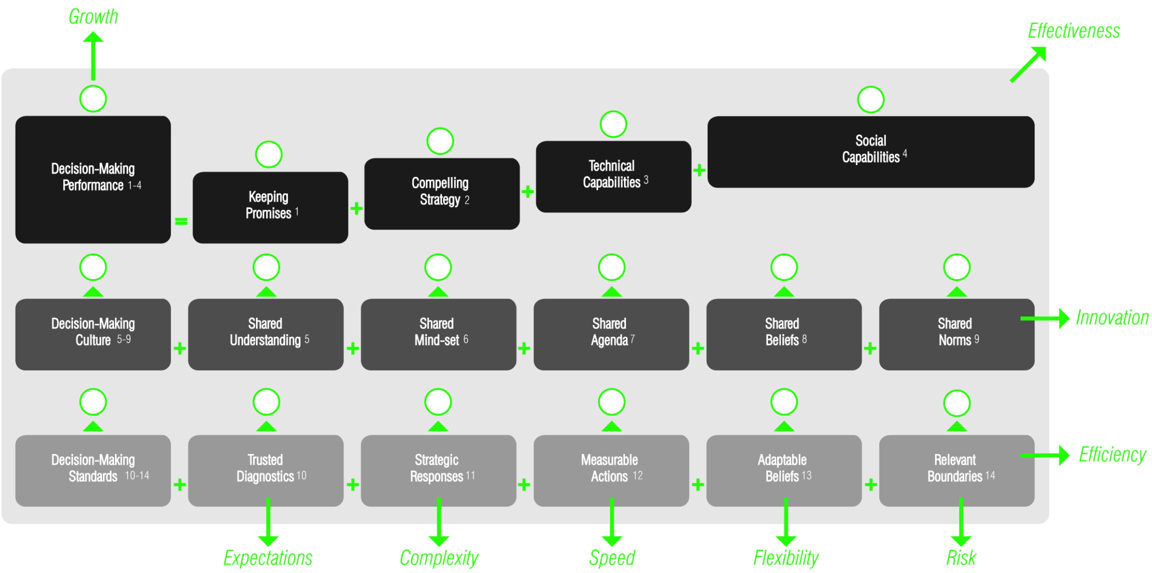


Fig.24 | Decision making Balance Scorecard nine principles (Michel, 2007, p.40)

In fact to measure decision making there are three possible approaches: a) The result of good quality decisions as content (Yates et al, 2002) or organizational performance; b) The use of formal decision-making practices and how they create leadership team alignment (Kopeikina, 2005) and c) The quality of the underlying practices as the standards of formal decision making.

In order to understand how decision making creates values in organizations Michel (2007, p.36) created the decision making balance scorecard presented in Figure 23. Michel has selected fourteen distinct metrics to address how well the processes, practices and principles

Using the scorecard to adress the control levers		
PRINCIPLES	*LEVERS*	*BENEFITS*
1. Align the organization for higher *efectiveness*	Design and use of integrated and formal management systems	An organization that delivers on its promises
2. Remove interferences for higher *growth*	Convergence of systems, practices and principles	Employees that capture opportunities - develop
3. Create the shared context for *innovation*	Use of a formal leadership cycle	Employees that adapt and focus
4. Use information and feedback to clarify *expectations*	Design and use of measurement	Employees that understand and take informed decisions - learn
5. Decompose *complexity*	Design and use of diagnostic and interactive strategic management	Employees that do the right things - think
6. Clarify accountabilities for greater *speed*	Design and use of diagnostic and interactive organizational performance management	Employees that get things done - act
7. Enable freedom to act for more *flexibility*	Design and use of diagnostic and interactive individual performance management	Employees that know how things are being done - achieve
8. Establish risk limits and standards to adress the *uncertainties*	Design and use of governance principles	Employees that know what is inside and outside of scope - contribute
9. Standardize decision making for higher *efficiencies*	Design and use of formal controls	Employees that do things right

Table 5 | Using the Scorecard to address control levers (Michel, 2007, p.40)

generate rigor in decision making, and to measure how well the systems are employed to convey the expected performance.

When assessing Michel's Scorecard it is necessary to know that scores greater than 75 indicate decision making competences that are well developed and that have the impending to deliver performance, decrease risks or fuel growth. Scores between 55 and 74 designate decision making capabilities that entail enhancement. These capabilities are about industry average. Scores below 54 signify decision making capacities that do not convey value.

Figure 24 presents the scorecard combining nine principles that can be activated through various control levers. The ultimate goal is to ensure that decision balance the various trade-offs.

A brief explanation of these nine principles its levers and benefits is done in Table 5.

The possibility of having a Balanced Scorecard that is built up having a focus on decision making is that it makes easier to see how design process can contribute to the overall business strategy. In fact it presents the possibility of establishing it as a common tool shareable both by the managers and the designers. In that way it can be seen as a bridging tool being decision making the shared, 'language' .

SUMMARY OF THE STRATEGIC ADEQUACY OF DESIGN PROCESSES

The strategic adequacy of design processes was defined as an operational concept central to this research.

It assumes that the design outcomes must contribute to brand consolidation, firm's reputation and to the success of the overall strategy of the business. That implies Design to be seen as a strategic resource in Business.

From literature on this topic it is possible to assert the positive impacts of Design in the performance of forms. However, despite the strategic importance of design there are several problems in its consistent use on the part of the firms. That has to do with a few aspects such as: 1) the conceptual and organizational diffuseness of design; 2) the variety of attitudes and strategies, on the part of firms, towards design; 3) the phenomena of 'silent design' (Dumas and Mintzberg, 2000); 4) the leadership role of design.

On the other hand, it is important to consider the three levels of design processes inside firms: the operational, the tactic and the strategic one.

The approach to design process in our study is focused essentially on the operational level but considering its impact and relationship with the other two levels. Furthermore the focus is placed in decision making and that gave us the opportunity to present some traditional business tools such as the Balanced ScoreCard as a promising tool in decisional processes since it promotes a better understanding of Design's place in Business for both the managers and the designers.

BIBLIOGRAPHIC REFERENCES

BORJA DE MOZOTA, B. 1985. *Essai sur la fonction du design et son rôle dans la stratégie marketing de l'entreprise*, Université de Paris I Panthéon Sorbonne.

Design Council. 2004. The impact of Design on Stock Market Performance: An Analysis of UK Quoted Companies 1994-2003. [Accessed 19 April 2007].

Design Council. 2005. The Business of Design: Design Industry Research 2005. Available:http://www.designcouncil.org.uk/Design-Council/3/Publications/?PageNum=2 [Accessed 19 April 2007].

DOUGHERTY, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organization Science*, 3(2), pp.179-202.

DUMAINE, B. 1990. Who needs a boss? *Fortune*. Time Inc's Fortune/ Money Group.

DUMAS, A., WHITEFIELD, A. 1989b. Why design is difficult to manage: A survey of attitudes and practices in British industry *European Management Journal*, 7(1), pp.50-56.

GORB, P., DUMAS, A. 1987. Silent Design. 8(3), pp.150-156.

HAMMOND, J., KEENEY, J., RAIFFA, H. 1999. *Smart Choices: A Practical Guide to Making Better Decisions*, Boston, MA, Harvard Business School Press.

HERTENSTEIN, J., PLATT, M., BROWN, D. 2001. Valuing Design: enhancing corporate performance through design effectiveness. *Design Management Journal*, 12(3), pp.10-19.

JEVNAKER, B. 2000. Championing design: perspectives on design capabilities. *Design Management Journal; Academic Review*,1, pp.25-39.

JEVNAKER, B. 2000b. How design becomes strategic. *Design Management Journal*, 11(1), pp.41-47.

KATZENBACH, J., SMITH, D. 1993. *The Wisdom of Teams: Creating the High-Performance Organization*, Boston, Harvard Business School Press.

KOPEIKINA, L. 2005. The Right Decision Every Time: *How To Reach Perfect Clarity on Though Decisions*, Upper Saddle River, NJ, Prentice-Hall.

KOTLER, P., RATH, G. 1984. Design: a powerful but neglected strategic tool. *Journal of Business Strategy*, 5(2), pp.16-21.

KRISTENSEN, T. 1998. The Contribution of Design to Business: A competence-based perspective. *In*: BRUCE, M., JEVNAKER, B. (EDS) (ed.) *Management of Design Alliance. Sustaining Competitive Advantage*. Chichester: Wiley

MICHEL, L. 2007. Understanding decision making in organizations to focus its practices where it matters. *Measuring Business Excellence,* 11(1), pp.33-45.

MOODY, S. 1984. The Role of Industrial Design in the Development of New Science based Products. *In*: LANGDON, R. (ed.) *Design and Industry*. London: The Design Council

NEVADO, P., BARATA, J., ALMENDRA, R., ROMÃO, L. 2008. The "Igloo Model": A proposal for an analysis of the contribution of design to the competitiveness of companies. *ICAM - 15th Annual International Conference on Advances in Management*. Hyatt Harborside Hotel,Boston.

NIEMINEN, T., LAUTAMAKI, S., SALIMAKI, M. 2005. Modelling the Strategic Impacts of Design in Businesses. Helsinki: UIAH/ Designium.

OWENS, D. 2000. Structure and status in design teams: implications for design management. *Design Management Journal, Academic Review,* 1(1), pp.55-64.

POTTER, S., ROY, R., CAPON, C., BRUCE, M., WALSH, V., LEWIS, J. 1991. The Benefits and Costs of Investment in design: using professional design expertise in product, engineering and graphics projects. Design Innovation Group, Milton Keynes: The Open University and UMIST.

PRESS, M., COOPER, R. 2003. *The Design Experience – the Role of Design and Designers in the Twenty-first Century,* UK, Ashgate.

RIEDEL, J., ROY, R., POTTER, S. 1996. Market Demands that Reward Investment in Design. *8th International Forum on Design Management Research and Education*. Barcelona.

ROY, R., POTTER, S. 1993. The commercial impact of investment in design. *Design Studies*, 14(2), pp.171-193.

ROY, R., RIEDEL, J., POTTER, S. 1998. Market Demands that Reward Investment in Design (MADRID): Final Report submitted to the Design Council. Design Innovation Group, Milton Keynes: The Open University.

ROY, R., SALAMAN, G., WALSH, V. 1986. Research Grant Final Report, Design-based Innovation in manufacturing Industry. Principles and Practices for Successful Design and Production. Milton Keynes: Design Innovation Group, Open University.

SENTENCE, A., CLARKE, J. 1997. The Contribution of Design to the UK Economy. *In*: COUNCIL, D. (ed.). London: Centre for Economic Forecasting, London Business School.

SVENGREN, L. Year. Industrial Design as a Strategic Resource. *In*: The European Academy of Design, 11-13 April 1995 University of Salford

WALSH, V. 1995. The evaluation of design. *International Journal of Technology Management*, 10(4/5/6), pp.489-509.

WALSH, V. 2000. Design, Innovation and the Boundaries of the Firm. *Design Management Journal*, Academic Review, pp.174-92.

WALTON, M. 2003. Building a case for added value though design. *Report to Industry New Zealand*. Wellington: NZ Institute of Economic Research (Inc.).

YATES, J., VEINOTT, E., PATALAN, A. 2002. Hard Decisions, Bad Decisions: on Decision Quality and Decision Aiding. *In*: SCHNEIDER, S., SHANTEAU, J. (EDS.) (ed.) *Emerging Perspectives on Judgment and Decision Research*. Boston, MA: Cambridge University Press.

4. QUALITY AND DESIGN PROCESSES

The quality of the design outcomes is essential since it enhances the possibility of the product's success in markets. On the past 30 years several quality systems were developed having its origins either in the management field or in the engineering one. The most known is probably Total Quality Management (TQM) approach (Deming, 1986,1993; Feignbaum, 1951; Ishikawa, 1982,1985; Juran, 1995,2004; and Taguchi, 1984) that seeks to integrate all the elements of an organization in order to meet the needs and expectations of its customers.

Also in the field of design management the quality topic was addressed. Peter Gorb assessed its importance and (1991, p. 74) described it in the following words:

"Quality is usually measured and controlled in three ways: a) by inspecting at the end of the process (…); b) by an attitude among the people concerned in manufacture (…) (that) place quality at the forefront of their thinking during the manufacturing process (…) Quality circles and related organizations systems fall in this category and c) by ensuring that specification itself is developed in such a way that it becomes very difficult not to meet that specification. All of these ways of dealing with quality have their place and none is mutually exclusive. Nevertheless the third one contributes the most effective route – it shifts the problems of controlling quality to a point in the process before manufacture (…)The fact is that it is generally recognized that it is better designing quality into a product than inspecting it out."

Moreover and according to Mozota (2003, p. 77) "(…) design and design management can be measured and improved by total quality methods. (…) design processes optimize total quality, and methods are developed to measure perceived quality, which is then incorporated in total quality management methods. (…) Designers contribute to creating perceived quality."

Quality is then a key part of design processes which specifically contributes to the quality of the end products that can be experienced at different levels.

The quality of design, being a way of validating the outcomes of design processes, was one of the first issues to be addressed in this study. In fact the researcher (2008, p. 1) tried to follow the backwards trajectory (in terms of quality) from the "end product" to the "designed product". That way it was thought to be feasible to put forward and assess possible components of quality in a design process so that designed quality could be reached through materialized quality. The developed framework of quality analysis is presented in the next pages.

4.1 From *Total Product Quality* to P*roduct Designed Quality*

Henry Stoll (1999, p. 22) proposed that "each design decision contributes in some way to the quality of the end product." Hence, the concept of *total quality* is broken down so that the designer can clearly and systematically focus on quality as an objective that structures the design throughout the creation process. Stoll's *total quality system* envisages the subdivision of the *total quality* of the product design into: a) the quality of the product design as a finished product and b) the quality of the product design as a process referring only to end products and not specifically to quality of the design of the product.

Therefore it was made an effort to follow the process from the "finished product" to the 'product design' from which it originates in order to identify and describe the components that can characterize quality in its different facets and at different points in time. This way hopefully it will become more clear the contexts and constraints of 'designing quality'.

4.1.1. Total Product Quality

Total product quality as proposed by Stoll (1999) can be divided into *external quality* and *internal quality*; the former refers to how the products satisfy the consumers whereas the latter relates to the quality achieved in product production.

The *external quality* of a product depends on consumers' perception and their evaluation of its value and this is one of marketing's privileged areas of intervention. The *internal quality* of a product qualifies the product's performance and capacities in terms of manufacturing and it is the focus of the production engineers' special attention.

As can be seen in Figure 25, *external quality* can be subdivided into:

A – *quality of the concept*, which concerns the performance, product features, aesthetic and ergonomic questions, in other words, the aspects which make the product desirable to the end consumer and make him acquire it.

B – *quality of ownership*, namely the experience that the user has as a result of owning and using the product. The criteria that determine this quality are: ease of use, cost of operation (measurement of ease of use, safety and economics), durability (material-related, involving a trade-off between manufacture costs and operational costs) reliability, service orientation, maintenance, the condition of the product when purchased, and client service. This kind of quality should give rise to repeat business and client satisfaction. It is closely linked to the company's reputation and can be achieved for example by: a) identifying all defects that may occur; b) anticipating the likelihood of defects occurring; c) implementing corrective action to prevent or reduce the probability of occurrences. Conditions must therefore be created for easy repairs and the product structure must be determined by questions related to improved conditions for assembly and dismantling and ease of maintenance, etc.

C – *Operational robustness*, which characterizes the product's capacity to tolerate changes in variables that are difficult to control and that affect the working of the product. There may be three kinds of variables: a)variables linked to the environment in which the product is used: temperature, humidity, input of voltage dust, external load, type of use; b)variables resulting from changes and degradation that occur over time and/or use of the product: loss of strength due to corrosion, deterioration caused by high temperatures,

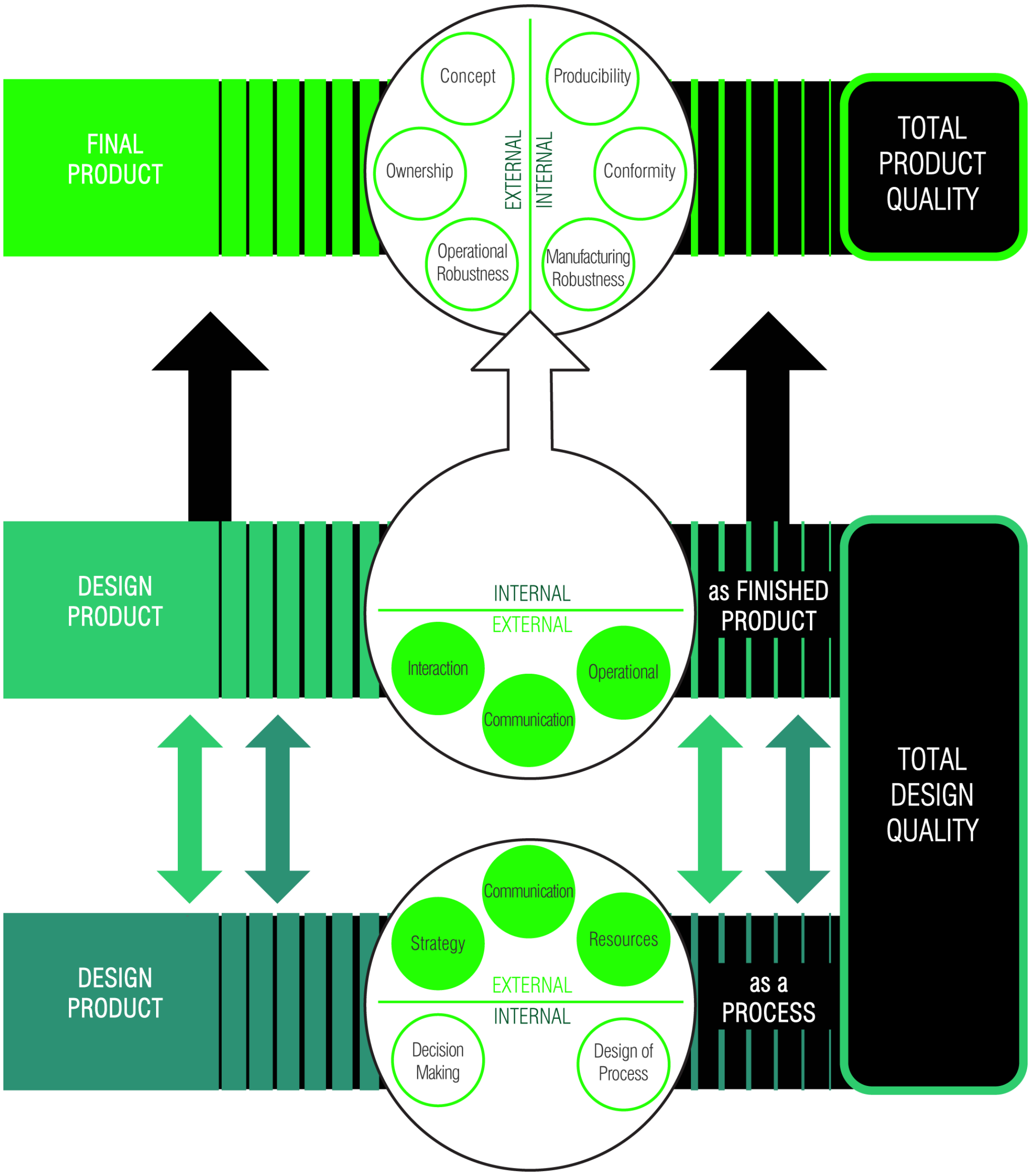


Fig.25 | From Total Product Quality to Total Design Quality (Almendra, 2008)

change of calibration or adjustment of slack; c)variables that occur due to product-to-product variation, though manufactured with the same specification: variation in the size of the parts, calibration levels resulting from the manufacturing process.

Maximizing operational robustness involves the development of a robust conceptual design, optimizing the setting of parameters and the setting of specifications, and tolerances.

In what concerns *internal quality*, as can be seen from Figure 25, this one is subdivided into:

D – *Producibility* which refers to the ease of manufacturing, assembly, inspection and testing of a product and also includes considerations regarding the available supply of components, raw materials and resources for production; the clarity and simplicity of detailed information supporting the manufacture of the product is also implicit. A producible design is one that is suitable to the quantity required in accordance with production planning and one where trade-offs can be made in order to optimize costs in minimum time, and one where conformity with the set specifications is acceptable. A high level of producibility raises the *internal quality* by reducing the complexity of manufacturing. Producibility can be maximized by: a) identifying design concepts that are intrinsically easy to manufacture and have a good cost/time balance; b) focusing on the design of components so as to simplify manufacture and assembly; c) integrating the product design and the manufacturing process to assure the best articulation between needs and requirements.

E – *Conformity* which refers to the extent to which a product or component conforms to the design aim – where the aim is the intended value or target value of the characteristic. The specifications of widths or tolerances are essential and, in order to improve the conformity quality, the product must be designed so that it is possible to use extensive width specification measurements; very easy to control and extremely repetitive processes are used.

F – *Robustness of manufacturing* which means the manufacturing system's capacity to tolerate alterations in the product and in its volume of production resulting from changes in market needs, business needs and technological innovation. The aim is to minimize the consequences on capital and time invested, incurred due to indispensable changes. A product with a high level of manufacturing robustness can be rapidly adapted to market changes with a minimum impact on production operations and investment. To improve manufacturing robustness, the designers should study and plan for the future five or six generations of the product anticipating probable changes.

The researcher approach explored the relationship between the quality of the design of the product and the quality of the product itself; this occurs insofar as guaranteed quality of the design reduces the risk of a lack of quality or decline in the quality of the design's end result i.e. the end product. It is therefore essential that the design works on all the components of total product quality in advance and incorporates them into the initial statement of the problem.

As such, (Figure 25) part of the *total quality of the design* is determined by its capacity to assume itself as the complete response to *total product quality*. One of the components of the *quality of the design* is therefore defined; in other words, its direct implication in the product quality, defined here as its *internal* component, is the element that promotes interface with the end product.

The second component of the *design quality*, referred in Figure 25 as the *external quality* of the design, characterizes specific aspects of the design, its process, what forms it, its presentations and communicative capacities etc.

Which criteria should be defined to determine the *external quality of a product design*?

Which aspects of the design contribute directly to this *external quality*?

Should the design be characterised as a "finished product" in itself which could be evaluated in terms of quality, or, alternatively, should we focus on the design process to characterise and assess *external quality*?

Just as with the part of the diagram that shows the components of *total product quality*, if the design is taken as an 'end product', it is possible to devise an *external quality* – based on client-related aspects and included above all in the sphere of graphic/communication design – and an *internal quality* – based on the technical aspects of the production of the product itself.

4.1.2 The *Design outcome* as an *end product*

Internal Quality of the Design

A - The *internal quality of the design* concerns the suitability of the design to the product as a response to all its *total quality* components.

It therefore includes considerations related both to aspects involving the design's incorporation of elements/response to the *quality of the concept, ownership* and *operational robustness* and also contents/responses related to the *producibility, conformity* and *manufacturing robustness.* A design with high *internal quality* is also one that strategically fits the business goals, optimising the creation, introduction and continuation of a product in the market in terms of costs, time, manufacture and human capital.

The *design's internal quality* can be maximised by: a) The correct identification of the components of the total product quality; b) The correct assumption and integration in the company strategy; c) The design that responds to the organisational contexts – human and material resources – from the very first phase; d) The integration of the design, manufacture process and product so as to assure greater articulation between needs and requirements.

External Quality of the Design

The *external quality* of the design relates to aspects of interaction with the client and is placed above all in the sphere of graphic/communication design. It includes three aspects, namely:

B – The *quality of the communicative interaction* which refers to the design's capacity to trigger interaction with all those involved in the design process, in other words, all the stakeholders implicated in the design value chain. This involves the potential to visually and verbally stimulate intervention so as to guarantee the total understanding of the ideas, contexts, concepts and technical solutions which make up the product design. It concerns competence to balance the synthesis and the development of the parts, thereby triggering proactive questioning that fosters critical thought and the growth of knowledge about the product and its implications at the "cycle of experience" level proposed by Darrel Rhea (1992, p. 12) that foresees four phases : context; involvement; use and resolution[34]. It can be maximised if a culture of communication and information-sharing is fostered and if channels and precise tools are developed for recording and inquiry that are in the common use of all those involved and are activated at key moments of the processes.

C – the *quality of communication*, namely the design's communication capacities in verbal and visual terms. It characterises the capacity of design and writing, of coherent visual and verbal meaning through the use of different means of communication. It is related with the creation of sign systems of the six communicative functions referred by Clive Ashwin (1989, pp. 203-209) as: a) referential – objective communication, use of standard codifications -, b) emotive – emotive communication that tries to trigger subjective responses of an emotional nature -, c) conative – communication that tries to persuade the receiver to respond and act in a specific way -, d) poetic – communicates in a way that is intrinsically self justifying - , e) phatic – communication that does not seek the recording or communication of information but has the purpose of starting, maintaining or concluding the communication - and f) meta-linguistic – created in order to explain other signs e.g. caption; these are combined at different levels depending on the kind of representation and/or of the written document.

The *quality of communication* can be maximised if competences are developed in communicative design and if a communicative strategy is defined for the design, which take the six communicative functions into consideration and anticipate its effective use and incidence.

D– The *operational quality* which is related to the ease and clarity that accompany the verbal and visual dismantling of the design. This concerns the use of the elements that make up the design and characterises its capacity to integrate the diversity of information and the multiple forms of communicating. It is also linked to the design's ability to transform complex

34. Darrel Rhea (1992) phases of the *design experience model* integrate: a) the *context* that has to do with the social and cultural background of each new design. It includes the people behaviour, life patterns, cultural issues, beliefs as well as all the products and innovations that help moulding that context. b) *involvement* a phase related with the acknowledgement of the product on the part of the customer. It has to do with the development of at least three tasks: the development of the awareness of a distinctive presence of the product, the attraction and maintenance of interest on the part of the customer and finally the communication of the key attributes of the product; c) *use* - the phase where the product is used and integrates a life experience on the part of the customer. The experience must deliver pleasure and fit with the life of the customer and d) *resolution*, a phase related with the lasting impression of the product with the reflection on its experiencing that should conduct to the satisfaction of the customer in order for him to integrate a new cycle of design experience.

information, maximising consultation of it through the use of diagrams, matrixes, figures and other forms of abbreviated information and analytical support. This quality enables reading time to be reduced and simplifies the interpretation of the elements of the design.

This quality can be tested using what Press and Cooper (2003, p. 145) call the "silent test" in which the design is presented without verbal explanations; if it has *operational quality* there should be perfect harmony between the interpretation of the brief made by the designer and the set of intentions expressed by the clients.

The *operational quality* can be maximised if the qualities of communicative interaction and communication are correctly articulated.

4.1.3 The Process as a component of Total Design Quality

Considering the etymological definition of Process, which comes from the Latin *procedere*, it is to assume that a verb designates the action of advancing, moving ahead. As such, the prominent idea is one of progress, of making a positive advance; the idea is also of a series of steps or actions that formalise this 'progression'. In fact, most processes are no more than a set of (usually sequential and with recurrent iteration) pondered actions aimed at reaching a specific target.

It is also important to consider that the process concept is associated to actions of creation, planning, transformation, production, control, maintenance and use of products and systems.

In the *design as* a *process* (Figure 25) there are several descriptors of quality and they are linked to the management of: a) communication (information and knowledge as it is managed internally and between the different parties); b) decision making (uncertainty, risk); c) resources (human, material, immaterial – ideas, time; etc) d) design of the process (stages, links, decisions) and f) creation of the strategic contents.

In terms of *external quality* of the *design as a process* we considered three components that relate the process with the outside. They are:

A - The *quality of communication* which, in exactly the same way as in the *design as a final product*, is linked to the design's communication capacity in verbal and visual terms but which also refers to the mechanisms that are developed so that the information and knowledge is managed between the different agents effectively and throughout the process. It can be maximized through the correct management of information and with the creation of mechanism for the dissemination and control of vital information.

B - *Strategic quality*, which involves the articulation between the different areas involved in the process bearing in mind the company's planning, formulation and strategic implementation. It can be maximized if there is a translation in terms of the process of the strategy, product/market matrix, internationalisation and diversification. This translation foresees an alignment of the process with the formulated strategy and a connection with all the operational, support and strategic areas implicit at the different points in time in the defence of this same strategy.

C - *Quality of resources*, mainly: a) human – where the evaluation of the leadership in design is of great importance notably in what Turner and Topalian (2002) defines as 'leadership by Design', the sustained leadership of Design over time, and the gaining of knowledge through the intervention of Design. According to these authors, the responsibilities of leadership can be summarised in six activities: vision of the future; manifestation of strategic intent; direction of design investment; management of the company reputation; creation and feeding of an environment of innovation and training for leadership in design. b) material – besides striving for the physical quality of the materials, this also strives for the design of specifications and conformity, thereby assuring the quality of the end product. c) immaterial – this quality is linked with the way the knowledge produced and used on the basis of ideas, brand reputation etc is managed and directed.

It also includes time and the way this is managed throughout the process.

In terms of the i*nternal quality of the design as a process* there were defined two components that relate to the nature, form and substance of the process. These are:

A - The *quality of the design of the process*, which can be determined by the internal coherence of the process, by the definition of the stages that can be flexibly managed and the capacity to absorb change, adaption, the dissemination of the key elements that structure the design. It should also include a system that can envisage review and control, anticipate mistakes and integrate the adoption of corrective measures and the incorporation of forms of active records.

B - *Quality of decision making*, which is linked to reducing risks, managing uncertainty and enhance the efficiency of resource's usage. It can be maximized if a comprehensive set of methods and techniques is used that incorporate the identification of uncertainties and their impacts, their mitigation and exploitation so that the negative effects can be reduced and positive effects increased, the clarification of future alternatives, the construction of risk plans and the construction of internal control systems.

SUMMARY OF QUALITY IN DESIGN PROCESSES

The quality of the design outcomes is determinant for the success of the products. Therefore it is important to understand how that quality is built up along design process.

There exist several quality systems developed mainly by the areas of Engineering and Management. However, these quality systems focus on the end product and not on its design.

What is then 'designed quality'?

To answer that question the researcher developed a framework to analyse 'designed quality'. The 'model' departures from Total product Quality (as it was defined by Henri Stoll, 1999) and it is develop trying to address the Total Design Quality in a twofold perspective: a) the design as a 'finish product' and b) the design as 'a process'.

Regarding the first one, the design as 'a finish product', two components were considered: a) an internal one were design must have the ability to match completely all of the eight components of Total Product Quality and b) an external one that integrates aspects such as: 1. the quality of communicative interaction; 2. the quality of communication and 3. the operational quality.

In what concerns the quality of design as 'a process' again two components were created: a) an external one, that relates directly with the design as a 'finished product' and that integrates three aspects: 1. the quality of communication; 2. the strategic quality and 3. the quality of resources and b) the internal component that comprehends two aspects: 1. the quality of the design of the process (in terms of its coherence and structuring) and 2. the quality of decision making.

With this exploratory work it was aimed to expand the awareness about quality to the level of considering not only the quality of Product but also the quality of the design behind it.

5. HYPOTHESES OF THE RESEARCH

After the literature review it was possible to formulate the hypotheses of this research. Being an exploratory study the hypotheses are justifiable as guidelines of an also exploratory evaluation of the effectiveness and efficiency of the models and tools created. In fact, hypotheses in this approach are assumed as assumptions of the researcher that have oriented both the literary critics and the experiments contents and its treatment and interpretation.

The design process as previously presented in this chapter is seen as a dialogical cycle of question and answer were what is questioned are mainly the prejudgments, the pre-understandings values and attitudes that the designers bring to the design situation. This also establishes the difference from hermeneutic projection and scientific hypothesis as stated by Snodgrass and Coyne (1997, p. 93):

"It would be an error to suppose that hermeneutic projections are simply hypotheses, or that the hermeneutical design process described in the preceding is nothing other than the hypothesis-testing model of designing. The hermeneutical circle is wholly different to the process of verification or falsification of a hypothesis. The hypothesis, as conceived in Positivist methodology, formulates a specific anticipation, which is accepted in total or rejected outright on the evidence of testing procedures; experience answers the hypothesis with a simple yes or no, but in no way alters its content. The state of affairs proposed in the hypothesis is existent or non-existent. The hermeneutical anticipation, by contrast, feeds back into the particularities of the situation. The anticipation is either "fulfilled" or "disappointed"; if fulfilled it enriches the particularities, which then play back to enrich the anticipations; and if disappointed it likewise places the particularities in a new light, opening up new expectations and triggering further projections. In either case, whether the projection is fulfilled or disappointed, the horizon is enlarged."

In fact the logic based models are unfitted to capture the contradictory and complex nature of much of the designer's activities. As Snodgrass and Coyne explain it (1997, p. 94) "Design actions and design situations make up a "text" that can be read. This "reading," however, can only be explained not by reference to some external criterion, but to other readings that have reference to a projected whole. No argument based solely on logic is relevant in this never-ending play of interpretive readings."

As Gadamer (1975; p. 327) points out:

"The openness of the question is not boundless. It is limited by the horizon of the question. A question which lacks this is, so to speak, floating. It becomes a question only when the fluid indeterminacy of the direction in which it is pointing is overcome by a specific alternative being presented. In other words, the question has to be asked. The asking of it implies openness, but also limitation. It implies the explicit establishing of presuppositions, in terms of which can be seen what still remains open."

That means that as Snodgrass and Coyne (1997, p.95) mention "the design process is an uncovering of tacit understanding, and this hidden understanding is not something fixed, crystalline, frozen. It is processual, fluid, in incessant flux. (…) Understanding is always in process, and this process is unending. It has no endpoint; it can never reach finality or completion. We never reach a point where it can be said, "Disclosure is complete," because new understandings are ever possible. Interpretation is never at an end."

After making explicit the way hypotheses must be understood in this research process it is possible now to present it. The main hypotheses or assumptions are stated below.

1. It is possible to identify and describe the major determinants intervening in Design Processes that have a major influence in the strategic adequacy and overall quality of its outcomes.

2. Knowledge management and idea generation are narrowly linked to decision making and influence in decisive ways the outcomes of design processes;

3. The development of analysis models of how decision making occurs in design processes can provide a basis to the improvement of these processes both at the Design Education and Companies levels;

4. Decision making is a key factor in determining strategic adequacy and overall quality of the design process's outcomes.

BIBLIOGRAPHIC REFERENCES

ALMENDRA, R. 2008. Reflection on the quality of design: from the product to the project. *Journal of Design Principles and Practices: an international Journal.*, 2 (1), pp.1-6.

ASHWIN, C. 1989. Drawing Design Semiotics. *In*: MARGOLIN, V. (ed.) *Design Discourse*. Chicago: The University of Chicago Press

BORJA DE MOZOTA, B. 2003. *Design Management. Using Design to Build Brand Value and Corporate Innovation*, New York, Allworth Press.

DEMING, W. 1986. *Out of the Crisis*, MIT Press.

DEMING, W. 1993. *The New Economics for Industry, Government, Education.*, Cambridge, MA, MIT Centre for Advanced Engineering Study.

GADAMER, H.-G. 1975. *Truth and Method*, London, Sheed and Ward.

GORB, P. 1990. *Design Management*, London, Architecture Design and Technology Press.

ISHIKAWA, K. 1982. *Introduction to Quality Control*, Tokyo, JUSE Press Ltd.

ISHIKAWA, K. 1985. *What is Total Quality Control? The Japanese Way.,* Englewood Cliffs, NJ, Prentice-Hall.

JURAN, J. 1951. *Quality Control Handbook*, New York, McGraw Hill.

PRESS, M., COOPER, R. 2003. *The Design Experience – the Role of Design and Designers in the Twenty-first Century,* UK, Ashgate.

RHEA, D. 1992. A new perspective on design: focusing on customer experience. *Design Management Journal*, 9(4), pp.10-16.

SNODGRASS, A., COYNE, R. 1997. Is Designing hermeneutical? *Architectural Theory Review, Journal of the Department of Architecture,* 2(1), 65-97.

STOLL, H. 1999. *Product Design Methods and Practices,* New York, Marcel Dekker, Inc.

TURNER, R., TOPALIAN, A. 2002. Core Responsabilities of Design Leaders in Commercially Demanding Environments. *Design Leadership Forum* (Inaugural session). London: Alto Design Management.

CHAPTER III – METHODOLOGY AND METHODS

1. METHODOLOGIES FOR DESIGN RESEARCH

The establishment of a methodology to be used in a research made in the area of Design requires the knowledge of the discipline both in epistemological and praxiological terms.

Regarding the plans and methodologies used in Design acknowledging the subjective nature of human behaviour as well as the dialoguing nature of design processes was recognized since the first instance. As Bruce Archer (1979, pp.17-20) proposes it is assumed that design has its own distinct things to know, ways of knowing them, and ways of finding out about them.

Being so the methodology and methods to be used in Design should embrace this complexity and creativity of Design nature and processes.

After studying the specialized literature about the subject and the one related with Design research in general, it becomes clear that the qualitative approach[35] bears a fundamental importance in design research especially when combined with a quantitative approach[36] in what is called a mixed methodology.

A mixed methodology is what Johnson and Onwuegbuzie (2004, p. 17) define as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study."

As the authors explain, in philosophical terms, "(…) mixed research uses the pragmatic method and system of philosophy"[37]. Its logic of inquiry includes the use of induction (or discovery of patterns), deduction (testing of theories and hypotheses), and abduction (uncovering and relying on the best of a set of explanations for understanding one's results)". So, it suggests an eclectic approach to method selection and to the entire development and orientation of the research.

In fact, mixed methods research presents challenges in writing the research question and hypotheses since so little literature addresses this step of research. Normally

35. The major characteristics of traditional qualitative research are induction, discovery, exploration, theory/hypothesis generation, the researcher as the primary "instrument" of data collection, and qualitative analysis.
36. The major characteristics of traditional quantitative research are a focus on deduction, confirmation, theory/hypothesis testing, explanation, prediction, standardized data collection, and statistical analysis.
37. Building on Peirce's lead, James (1995, 1907 original) argued that "The pragmatic method is primarily a method of settling metaphysical disputes that otherwise might be interminable. . . The pragmatic method in such cases is to try to interpret each notion by tracing its respective practical consequences" (p. 18). Extending the works of Peirce and James, Dewey spent his career applying pragmatic principles in developing his philosophy and in the practice of educating children (e.g., the Experimental School of Chicago). Dewey (1948, 1920 original) stated that "in order to discover the meaning of the idea [we must] ask for its consequences" (p. 132. (see operational concepts)

authors make the option of specifying purpose statements rather than research questions. However the construction of both research question and hypotheses in a mixed method study that includes both qualitative and quantitative research helps to narrow and focus the purpose statements, even when predictions on the basis of existing theory can not be made yet.

Also important to consider is the fact that the Design discipline is trying to consolidate its own way of researching. Therefore is important to take into account the circumstance that "in many cases the goal of mixing is not to search for corroboration but rather to expand one's understanding" (Onwuegbuzie & Leech, 2004; p. 18) being this attitude fundamental to the development of Design Research.

The correctness of the use of a mixed approach implies a deep knowledge of the strengths and weaknesses of both qualitative and quantitative approaches (see Tables 6 and 7) so researchers as Johnson and Onwuegbuzie point out (2004, p.18) can "mix or combine strategies and make use of what Johnson and Turner (2003, p.301) call the *fundamental principle of mixed research*. According to this principle, researchers should collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non overlapping weaknesses."

Also important is to synthesize and get aware of the advantages and disadvantages of a mixed approach that obviously derive from both qualitative and quantitative research characteristics as it can be found in Table 8 presented in page 108.

What type of mixed methods research design can be used in our study?

Johnson and Onwuegbuzie (2004, p.20) claim that mixed research derive from two major categories known as *mixed-model* (mixing qualitative and quantitative approaches within or across the stages of the research process) and *mixed method* (the inclusion of a quantitative phase and a qualitative phase in an overall research study). "Based upon that classification the authors have created six *mixed-model* designs that are shown in Figure

STRENGHTS	WEAKNESSES
Testing and validating already constructed theories about how (and to a lesser degree, why) phenomena occur.	The researcher's categories that are used may not reflect local constituencies' understandings.
Testing hypotheses that are constructed before the data are collected. Can generalize research findings when the data are based on random samples of sufficient size.	The researcher may miss out on phenomena occurring because of the focus on theory or hypothesis *testing* rather than on theory or hypothesis *generation* (called the *confirmation bias*).
Can generalize a research finding when it has been replicated on many different populations and subpopulations.	Knowledge produced may be too abstract and general for direct application to specific local situations, contexts, and individuals.
Useful for obtaining data that allow quantitative predictions to be made.	
The researcher may construct a situation that eliminates the confounding influence of many variables, allowing one to more credibly assess *cause-and-effect* relationships.	
Data collection using some quantitative methods is relatively quick (e.g., telephone interviews).	
Provides precise, quantitative, numerical data.	
Data analysis is relatively less time consuming (using statistical software).	
The research results are relatively independent of the researcher (e.g., effect size, statistical significance).	
It may have higher credibility with many people in power (e.g., administrators, politicians, people who fund programs).	
It is useful for studying large numbers of people.	

Table 6 | Strengths and Weaknesses of Quantitative Research - (adapted from: Johnson and Onwuegbuzie, 2004, p.19)

26 (mixed models range from design 2 to design 7). These are what the authors refer to as being "across-stage mixed-model designs because the mixing takes place across the stages of the research process."

Regarding the *mixed-method* designs Figure 27 presents nine of them. In respect to these designs it is determinant that the researcher at the beginning of the process establishes whether she/he wants to operate largely within one dominant approach or not and whether s/he wants to conduct the research phases concurrently or sequentially. As defended by the authors it is possible to create more complex designs inclusively also those that include both *mixed-models* and *mixed-methods* design features.

STRENGHTS	WEAKNESSES
The data are based on the participants' own categories of meaning.	Knowledge produced may not generalize to other people or other settings (i.e., findings may be unique to the relatively few people included in the research study).
It is useful for studying a limited number of cases in depth.	It is difficult to make quantitative predictions
It is useful for describing complex phenomena.	It is more difficult to test hypotheses and theories
Provides individual case information.	It may have lower credibility with some administrators and commissioners of programs
Can conduct cross-case comparisons and analysis.	It generally takes more time to collect the data when compared to quantitative research
Provides understanding and description of people's personal experiences of phenomena (i.e., the "emic" or insider's viewpoint).	Data analysis is often time consuming.
Can describe, in rich detail, phenomena as they are situated and embedded in local contexts.	The results are more easily influenced by the researcher's personal biases and idiosyncrasies.
The researcher identifies contextual and setting factors as they relate to the phenomenon of interest.	
The researcher can study dynamic processes (i.e., documenting sequential patterns and change).	
The researcher can use the primarily qualitative method of "grounded theory" to generate inductively a tentative but explanatory theory about a phenomenon.	
Can determine how participants interpret "constructs" (e.g.,self-esteem, IQ).	
Data are usually collected in naturalistic settings in qualitative research	
Qualitative approaches are responsive to local situations, conditions, and stakeholders' needs.	
Qualitative researchers are responsive to changes that occur during the conduct of a study (especially during extended fieldwork) and may shift the focus of their studies as a result.	
Qualitative data in the words and categories of participants lend themselves to exploring how and why phenomena occur.	
One can use an important case to demonstrate vividly a phenomenon to the readers of a report.	
Determine *idiographic* causation (i.e., determination of causes of a particular event).	

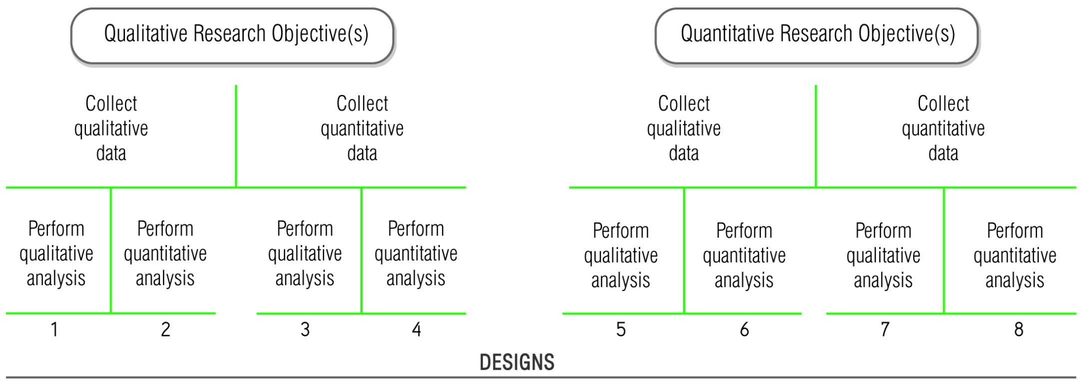
Table 7 | Strengths and Weaknesses of Qualitative Research (Source: Johnson and Onwuegbuzie, 2004, p.20)

STRENGHTS	WEAKNESSES
Words, pictures, and narrative can be used to add meaning to numbers.	Can be difficult for a single researcher to carry out both qualitative and quantitative research, especially if two or more approaches are expected to be used concurrently; it may require a research team.
Numbers can be used to add precision to words, pictures, and narrative.	Researcher has to learn about multiple methods and approaches and understand how to mix them appropriately.
Can provide quantitative and qualitative research strengths (i.e., see strengths listed in Tables 1 and 2).	Methodological purists contend that one should always work within either a qualitative or a quantitative paradigm.
Researcher can generate and test a grounded theory.	More expensive.
Can answer a broader and more complete range of research questions because the researcher is not confined to a single method or approach	More time consuming.
The specific mixed *research designs* have specific strengths and weaknesses that should be considered (e.g., in a two-stage sequential design, the Stage 1 results can be used to develop and inform the purpose and design of the Stage 2 component).	Some of the details of mixed research remain to be worked out fully by research methodologists (e.g., problems of paradigm mixing, how to qualitatively analyze quantitative data, how to interpret conflicting results).
A researcher can use the strengths of an additional method to overcome the weaknesses in another method by using both in a research study.	
Can provide stronger evidence for a conclusion through convergence and corroboration of findings	
Can add insights and understanding that might be missed when only a single method is used.	
Can be used to increase the generalizability of the results.	
Qualitative and quantitative research used together produce more complete knowledge necessary to inform theory and practice.	

Table 8 | *Strengths and Weaknesses of Mixed Research* (Source: Johnson and Onwuegbuzie, 2004, p.21)

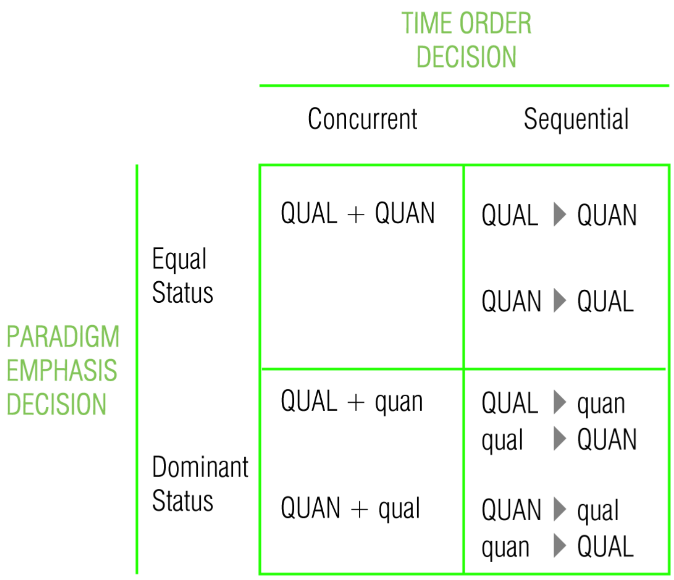
In the face of the previously presented information regarding mixed methods designs Johnson and Onwuegbuzie (2004, p. 22) advanced a mixed methods research model (Figure 28) that comprises eight steps: (1) determination of the research question; (2) determination of the appropriateness of the mixed design; (3) selection of the mixed method or mixed-model research design; (4) collection of the data; (5) analysis of the data; (6) interpretation of the data; (7) legitimating of the data; and (8) drawing conclusions (if warranted) and writing the final report.

The model assumes that variation can occur regarding the order of the steps (i.e., they are not necessarily linear or unidirectional), and also assumes that the question



Note: Designs 1 and 8 on the outer edges are the monomethod designs. The mixed- model designs are Designs 2,3,4,5,6 and 7.

Fig.26 | Monomethod and mixed-model designs. (Source: Johnson and Onwuegbuzie, 2004, p.21)



Note: "qual" stands for qualitative, "quan" stands for quantitative, "+" stands for concurrent, "▸" stands for sequencial, capital letters denote high priority or weight, and lower case letters denote lower priority or weight.

Fig.27 | Mixed-method design matrix with mixed-method research designs shown in the four cells. (Source: Johnson and Onwuegbuzie, 2004, p.22)

and/or purpose can be revised when necessary. Also it is visible in the model that we are facing a research that involves a recursive interactional process. That recursion can occur within a single study but also across related studies. That way it can support of future research and conducting to new or reformulated research purposes, questions and hypotheses. The steps referring to purpose (2) data analysis (5) and legitimation (7) are central in mixed methods research.

In what regards the purpose, Greene et al (1989, p. 259) identified five rationales for conducting mixed methods research: a) Triangulation (here assumed as a methodological one) that Mackey and Gass defend (2005, p. 181) involving the use of multiple research techniques and several sources of data in order to explore the issues from all feasible perspectives. Triangulation seeks convergence and corroboration of results from different methods and design studying the same. (b) Complementarity, meaning the search for enhancement, illustration, and clarification of the results from one method with results from the other method. (c) Initiation that has to do with discovering paradoxes and contradictions that lead to a re-framing of the research question); (d) Development by using the findings from one method to help inform the other method); and (e) Expansion or seeking to expand the breadth and range of research by using different methods for different inquiry components).

The model presented in Figure 28 incorporates Onwuegbuzie and Teddlie's (2003, p. 363) seven-stage conceptualization of the mixed methods data analysis process. In their work the authors identify the following seven data analysis stages as follows: (a) data reduction, (b) data display, (c) data transformation, (d) data correlation, (e) data consolidation, (f) data comparison, and (g) data integration. Data reduction has to do with the reduction of the dimensions of both qualitative and quantitative data; Data display concerns the description in pictorial terms of both qualitative and quantitative data; This can be followed by the data transformation stage, wherein quantitative data can be converted into narrative data that can be analyzed qualitatively and/ or qualitative data are converted into numerical codes that can be represented statistically. Data correlation involves the quantitative data being correlated with the qualitized data or the qualitative data being correlated with the quantitized data.

Data consolidation comes after, wherein both quantitative and qualitative data are combined to create new or consolidated variables or data sets. Next, data comparison that has to do with comparing data

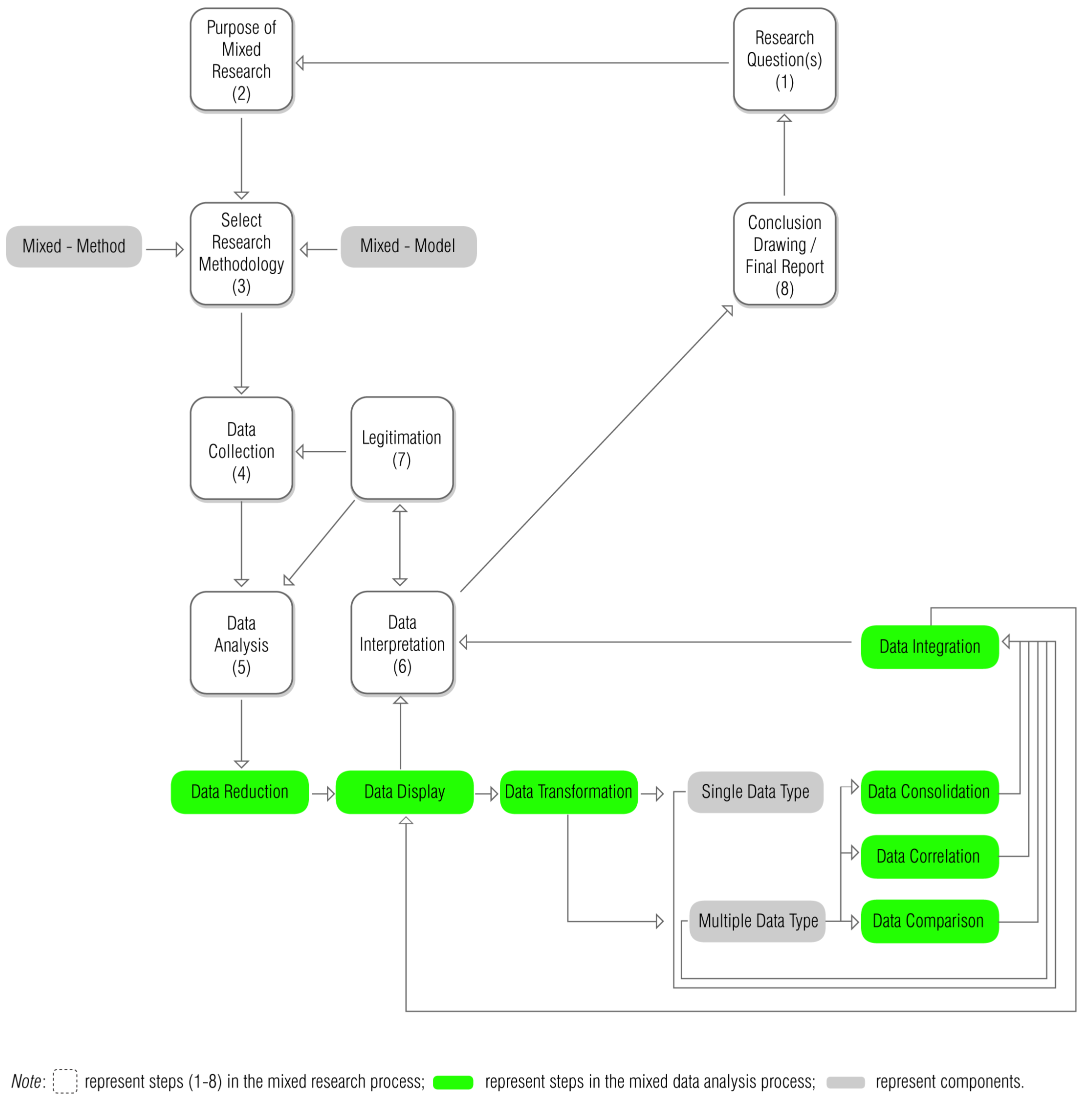


Fig.28 | Mixed research process model. (Source: Johnson and Onwuegbuzie, 2004, p.23)

from the qualitative and quantitative data sources. Data integration characterizes the final stage, whereby both quantitative and qualitative data are integrated into either a coherent whole or two separate sets (i.e., qualitative and quantitative) of coherent wholes. The legitimation step involves assessing the trustworthiness of both the qualitative and quantitative data and succeeding interpretations.

2. THE METHODOLOGY FOR THIS RESEARCH

In methodological terms this study is a mixed form of both an exploratory study and a descriptive one that has a sequential nature with the dominance of qualitative methods over quantitative ones but that also uses within its stages the mixing of qualitative and quantitative approaches.

To consider also that the general aim was that this research would be able to translate the praxiological and hermeneutical aspects of product design processes. That was possible by dominance of active research done through the use of several experiments. The initial synthesis of the research framework is presented in Figure 29.

The final adopted research design excludes the creation of a methodology and proposes, as one of the final

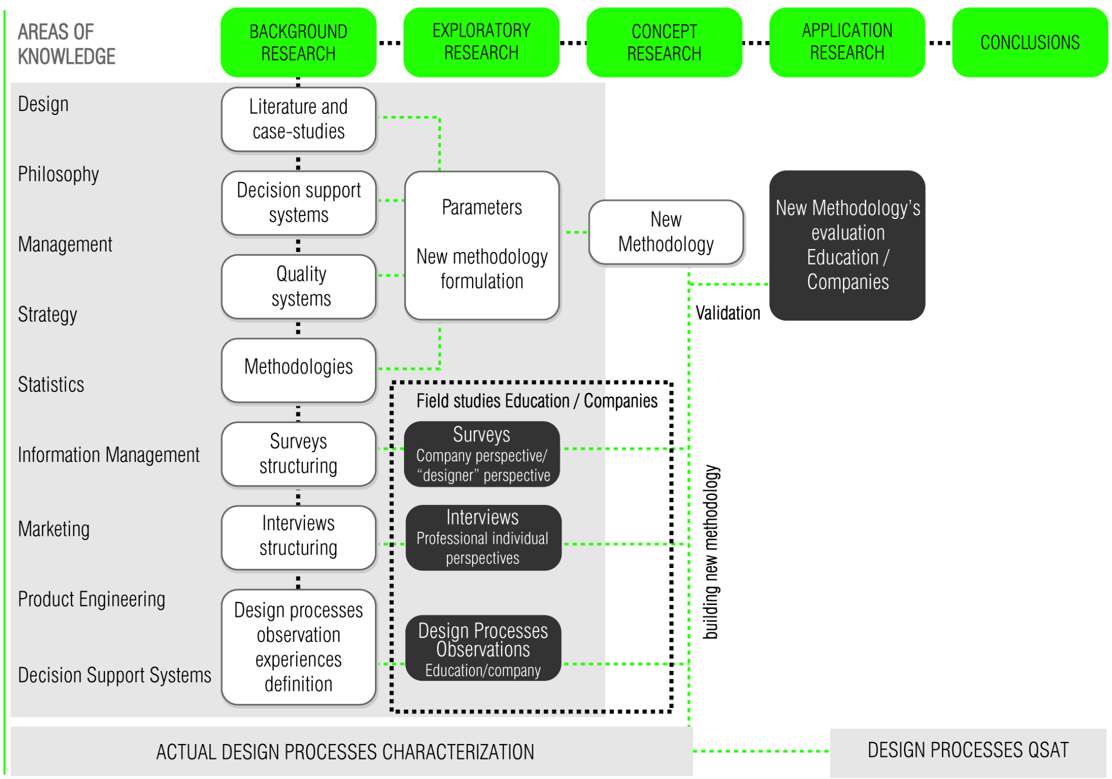


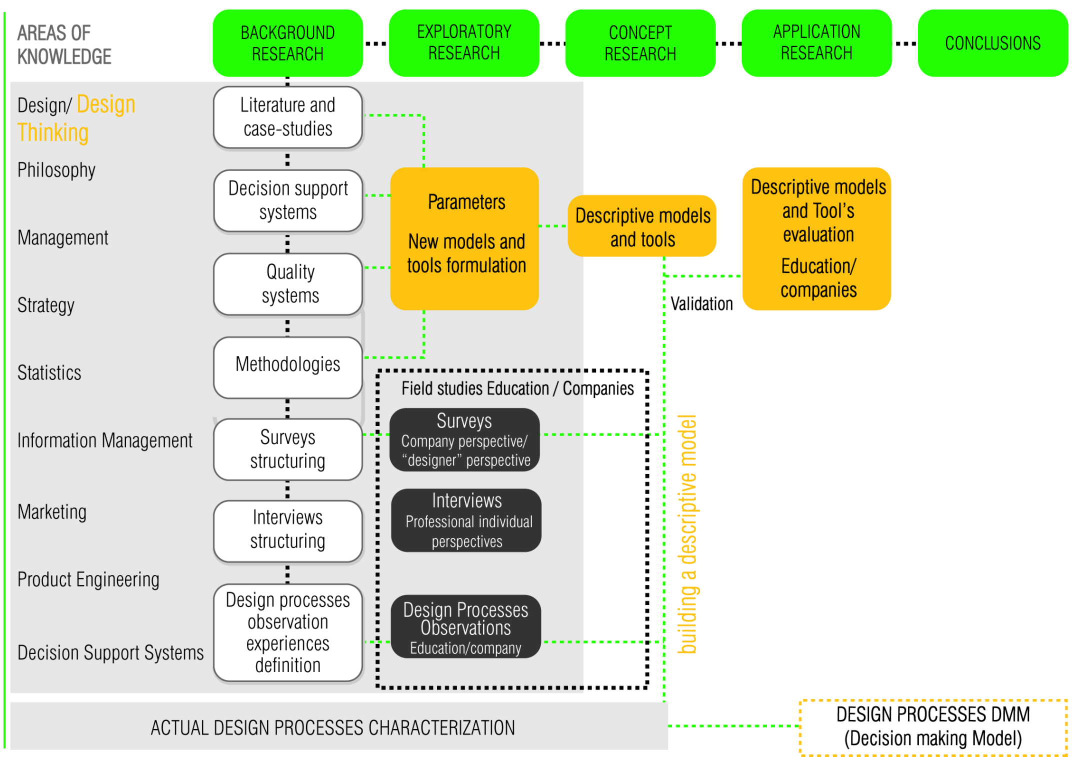
Fig.29 | Synthesis of the Initial Research Framework outcomes of the research, the creation of a descriptive model that can be used in the future by teachers and professional designers as a framework to the development of their own methodologies.

The areas identified in Figure 30 with the orange colour were the ones either added or changed when reformulation occurred in the research.

It is also important to refer that Figure 30 does not translate with precision the complementarities and interactions among different methods. For that purpose a specific diagram (Figure 31) was designed that aims to highlight those relationships.

Regarding the classification of the mixed research designs proposed by Johnson and Onwuegbuzie in point 1 of this chapter, this study is a combination of both *mixed-model* and *mixed-method* types since it combines designs that integrate each of the approaches.

Fig.30 | Synthesis of the Final Research Framework



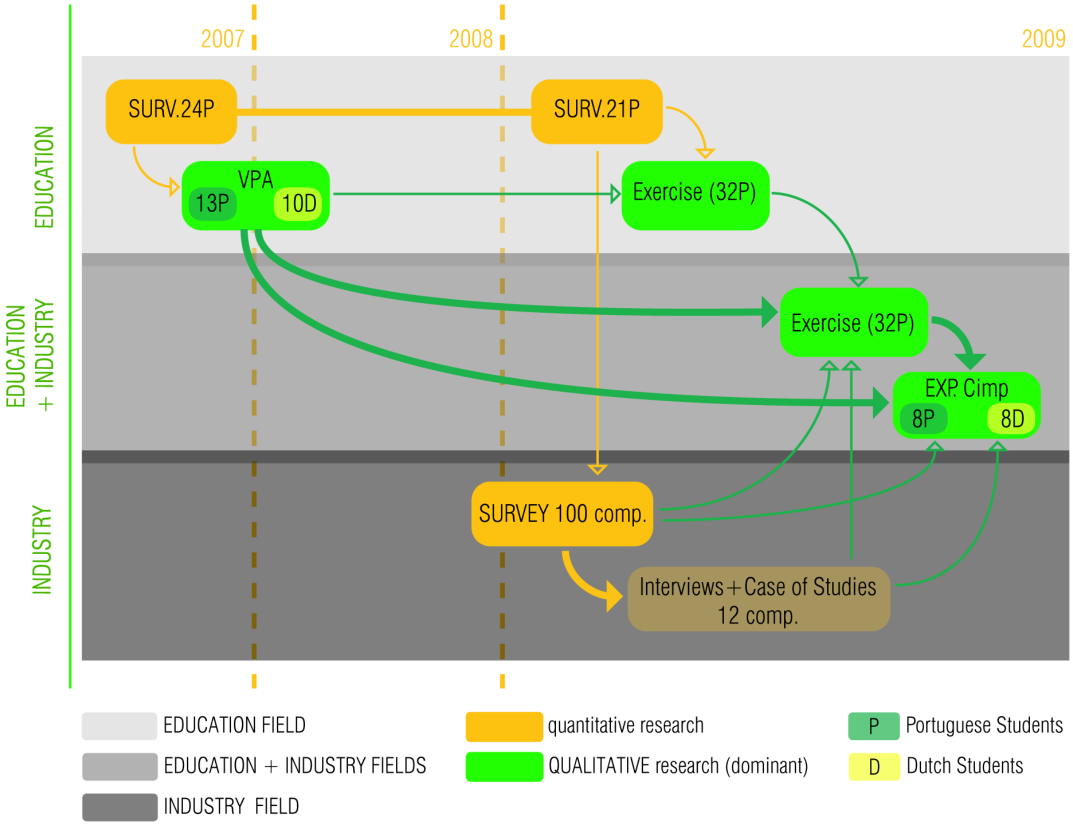


Fig.31 | The activities / methods undertaken

On the subject of the activities undertaken it is to mention that it will be presented in detail in Chapter IV. Below it are just listed the main characteristics of it.

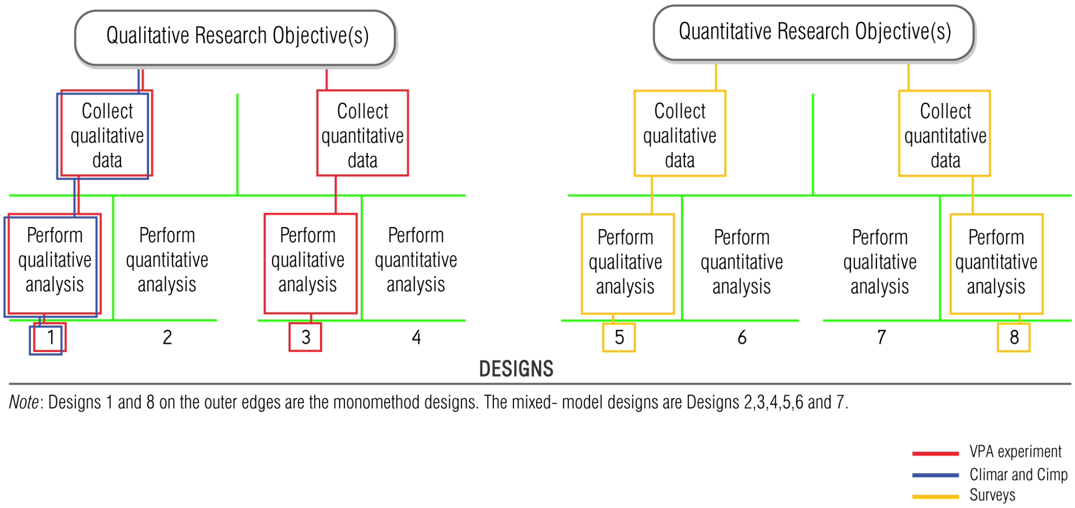
The study with design students included the following methods:

> two surveys – the same questionnaire (one concluded in 2007 with the participation of 24 students; the other one in 2009 with the participation of 21 students)

> verbal protocol experiment - individual exercise with both Portuguese (13) and Dutch (10) students (initiated in 2007 and finished in 2008)

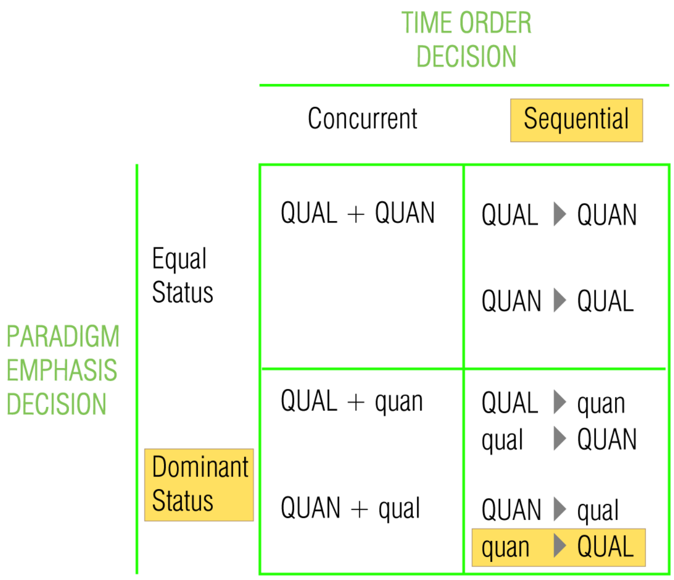
> an individual exercise about design processes characterization and improvement , with the participation of 32 Portuguese students (in an education context since it was integrated in the *Design processes management* course) of the Design Program of FA.

> an experiment where a Portuguese group of students



Note: Designs 1 and 8 on the outer edges are the monomethod designs. The mixed- model designs are Designs 2,3,4,5,6 and 7.

Fig.32 | Monomethod and mixed-model designs used in this research. (Adapted from Johnson and Onwuegbuzie, 2004, p.21)



Note: "qual" stands for qualitative, "quan" stands for quantitative, "+" stands for concurrent, "▶" stands for sequencial, capital letters denote high priority or weight, and lower case letters denote lower priority or weight.

Fig.33 | Mixed-method design matrix with mixed-method research design used in this investigation. (Adapted from: Johnson and Onwuegbuzie, 2004, p.22)

(32 in total) worked for a company (CLIMAR experiment, May-June 2009, that integrated also the *Design processes management* course) and

> an experiment with Portuguese (8) and Dutch (8) design students groups inside a company (CIMP experiment, June – July 2009)

The study of companies is integrated in the research project "Design as a company's strategic resource: a study of the impacts of design" (FCT ref. PTDC/AUR/70607/2006). It included:

> an electronic survey, launched in October 2008, to a sample of 1370 companies from the Portuguese manufacturing industry about the use of Design (that was preceded by a pilot survey in 2007)

> Companies Case –studies (12) - include interviews to CEO's and other managers in companies that were selected from the sample used in the Portuguese manufacturing Industry survey. From these only 3 had the complete intervention of the researcher. The remaining had no direct participation.

These case-studies are not yet complete. Being so the data gathered served to complete information obtained in the survey.

In the sequence of the identification of the different methods we made use of the two types of mixed research designs models presented in point 1 of this chapter to illustrate the combined nature of this investigation. The Figures to attend are Figure 32 and Figure 33.

3. APPLIED METHODS

3.1 Surveys

In this research we made use of three surveys: two in the education field and one in the industry field.

The ones on education field were addressed to design students (two groups of Design students from the final year were questioned in two sequential education years, 2007; 2009). They were preceded by a pilot survey and were based upon online questionnaires.

The one in the industry field was addressed to the Portuguese manufacturing companies (2008-2009) and had the participation of the researcher in its creation and data interpretation. It was also preceded by a pilot survey and was also based upon online questionnaire.

The main goal behind the use of this methodology was to identify the way design, its nature, methods and practices are thought and evaluated on the part of both design students and companies.

As previously mentioned, the work done with companies was developed inside the research project with the title "Design as a company's strategic resource: a study of the impacts of Design" that was funded by the Portuguese Science and Technology Foundation (FCT).

This research project was developed by a multidisciplinary research team that includes the knowledge areas of economy, management, design, engineering, statistics, and artificial intelligence. This enlarged study includes the analysis of company's design processes of a representative sample of Portuguese Manufacturing Industries one of the most important markets for Designers being important to assert the strategic adequacy and overall quality of the outcomes under the perspective of these stakeholders.

3.2 Semi structured – Interviews

The interviews in this research were implemented in the Industry field. They were undertaken with managers, marketers and designers from different companies and with the purpose of identifying and consolidating quality criteria of product design projects and possible project tools based upon time management and strategic adequacy management to be tested throughout the experiences. The role of the interviews was also determinant for the construction of the case studies.

An interview script was developed to support the interviews; it was based on the survey previously conducted with the company and on data collected from literature.

The interview script addressed the thematic blocs that structured the questions of the survey seeking to disclose deepest data and previously gathered less clear or inexistent data.

3.3 – Individual Exercise analysis

An exploratory exercise was created in order to reveal the way design students perceived and represented their own design processes. That allowed the researcher to make the analysis of an individual assignment that had as outcomes: a) the student's analysis of his/her design process (based upon a design he/she had developed previously) and b) a model of a design process that would "correct" and improve the weaknesses identified in the previous analysis.

The analysis to be done was based on content analysis and some criteria were defined in order to classify the student's outcomes. The criteria adopted were:

Macro level: inductive and deductive reasoning abilities;

Micro level: identified design phases; identified variables in design process; identified constraints in design processes; identified methods and tools used in design process; visual synthesis of the parts and whole process (communication quality of the outcome);

3.4 – Experiments

The use of experiments (Active Research) was one of the chosen methods to investigate project design processes and that was related with the intention to gather a detailed observation of designers in action in order to achieve to a critical vision of the product design project's practice and results through the qualitative characterization of designer's processes in respect to their sensibility, ideas and *modus operandi*. Another reason that has governed the method's choice was the fact that design discipline never coded in a systematic way its practices in order to include a critical reflection based upon ethnographical methods analysis.

In experiments it is particularly relevant the coding of data. Coding data is a data reduction method that as previously said helps to manage information and to keep focus on the relevant issues that should be scrutinized critically.

The analysis of data is consequently determinant for the defense of this method. It involves two types of processes: a) a process of immersion where researcher immerses himself/herself in the collected data by reading or examining some portion of the data in detail; b) a process of crystallization wherein the researcher suspends temporarily the process of reading and examining the data (immersion process) in order to reflect on the analysis experience attempting to identify and concatenate patterns or themes perceived during immersion course.

The research experiments in this research had three formats: passive observation of design practice processes in a classroom environment (CLIMAR experiment); practical experience with the intervention of both professional designers and industrial staff (CIMP experiment - active research, using sample groups) and, finally experiences made with individual students in a room, with a specific brief, with a time limit of 2:30 hours for the accomplishment of the task, that served a verbal protocol analysis (VPA). Below it is presented a brief description of the different experiments in its major characteristics.

3.4.1 – Verbal Protocol Analysis – Individual Exercise

The use of verbal protocol analysis in design now has built up a tradition of about 20 years. The method, meant to get an understanding of the cognitive process, has proved to be efficient in describing a number of characteristics of the design process. Examples are the use and the role of drawing, the information-seeking behaviour, and the decision taking process. The results of such experiments aim in general to contribute to support and improve problem solving in design practice, and to train design students and practitioners in a more effective way.

In Verbal Protocol Analysis the verbalization can occur either during decision making (concurrent data) or after (retrospective data). Although both methods have advantages and disadvantages there is some evidence namely in the study performed by Kuusela and Paul (2000, pp. 387-404) that compares the effectiveness of both approaches, that in general the concurrent protocol analysis method outperformed the retrospective one. In its own words "(…)Not only was the number of concurrent protocol segments elicited higher than that of retrospective protocol segments, but concurrent data provided more insights into the decision-making steps occurring between stimulus introduction and the final choice outcome" Kuusela and Paul (2000, p. 387).

In this respect also Ericsson and Simon (1984, p.239) observed that "verbalization of complex recalled thoughts is in many ways similar to verbalization of new sequences of thoughts. Because of the limits of short time memory (STM)[38] capacity, complex thoughts are not kept as entities in STM. A complex thought can be heeded as a whole only in the sense that all the subordinate elements are directly available for retrieval and subsequent attention.

It is also assumed by these authors (1984, p. 242) that "For both newly generated thoughts and (to a lesser degree) thoughts recovered from memory, the evidence shows that the sequence of verbalization parallels closely the sequence of thoughts.". Also to mention the fact pointed out by these authors (1984, p. 379 that "For tasks of longer duration, the validity of think-aloud reports appears to be higher than of retrospective reports").

3.4.2 Experiments – Verbal Protocol Analysis – Group Exercise

The use of Verbal protocol experiment analysis can also be done in group sessions. That occurred in this study. However, in this case the experiments included different methods of capturing information that were combined with the traditional videotaping of the experiment.

In both developed experiments there was made a passive observation. Some groups were videotaped and others were only audiotaped. One of the experiments was undertaken in a classroom environment and the other one was developed in a company's context. This

38. Definition of STM - Short-term memory (sometimes referred to as "primary memory" or "active memory") refers to the capacity for holding a small amount of information in mind in an active, readily available state for a short period of time. The duration of short-term memory (when rehearsal or active maintenance is prevented) is believed to be in the order of seconds. Estimates of short-term memory capacity limits vary from about 4 to about 9 items, depending upon the experimental design used to estimate capacity. A commonly-cited capacity is 7±2 elements. In contrast, long-term memory indefinitely stores a seemingly unlimited amount of information. Short-term memory should be distinguished from *working memory* which refers to structures and processes used for temporarily storing and manipulating information (see more details below). Source: Wikipedia

last case introduced new players in the experiment, the company's agents that interacted directly with the students. The procedures undertaken as well as the method used to encode the information will be accessed in detail in Chapter IV of this document.

As a final remark it is important to underline the relevance of the experiments in this research. In reality it is made use of triangulation of three distinct experiments in order to devise the existence of congruence in its outcomes. It was by purpose that there were selected different context, and general characteristics of the experiments. In this study we cross information gathered from one individual experiment of two hours with two group experiments: one developed in an education context and the other one inserting students in a professional environment.

SUMMARY

This is a mixed research supported by the use of several methods both qualitative and quantitative ones with a special focus on the last ones. This option was made since we aimed to make an exploratory descriptive study about designer's behaviour and cognition along design processes. Being this the scope of the research a qualitative approach, mostly supported in an active research made through the use of experiments as methods to gather information, appeared to be the most adequate.

The main reasons to have had a stronger focus on the qualitative approach have to do with the fact that it provides and understanding and description of people's personal experiences of phenomena, i.e. the 'emic' or insider's viewpoint. On the other hand it gives the chance to have rich detail in descriptions as the phenomena is situated and embedded in local contexts. Furthermore it is possible to study dynamic processes and document sequential patterns and changes.

Finally, using these qualitative methods (experiments; exercise) along with quantitative (survey) ones allowed us to produce a more complete knowledge since it was possible to add insights and understandings that might be missed when only a single methods is to be used.

BIBLIOGRAPHIC REFERENCES

ARCHER, B. 1979. The three R's. *Design Studies*, pp.117-20.

JOHNSON, R., ONWUEGBUZIE, A. 2004. Mixed methods research: a research paradigm whose time has come. *Educational Researcher*, 33(7), pp.14-26.

ONWUEGBUZIE, A., LEECH, N. 2004. Enhancing the interpretation of significant findings: The role of mixed methods research. *Annual meeting of the Eastern Educational Research Association*. Clearwater.

JOHNSON, R., TURNER, L. 2003. Data collection strategies in mixed methods research. *In*: TASHAKKORI, A., TEDDLIE, C. (ed.) *Handbook of mixed methods in social and behavioral research* Thousand Oaks, CA: Sage, pp.297-319.

GREENE, J., CARACELLI, V., GRAHAM, W. 1989. Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis,* 11(3), pp.255-274.

KUUSELA, H., PAUL, P. 2002. A comparison of concurrent and retrospective verbal protocol analysis. *The American Journal of Psychology, University of Illinois Press*, 113(3), pp.387-404.

ERICSSON, K., SIMON,H. 1984. *Protocol Analysis. Verbal Reports as Data*, Cambridge, MIT Press.

YIN, R. 1994. *Case Study Research: Design and Methods. Applied Social Research Methods*, SAGE Inc.

ONWUEGBUZIE, A., TEDDLIE, C. 2003. A Framework for Analysing Data in Mixed Methods Research. *In*: (EDS), C. T. (ed.) *Handbook of Mixed Methods in Social and Behavioral Research*. Thousand Oaks, CA: Sage, pp.351-383.

MACKEY, A., GASS,S. 2005. *Second Language Research: Methodology and Design*, New Jersey, Lawrence Erlbaum Associates, Inc.

Part three: Exploring Design Processes

CHAPTER IV - ACCESSING/EXPERIMENTING/ DESCRIBING DECISION MAKING IN DESIGN PROCESSES

The in depth study of how decision making occurs in design processes was done through the use of different methods already referred in Chapter III with special emphasis in the experiments. Those studies served also the purpose of the construction of theoretical models to support hypothesis to be tested along the research and afterwards.

1. AN INNER ASSESSMENT – DESIGN STUDENTS AND COMPANY VIEWS OF DESIGN PROCESSES

The inner assessment was made both by the gathering of data regarding (i) the way students see and describe their own design processes and (ii) the way companies see/describe design processes. On the following pages a description and analysis of the results in both cases will be presented.

1.1. How design students see their own processes

The way students see their own design processes was studied making use of different methods – two surveys (to students of the 5th grade in 2 sequential years) and an exercise about 'design processes' done in the course 'design processes' management' (optional course from the 5th grade of Design Program). There were two moments of collecting data (2007 and 2009) but the data was treated as a whole.

Also important is to notice that regarding the survey data analysis next to the analysis of the collected data there existed a second moment of analysis when information collected from the experiments was confronted with the ones of surveys. This way it was possible to make some statistical hypothesis tests and to associate information that was collected in different phases of the research.

1.1.1 Surveys undertaken in 2007 (24) and 2009 (21) – students from the 5th grade

The launch of an electronic questionnaire created to access the way students view design processes was preceded by a pilot questionnaire (undertaken by 20 students at the end of 2007- Appendix B). Some of the preliminary results of that pilot survey are worth to mention since they helped to redesign the final questionnaire and to prepare the first experiment with design students. Among the results, the most significant are:

> Being time been evaluated by only 23,7% students as an important factor in respect to their performance in Design studio course, it was identified at the same time by 84% of the sample as a decisive factor in terms of student's low performance results. The reason appointed to that fact is a bad management of time in general as well as in what concerns design process (92% of respondents).

> Students that keep a record of ideas (notebook) tend to find it less difficult to manage time.

> Students that frequently appeal to the construction of 3D models have a tendency to iterate less in the design process and to have less management problems with time.

> The first action taken by students after the moment they are confronted with a brief is: to search for similar problems and its solutions (89%).

> Drawing (software) programmes usage is seen as a possibility to generate a greater number of ideas in less time (65%) but it also promotes a loss of control over the global time management (84%).

Design questionnaire – the Design process in the perspective of the designers/students

The questionnaire [Appendix C] served the purpose of inquiring the design students about their perception and beliefs about their own design processes. It had as central aims:

> The identification of claimed critical moments in the design process

> The description of how students assume the approach to critical moments

> The understanding of the role time and information management had in design process

> the acquisition of a better knowledge of how subjects define quality in the process and final outcomes

> the disclosure of possible elements in design processes that are worth to be studied.

In terms of the questionnaire's design this was done taking into account several issues: the method, the formal aspects of the tool and the contents – its structure and nature.

Method – the option to develop a survey based in an online questionnaire was supported by the following considerations: it is quicker than traditional methods, it reduces data transfer errors, it gives the researcher the opportunity to cross information in a quicker way and it is less expensive. Nevertheless unlike usual online surveys this one was filled up during two plenary sessions in which the researcher was present (has it occurred in the pilot survey on paper) in order to respond to possible unclarities. This was possible because the sample was not randomly chosen but instead selected since the aim was specifically to gather information from design students who were in the last year of their undergraduated course.

Formal aspects of the questionnaire – being a "long" questionnaire (47 questions) the formal aspects of this tool were taken into account. The idea was the construction of a visual interface that would favour the openness to answer and reduced the possible emergence of fatigue. Therefore, in spite the constraints of the electronic tool, the questionnaire was designed in such a way that the questions where clearly identified with a number, were easy to read (no more then 10 words in each line), had a legible type of letter, where the space for the answer was clearly marked and the nature of possible answer – multiple choice or not – was evident. The use of a different colour to differentiate the scale used facilitated data gathering and the full comprehension of the work to be done. The choice of the colour palette of the tool was also thought in terms of trying to reduce the fatigue along the fulfilment of the survey.

The content of the questionnaire – structure and nature

Structure – the pilot questionnaire was clearly divided in sections that identify the nature of the questions and the issues to be addressed. This option was abandoned in the final questionnaire because it was observed in the first case that people tended to respond according to the context of the question and to pay less attention to the last questions of the section. We realized that it would be better, even in terms of the dynamics of the fulfillment process, to mix the different issues addressed so the subjects were "forced" to pay attention to different issues and have less possibility to built a "social desirable" view (if that was the case); In practical terms this means that the titles of the sections were abolished. In fact, a certain structure of the adressed issues is still observable but only those that concern demographic data and information related with the course. The type of questions varies: there exist a few open questions, and regarding the close ones there are dichotomous questions (YES/NO) and also questions build upon a Likert scale (1-5). Moreover there are contingency questions so it is possible to isolate those that must answer some issues with a high level of detail. Finally there are also multiple choice questions (based upon checkbox matrixes).

Nature of contents:

1. Demographic data: age; sex; address area (this is important because usual claims of students are related with the amount of time they spend coming to and going from the university) mother's and father's profession (level of education; possible relation between the cultural level at home being related with the students performance);

2. Course related data: here it was aimed to know if the course was their first option or not, what was their first option, how they evaluate the course so far (in order to see if there is a relation between their course evaluation and the perception they have of their performance);

3. Design studio related data: here it was intended that subjects evaluate the design studio course as well as the weight of the course in the Design Program and the factors that affect their performance in the design studio course.

4. Design process related data: questions where constructed with the goal of obtaining information about the use of process methods and tools along the process; the way they describe their own processes; the relevant issues in a process; the critical moments and ways to overcome it;

5. Time related data: several questions were made regarding time: its management importance; the relevance it has in the process and its different phases; ways used to better manage/control time in the processes;

6. Quality related data: a question was made about the definition of design quality. This question presents several optional answers to be graded and later on this information will be crossed with the evaluation subjects have made of their Verbal Protocol experiments.

7. Information management related data: the role of information management in design processes was assessed through several questions; the nature of information, the easiness of access and use and the overall importance along the different phases of the process were some of the issues addressed.

Data Treatment and Analysis – the data was transferred to SPSS[39] to be subjected to statistical treatment and analysis. The global results are presented in Appendix D.

The number of students that answered the questionnaire was 45 (24 answered it in 2007 and 21 answered it in 2009) but only 39 questionnaires were validated. All the subjects filled in an Informed Consent (Appendix E) before filling in the questionnaire.

On the basis of those 39 questionnaires we will present some of the achieved results.

First, the characterization of the sample in its demographic data will briefly be presented:

39. See List of Acronymous

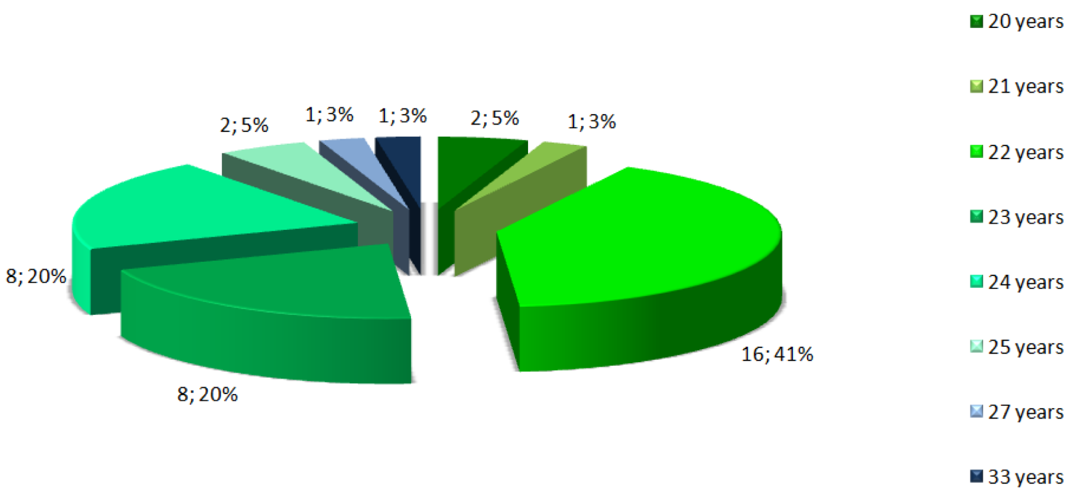


Fig.34 | Ages of the subjects (question 1)

> In relation with the age of the subjects it is visible in Figure 34 that the majority of the subjects was aged between 21 and 24 years old.

> In terms of the gender frequency the sample was divided into 71,8% of feminine subjects and 28,2% masculine ones (Figure 35). These numbers are consistent with the general average of the design program that displays normally a significant higher number of women over men.

> The majority of the subjects (82%) live in Lisbon or in the neighbourhood; the other 18% live in the Centre region of Portugal (more than 50 kilometres far from Lisbon)

> However it is important to mention that among those living in Lisbon around 40% are students that come from other regions of Portugal and had to rent a place to stay near the Faculty, Figure 36.

Regarding the course related data it was found out that:

> For 59% of the subjects the design course was the first choice they made when applying to the university (Figure 37).

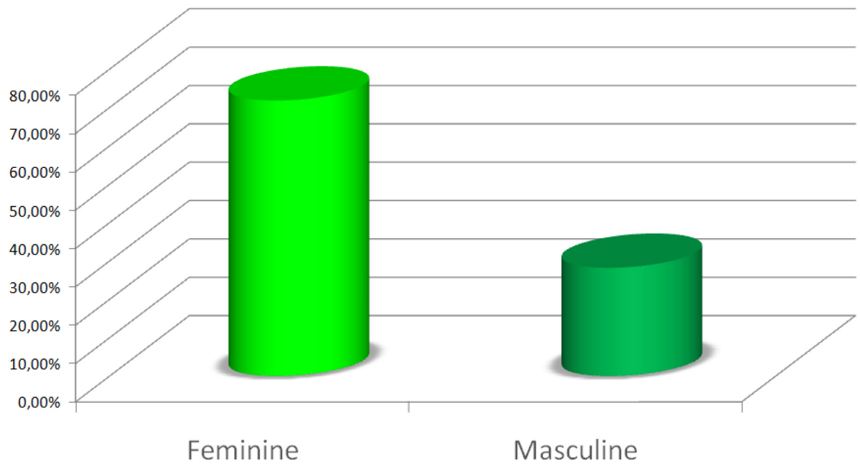


Fig.35 | Gender Frequency of the subjects (question 2)

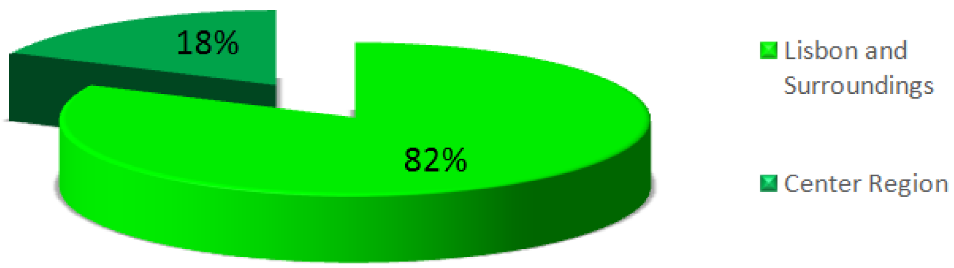


Fig.36 | Subjects' area of Residence (question 3)

> From the remaining 41% of the subjects, for 87% of them it was their second option and for 13% the third option (Figure 38).

> 54% of the subjects consider that the design course corresponds to their expectations, 10% answered that it exceeded their expectations and 36% classify it as being below their expectations (Figure 39).

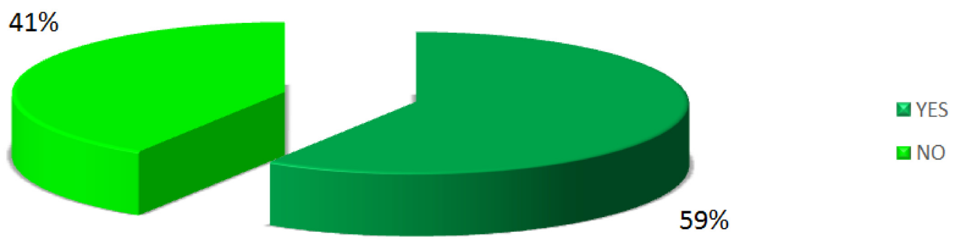


Fig.37 | Design Course as the first choice (question 6)

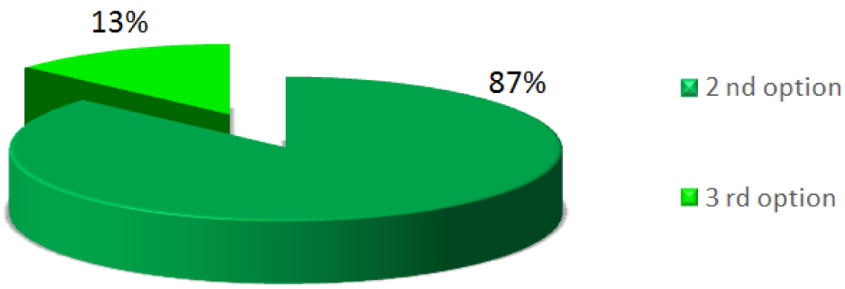


Fig.38 | Subjects order of design's course choice (question 7)

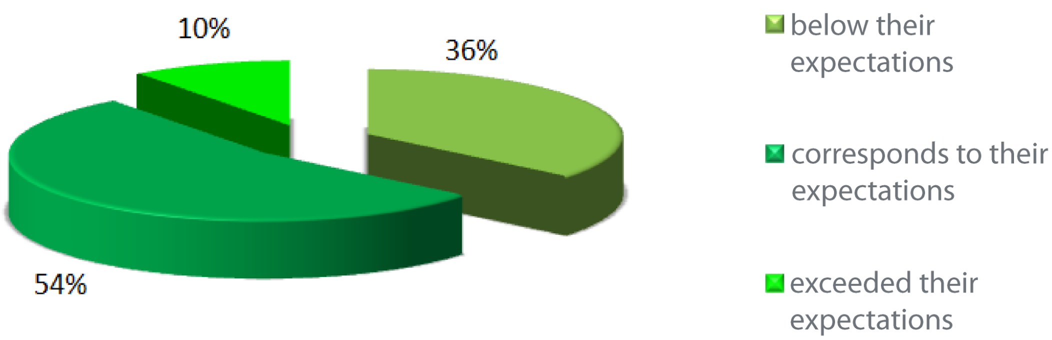


Fig.39 | Subjects evaluation of the Design course (question 9)

On the perception topic of subjects have of the Design Program and Design Studio course we decided to present the questions and the results of each synthesized in tables of frequency and means.

Question 10 - How do you perceive the design studio course in the 'design program' context?
(1 - COMPLETELY DISAGREE; 5 – FULLY AGREE)

	Mean	Std. Deviation
As the most important course	4,67	,621
As the central course that asks for the knowledge of the other courses	4,10	,995
As the course one should dedicate more time to	4,56	,718
As the most appealing course	4,18	,823
As the course that most easily can provoke stress and frustration	4,15	1,182

Table 9 | Subjects perception of the Design course (question 10)

The design studio course is perceived by the average of the subjects as being the most important one in the curricular structure and also the one to dedicate more time to.

Question 11 – Classify at what point the design studio course determines your appreciation of the Design program. (1 – DOES NOT DETERMINE AT ALL; 5 - DETERMINES COMPLETELY)

	Frequency	Valid Percent	Cumulative Percent
Does not determine at all	1	2,6	2,6
Hardly determines	0	0	2,6
Determines somehow	9	23,1	25,6
Determines	21	53,8	79,5
Determines completely	8	20,5	100,0
Total	39	100,0	

Table 10 | Subjects perception of the Design course/Design Program (question 11)

There is a high correlation between the degree of importance (Q10) and (Q11): those who perceive the design studio course as most important also perceive this course as determining the appreciation they have about the Design program.

In the face of such meaningful assumption of the design course's importance it was useful to assess the factors that could affect negatively the subject's performance in it (Table 11).

Question 12 - Which are the factors that mostly affect in a negative way your performance in Design Studio course? (1- DOES NOT AFFECT; 5 – AFECTS EXTREMELY)

	Mean	Std. Deviation
The nature of the design exercises - theme, complexity etcetera.	2,59	1,163
The design studio class´s dynamics	2,90	1,273
The tutorship on the part of design studio's teacher	3,15	1,479
Time to be dedicated to the design studio course	3,18	1,335
The articulation with other course's contents	2,69	1,260
At disposal facilities and equipments	2,87	1,218
Personal psychological factors	3,28	1,234

Table 11 | Factors affecting negatively design studio's performance (question 12)

The psychological personal factors along with the time to be dedicated to the course were the ones that gathered a higher average value.

The approach to Design processes perceptions and acknowledgement started with a question addressing the initial phase of the process: the brief.

Question 13 - When facing a design problem for the first time what are your immediate concerns? (1- LESS RELEVANT CONCERN; 5 – MOST RELEVANT CONCERN)

	Mean	Std. Deviation
Draw/test ideas	3,51	1,211
Search existent solutions	3,97	,932
Assume the user's point of view	4,10	,995
Evaluate the problem its origins and limits	4,28	,887
Search similar problems	3,41	,818
Identify personal knowledge that can be used in the exercise	3,33	1,177

Table 12 | Immediate Concerns facing 'Brief' (question 13)

The results of question 13 presented in Table 12 demonstrate that the concerns more valued by the average of the subjects when facing the brief are: a) the evaluation of the problem, its origins and limits and b) to assume the user's point of view.

After this analysis a cross analysis was made with the results of the experiments (verbal protocol analysis of an individual assessment to a design problem and a group exercise with a brief from the firm CLIMAR) of the subjects in order to understand if there was an association between the 'design strategy' (see page 256) of the subjects and the immediate concerns that were stated by them. The results show that in fact there is a direct correspondence among the stated concerns and the strategy displayed by the subjects. Table 13 presents the frequency of the three design strategies in terms of the sample.

The solution driven subjects were those that elected as first concern: search existent solutions; as a second concern it was placed draw/test ideas; The problem driven subjects elected as first concerns: evaluate the problem, its origins and limits and search similar problems; the co-evolution driven (later named integration driven) subjects were less clear in theirs options but all elected both problem and solution concerns as well as the assumption of the user's point of view. The evaluation of the subject in terms of their design strategy was done both by the researcher and an independent judge.

	Frequency	Percent	Valid Percent	Cumulative Percent
solution	17	43,6	43,6	43,6
problem	12	30,8	30,8	74,4
co-evolution	10	25,6	25,6	100,0
Total	39	100,0	100,0	

Table 13 | Problem / solution / co-evolution driven approach

In order to reduce subjectivity in the study it is also relevant to understand if the subjects acknowledge the different phases of design processes in similar ways. Table 14 synthesizes the way subjects describe the phases of design processes.

Question 14 - Which are the phases you identify in your design process? [Appendix F]

Broaden categories were created (on the basis of a thorough analysis made Appendix F), for the given

Moments in sequence	Synthetic Description	Count	%	%	4 Phases quest.
A	Acknowledge Brief/ Identification of problem and context of it	18	46,15%	46,15%	Initial / Conceptual
B	Research	25	64,10%	97,44%	
	Research of existent solutions	10	25,64%		
	Research of similiar problems	3	7,69%		
C	Brainstorming	3	7,69%	7,69%	
D	Sketching/ concept generation *	33	84,62%	87,18%	
	Mental modelling of the ideas *	1	2,56%		
	Study of the users and their needs	2	5,13%		
	Planning the process	2	5,13%		
E	Evaluation and choice of a concept	11	28,21%	28,21%	Development
F	Experiment/ determine possible solutions*	5	12,82%	87%	
	Technical/ functional development*	29	74,36%		
	Ergonomic studies	1	2,56%		
	Correcting aspects of solutions	4	10,26%		
	Modeling 3D	4	10,26%		
G	Detailing	4	10,26%	10,26%	Detailing
	Prototyping	6	15,38%	17,95%	Pre-production
	Pre-engineering	1	2,56%		
H	Presentation	6	15,38%	15,38%	

Table 14 | Phases of Design process

* Descriptors that were added and remeted in column 2 of percentages.

descriptions; After, an alphabetic code was attributed a letter to identify the sequence of the moments/ tasks described by the subjects; Furthermore, the matching of those categories within the four phases mentioned along the questionnaire was made by the researcher. The averages were calculated not only in terms of each category but also in a cumulative way to broad phases. The conclusions to be taken of the analysis of data gathered on question 14 are:

> The large majority of the subjects assume the existence of 3 phases that either are mentioned in a very synthetic way or in a detailed one. Those phases are the Research; the Concept and the Development of concept.

> A significant average of the subjects (46,15%) identify specifically what can be seen as a pre-phase

of the conventional one that gives respect to the Brief acknowledgement.

> The initial phases are consensual to the majority of the subjects but the more we go to the late moments in design processes the less information is given by the subjects and the given one is not homogeneous in terms of description.

Next, an attempt was made to isolate possible causes of quality level in its outcomes. As mentioned before time management and information management were particularly focused upon in the questionnaire.

Question 15 aims to find out if the subjects make use of a chronogram to support design process planning, monitoring and general development.

Question 15 - It is usual in your design process to establish a chronogram where you identify the tasks and the time of execution?

Table 15 | Chronogram Use

	Frequency	Valid Percent	Cumulative Percent
yes	25	64,1	64,1
no	14	35,9	100,0
total	39	100,0	

About 1/3 of the subjects do not make use of such a plan tool and about 2/3 do. The importance of these results is reinforced by the outcomes of question 16 that specifically addresses the eventual circumstance of subjects experiencing difficulties managing time along design process.

Question 16 - Do you have difficulties managing time along the design process?

Table 16 | Existence of difficulties managing time along the process

	Frequency	Valid Percent	Cumulative Percent
yes	33	84,6	84,6
no	6	15,4	100,0
total	39	100,0	

Almost 85% of the subjects recognize to have difficulties managing time along the design process. Such an impressive percentage asks for a deeper exploration by way of question 17 (Figure 40).

Question 17- If YES, what is(are) the reason(s)?

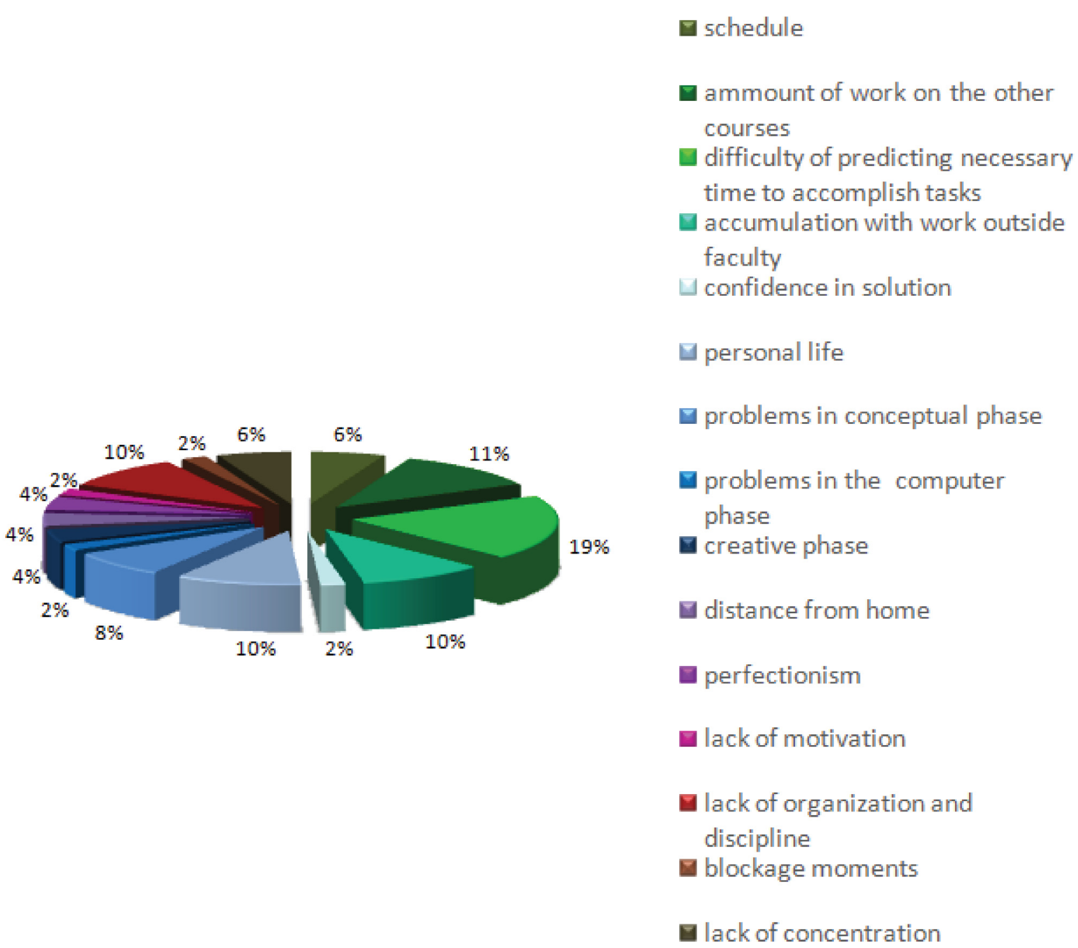


Fig.40 | Reasons for managing badly time

The answers to question 17 [Appendix G] were grouped in larger categories that can be seen in the legend of Figure 40.

The "difficulty of predicting the necessary time to accomplish the different tasks" was the reason more often mentioned by the subjects (19%); On second place the subjects attribute the difficulty of managing time to "the amount of work they have to deliver in other disciplines" (11%). Thirdly, but with a very close average to the previous reason (10%), there are three reasons pointed out by the subjects. These are: a) "Personal life"; b) "lack of organization and discipline on the part of the subjects"; c) "accumulation with work outside the Faculty".

Also important was to identify in which phases subjects usually spent more time (question 18) and what are the reasons behind it (question 19). The answers to those questions are presented in Table 17 and Figure 41, respectively.

Question 18 - Which is(are) the phase(s) in the process where you usually spend more time?

Table 17 | Phase of the process that takes more time

Phases of the Process	Mean	Std. Deviation
Conceptual	4,00	1,026
Technical development	3,92	,839
Detail phase	3,51	,854
Pre-production	3,18	1,167

In general, subjects spend more time in the conceptual phase followed by the one dedicated to technical development. It is relevant to note that at the faculty it is rare to develop the designs until the pre-production phase.

Question 19 - Why do you spend more time in this (those) phase(s)?

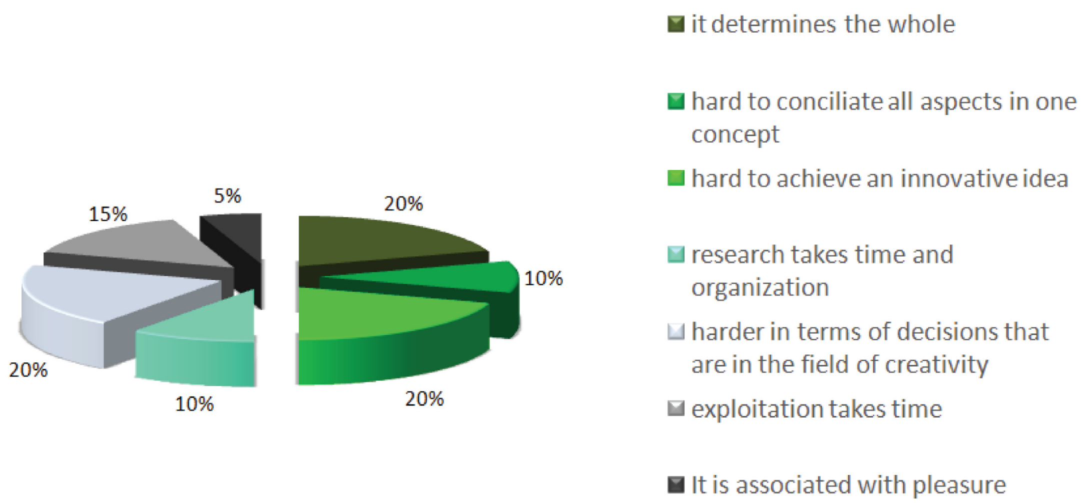


Fig.41 | Reasons for spending more time in conceptual phase

Regarding the conceptual phase (that has the highest mean in terms of time spent) subjects elected as the main reasons for spending more time in this phase: a) the fact that in this phase the decisions concern creativity and decisions on that are harder to be taken (20%); b) the circumstance of being this the phase that determines the whole process (20%); c) the condition that having an innovative idea is crucial and difficult to generate (20%).

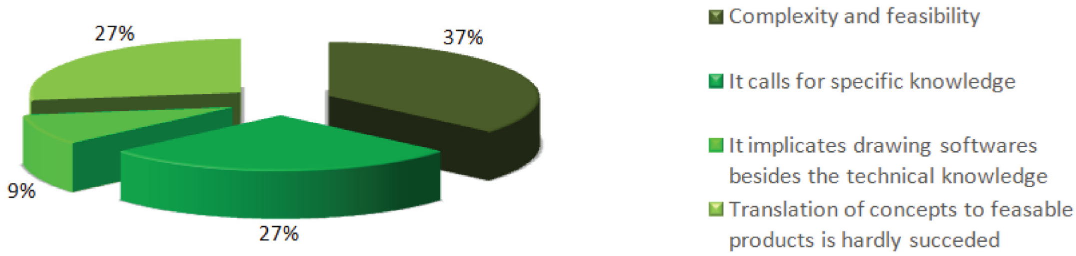


Fig.42 | Reasons for spending more time in technical development phase

Reasons to spend more time to the technical development phase are: a) the complexity of the tasks to be developed (37%); b) the specialized knowledge necessary to accomplish the task with success (27%); c) the fact that it is hard to match the rigorous representation of the product with the conceptual mental representation of it (27%).

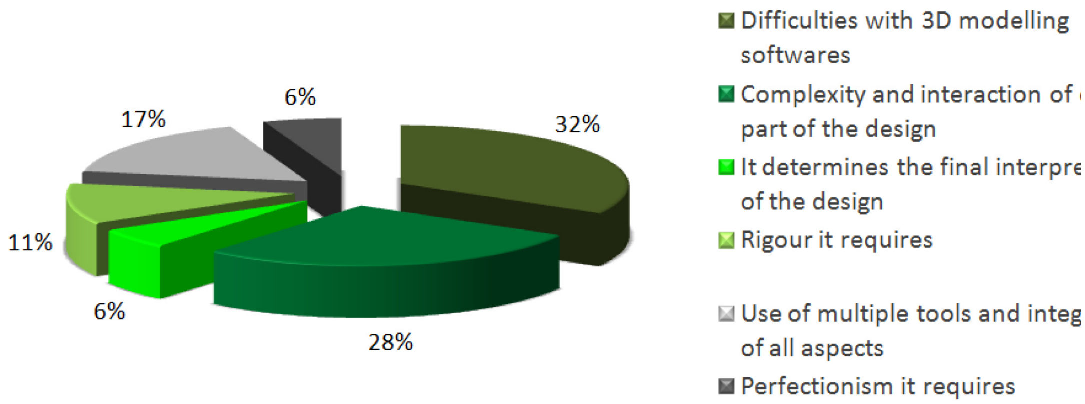


Fig.43 | Reasons for spending more time in detailing phase

Reasons to spend more time to the detail phase are: a) the fact that 3D modeling softwares are complex to use and the whole process of making renders takes time being the results not always the ones expected (32%); b) it has an high level of complexity not only in terms of contents but also in terms of the management of tasks and relationship of all the design parts (28%).

Using an exploratory method, the author wanted to disclose possible variables to be further investigated and also to validate some variables gathered during the literature revision. Therefore, a few of these variables were presented as being possibly critical in design process. The subjects had to evaluate them making use of a Likert scale[40] (Table 18).

Question 20 – Which elements usually appear as being critical along your design process? (1- NOT CRITICAL AT ALL; 5 – VERY MUCH CRITICAL)

Critical Elements	Mean	Std. Deviation
Understanding the brief	2,54	1,354
Obtaining market information	2,64	1,088
Obtaining technical information	3,38	,963
Obtaining production information	3,38	,782
Information management in general	2,85	1,040
Time(s) management of the process	3,51	1,275
Management of technical constraints	3,44	,788
Interaction with the client	2,85	1,136
Execution of technical drawings and models	3,13	1,196
Execution of other drawings and models	2,82	1,167
Execution of the written parts of the project	2,62	1,184

Table 18 | Critical elements along design process

Process time management and technical constraints management are the two elements that subjects perceive as being more critical along the design process. Also the gathering of information (both technical and of production methods) is considered to be of relevance.

As mentioned in the introduction of this survey study the assessment of the concept of 'quality of design' was one of the issues to explore in the questionnaire. Question 21 addresses it proposing several definitions that subjects had to classify at a Likert scale ranging from 'Not relevant at all' to 'Very much relevant'. The results are synthesized in Table 19.

Question 21 – Classify the definition of 'design with quality' with which you identify yourself more (1- NOT RELEVANT AT ALL; 5 – VERY MUCH RELEVANT)

40. Likert scaling is a bipolar scaling method, measuring either positive or negative response to a statement. Normally it is constituted by 5 Likert items that are the statements to be evaluated.

The Design that...	Mean	Std. Deviation
results in a quality product without having the need of substantial changes (in the pre/production phase)	2,95	1,191
optimizes resources - human, material and financial	4,05	,793
results in a commercially successful product	3,05	,759
generates and consolidates Knowledge	3,26	1,044
is integrated in the firm's strategy and accomplishes the defined goals	3,74	,850
anticipates market needs	3,59	1,069
present sustainable and ethically responsible solutions as an outcome	4,26	,938

Table 19 | 'design with quality' definition

The 'design with quality' definition with the highest mean are: a) the one "that presents sustainable and ethically responsible solutions as an outcome"[41] and b) the one that associates quality of the design with the optimization of the human, material and financial resources. The highest score is the one that is integrate the firm's strategy.

As previously said the questions were not grouped according to their nature or issue to be addressed. As a consequence along the questionnaire subjects were demanded to give information about different issues that did not obey to an organized sequence. That is the case of questions 22 and 23 that call again for their appreciation regarding the use of some instruments to manage design process. Furthermore there are questions like question 24 that is a repetition of a previous question (15) but formulated in a diverse way. This was done since it was necessary to guarantee the consistency of the subject's reasoning.

Table 20 | Use of facilitator schemes along design process

Question 22 - Do you make use of any type of schemes to facilitate the development of the design process?

	Frequency	Valid Percent	Cumulative Percent
yes	33	84,6	84,6
no	6	15,4	100,0
total	39	100,0	

The large majority of the subjects (84,6%) stated that they make use of schemes as design process facilitators. Question 23 offers the subjects the possibility to identify the nature of those schemes. The results on this question are shown in Table 21.

41. It is important to notice that this concern with sustainability and ethics in design practice were also relevant and verifiable in the experiments done within this research.

Question 23 - If YES, which ones and in what phase of the design process.

Table 21 | Schemes use/Phases of Design Process

Type of scheme	Phase of the Design Process		YES	NO	Total
Checklist	Initial Phase	Freq.	26	13	39
		%	66,7	33,3	100,0
	Development Phase	Freq.	28	11	39
		%	71,8	28,2	100,0
	Detail Phase	Freq.	27	12	39
		%	69,2	30,8	100,0
	Production Phase	Freq.	22	17	39
		%	56,4	43,6	100,0
Chronogram	Initial Phase	Freq.	15	24	39
		%	38,5	61,5	100,0
	Development Phase	Freq.	17	22	39
		%	43,6	56,4	100,0
	Detail Phase	Freq.	18	21	39
		%	46,2	53,8	100,0
	Production Phase	Freq.	13	26	39
		%	33,3	66,7	100,0
Diagram	Initial Phase	Freq.	9	30	39
		%	23,1	76,9	100,0
	Development Phase	Freq.	9	30	39
		%	23,1	76,9	100,0
	Detail Phase	Freq.	5	34	39
		%	12,8	87,2	100,0
	Production Phase	Freq.	4	35	39
		%	10,3	89,7	100,0
Grids	Initial Phase	Freq.	3	36	39
		%	7,7	92,3	100,0
	Development Phase	Freq.	2	37	39
		%	5,1	94,9	100,0
	Detail Phase	Freq.	2	37	39
		%	5,1	94,9	100,0
	Production Phase	Freq.	3	36	39
		%	7,7	92,3	100,0
Other Schemes	Initial Phase	Freq.	16	23	39
		%	41,0	59,0	100,0
	Development Phase	Freq.	13	26	39
		%	33,3	66,7	100,0
	Detail Phase	Freq.	9	30	39
		%	23,1	76,9	100,0
	Production Phase	Freq.	9	30	39
		%	23,1	76,9	100,0

In summary, a high percentage of subjects use a checklist in all phases of the design process; mostly in the development phase (71,8%).

The chronogram (that was specifically addressed by question 15 were 64,1% of the subjects confirmed its use) obtains in all the different phases percentages of use that are lower than previously ranging from 33,3% to 46, 2% of use. However, it is possible that this difference is due to the fact that question 15 addressed the use of chronogram in general and there is the possibility that some subjects answer question 23 in a negative way presuming that here it was referred to more detailed chronograms and not a general one.

Again a question was introduced that had the aim of testing the consistency of the answers given by subjects. It is the case of question 24 that is similar to question 15 (the one that refers the use of chronogram) but that uses a different set of options since it includes the option of 'sometimes'. This difference allow us to have a more refined assessment of the extent of use of this instrument.

Question 24 - Do you establish, at first, a plan of tasks limited in time?

	Frequency	Valid Percent	Cumulative Percent
yes	10	25,6	25,6
no	5	12,8	38,5
sometimes	24	61,5	100,0
total	39	100,0	

Table 22 | Establishment of a Plan of tasks

The results on question 24 show us that between those that always establish a plan of tasks and the ones that do it sometimes the account for the use of a plan of tasks limited in time is of 87% of the subjects. However, in question 15 (a YES/NO question) only 64,1% of the subjects acknowledge the use of a chronogram. The difference is relevant but it is possible that it is due to the fact that question 15 did not allow an 'in between' situation in terms of the use of this instrument. Another possible reason (although thought as being less credible) is that subjects are not used with the term chronogram and acted accordingly.

In order to go deeper in the assessment of this issue, another question was added for those subjects who answer Q24 with Yes and Sometimes.

Question 25 - If you answered 'Yes' or 'sometimes' to the previous question which of the following statements is close to your practice? (34 out of 39)

	Frequency	Percent	Cumulative Percent
The plan serves mainly the "take-off" of the process	2	5,9	5,9
The plan rules the whole process and it is regularly adjusted	8	23,5	29,4
The plan helps mostly the time management of the design process	24	70,6	100,0
Total	34	100,0	

Table 23 | Reasons to make a plan of the tasks

A significant percentage of subjects (70,6%) perceive the use of a 'plan of tasks with time limits' as helping mostly the time management of the design process. For 23,5% of the subjects the plan is an instrument of monitoring and adjustment of the process. Therefore it is possible to assess that the plan is for the majority of the subjects an under used instrument.

When identifying possible important elements in the design process the issue of blockage moments seem significant since for our own experience it was a very common reason stated by students in relation to a deficient performance in design outcomes.

Question 26 - Do you have blockage moments along your design process?

	Frequency	Valid Percent	Cumulative Percent
Never	0	0	0
Rarely	3	7,7	7,7
Sometimes	26	66,7	74,4
Several times	9	23,1	97,4
Always	1	2,6	100,0
Total	39	100,0	

Table 24 | Frequency of Blockage moments along Design process

It depends on how you judge the category 'sometimes' to define wether this is a problem or not. If we add the subjects that have at least 'sometime' blockages along we obtain a huge average (92,3%) meaning that it is really an issue in the design process. However, it is important to note that the number of those that have it 'rarely' or 'sometimes' is far more expressive (about 2/3) then the one obtained by the sum of the subjects that have it 'several times' and 'always' (about 1/3).

In which phases of the process those blockages occur more frequently?

Question 27 - Identify by order of importance the phases in which those blockages occur.

	Mean	Std. Deviation
Initial/ conceptual	3,82	1,430
Technical Development	3,10	,968
Detail	2,59	1,117
Pre-production	2,33	1,084

Table 25 | Frequency of Blockage moments in terms of process phases

As predicted it is the conceptual phase that is assumed to be more frequent in terms of blockage's occurence. These results are possible influenced by the fact that design students have a consecutive training on the two initial phases while this training is less in developing the "design until the detail" phase and even rarely in entering the pre-production phase. Being so it is possible that they don't consider having blockage moments in those particular phases since they do not develop it so often.

In addition, it is interesting to know what type of blockage they experience with question 28. The subjects had to classify it according a Likert scale ranging from 'less incidence' to 'major incidence'. (See Table 26)

Question 28 – Identify in terms of incidence the blockages that occur along design process.(1- LESS INCIDENCE e 5 –MAJOR INCIDENCE)

	Mean	Std. Deviation
Conceptual/ Creative	3,46	1,430
Technical/ related with lack of Knowledge	3,23	1,087
Technical/ articulation among parts	2,97	,843
Identification of sub-problems	2,64	1,112
Materials and its application	2,62	1,248
Production-choice/ selection	2,51	1,144

Table 26 | Frequency of Blockage type incidence

Again we found some consistency in the subjects answers. The blockage with highest incidence was the one related with the creative process; The second most frequent blockage type is the one that occurs during the technical development phase and that is related with the lack of specific knowledge.

Having hypothesized that blockage was an important element in the design process the question is how subjects overcome those inconvenient moments (question 29). Again a set of possible actions was previously selected based upon the experience of the researcher. The results of that assessment is presented in Table 27.

Question 29 - When blockage occur what type of actions you take in order to overcome the situation?

	Actions		YES	NO	Total
Conceptual/ creative	Design studio Teacher consultancy	Freq.	29	10	39
		%	74,4	25,6	100,0
	Other teachers consultancy	Freq.	9	30	39
		%	23,1	76,9	100,0
	Peers consultancy	Freq.	29	10	39
		%	74,4	25,6	100,0
	Process Revision	Freq.	19	20	39
		%	48,7	51,3	100,0
	Additional research	Freq.	31	8	39
		%	79,5	20,5	100,0
Technical/ related with lack of Knowledge	Design studio Teacher consultancy	Freq.	37	2	39
		%	94,9	5,1	100,0
	Other teachers consultancy	Freq.	34	5	39
		%	87,2	12,8	100,0
	Peers consultancy	Freq.	14	25	39
		%	35,9	64,1	100,0
	Process Revision	Freq.	1	38	39
		%	2,6	97,4	100,0
	Additional research	Freq.	28	11	39
		%	71,8	28,2	100,0
Technical/ articulation among parts	Design studio Teacher consultancy	Freq.	34	5	39
		%	87,2	12,8	100,0
	Other teachers consultancy	Freq.	30	9	39
		%	76,9	23,1	100,0
	Peers consultancy	Freq.	13	26	39
		%	33,3	66,7	100,0
	Process Revision	Freq.	6	33	39
		%	15,4	84,6	100,0
	Additional research	Freq.	17	22	39
		%	43,6	56,4	100,0

Identification of sub-problems	Design studio Teacher consultancy	Freq. %	31 79,5	8 20,5	39 100,0
	Other teachers consultancy	Freq. %	12 30,8	27 69,2	39 100,0
	Peers consultancy	Freq. %	18 46,2	21 53,8	39 100,0
	Process Revision	Freq. %	17 43,6	22 56,4	39 100,0
	Additional research	Freq. %	8 20,5	31 79,5	39 100,0
Materials and its application	Design studio Teacher consultancy	Freq. %	30 76,9	9 23,1	39 100,0
	Other teachers consultancy	Freq. %	29 74,4	10 25,6	39 100,0
	Peers consultancy	Freq. %	12 30,8	27 69,2	39 100,0
	Process Revision	Freq. %	5 12,8	34 87,2	39 100,0
	Additional research	Freq. %	28 71,8	11 28,2	39 100,0
Production choice/ selection	Design studio Teacher consultancy	Freq. %	30 76,9	9 23,1	39 100,0
	Other teachers consultancy	Freq. %	19 48,7	20 51,3	39 100,0
	Peers consultancy	Freq. %	9 23,1	30 76,9	39 100,0
	Process Revision	Freq. %	11 28,2	28 71,8	39 100,0
	Additional research	Freq. %	16 41,0	23 59,0	39 100,0

Table 27 | Actions undertaken to overcome blockage in design process

The most relevant insight given by the data treatment on question 29 is:

> In the conceptual creative phase (the one that subjects identified as being the one where blockage has more incidence) the first way used by students to overcome it is to do additional research (79,5%); Also important to prevail over these moments is the advise with the design studio teacher (74,4%) and with peers (74,4%);

> Regarding the blockages related with lack of knowledge that occur during the technical development phase it is unanimous among subjects that the best way to solve it is to consult the design studio teacher (94,9%) being also

important to assess to advise given by other teachers (87,2%) and to undertake additional research (71,8%). This is the phase among all, that presents more intense use of different resources to overcome blockage, either it concerns external advise or gathering of information.

> The peers advise is highly considered in the conceptual phase while the advise of both the design studio teacher and other teachers were considered when more technical phases are being addressed.

> The 'process revision' action obtains the lowest levels of adhesion on the part of the subjects although when compared with other actions it is not that low. That suggests that the reflection upon the already developed work is perceived by subjects as being less important than the reflection upon new information to be gathered (additional research action) or the reflection that is mediated by other individuals (teachers and colleagues).

Once again in the questionnaire is put forward another tool that can help the overall design process management: the diary. This is an instrument which use is traditionally incentivised along the design program. It aims to keep a record of both written ideas, sketches and schemes produced by the students. Table 28 gives the results on the subjects use of a diary.

Question 30 - It is usual for you to maintain a diary to register all the design process?

	Frequency	Valid Percent	Cumulative Percent
Yes	6	15,4	15,4
No	33	84,6	100,0
Total	39	100,0	

Table 28 | Use of a Diary

Not as predicted a significant percentage of the subjects state not to make use of a diary (84,6%). Although it was a bit surprising the high percentage of non use of this incentivised tool we tried to understand how subjects perceived the usefulness of that instrument. Moreover it was thought to go deeper and make an hypotheses test relating the use with the design strategies assumed by students along the design process. For that purpose it was necessary to make use of data collected from the experiments (done after the questionnaires) where it was possible to characterize each of the subjects in terms of their dominant design strategy. After and taking into account only those that make use of the tool (question 31 - If you answered YES to the previous question what is the usefulness of a diary? (1 – MINIMAL ;5- MAXIMAL)) the test was made.

Statistical anaysis of design strategy and design elements

A next step in the analysis is to evaluate if there is any relationship between the design strategy students choose (problem or solution or co-evolution driven) and a number of design related methods and tools they use or not.

Use and usefulness of a diary was in relation with design strategy was statistically tested by the Kruskal-Wallis test since three groups are compared (according to the design strategies with a variable on an ordinal scale, See Table 29 for the results.

Table 29 | Usefulness of a Diary vs Design Strategy – descriptive statistics (tested by Kruskal Wallis Test

Reasons to use the diary	Design Strategy	N	Mean	SD	Kruskal Wallis
It allows the identifications of all decisions taken along design process (31_01)	solution	17	,88	1,83	,97
	problem	12	,25	,45	
	co-evolution	10	,80	1,75	
It allows to reduce time when it is necessary to iterate in the design process (31_02)	solution	17	,65	1,32	,99
	problem	12	,50	1,17	
	co-evolution	10	,70	1,49	
It allows the evaluation of the process (31_03)	solution	17	,82	1,70	,96
	problem	12	,25	,45	
	co-evolution	10	,70	1,49	
It facilitates the characterization of the outcome (31_04)	solution	17	,76	1,60	,98
	problem	12	,50	1,17	
	co-evolution	10	,70	1,49	
It facilitates the defense and communication of the alternatives and solutions (31_05)	solution	17	,71	1,45	,98
	problem	12	,58	1,44	
	co-evolution	10	,60	1,35	
It allows the register of solution to be used in the future (31_06)	solution	17	,82	1,70	,98
	problem	12	,50	1,17	
	co-evolution	10	,70	1,49	

Although none of the values are statistically significant (no statistical significant differences were found with $p<0.05$.) it can be seen that Problem driven subjects display the lowest mean in all the usefulness options they had to classify. That is related with the fact that these students make less use of the tool.

A second element in design processes that was hypothesized to have an important role was 3D modelling. Therefore the question was raised up being the results presented in Table 30.

Question 32 - Do you model in three dimensions – models, mock ups – along your design process?

	Frequency	Valid Percent	Cumulative Percent
Yes	24	61,5	61,5
No	3	7,7	69,2
Sometimes	12	30,8	100,0
Total	39	100,0	

Table 30 | Frequency of modelling along design process

The analysis of the results confirms the use of modelling on the part of 93,3% of the subjects. Among them there are 61,5% that do it always and 30,8% that only do it sometimes.

In order to get more information about this 'tool' a follow-up (closed) question was posed. The answer alternatives were selected by the researcher on the basis of her professional experience both as designer and as teacher.

Answers on this question were compared with the design strategy chosen and statically tested with a Kruskal Wallis test (see Table 31).

Question 33 – If you answered YES or SOMETIMES in the previous question identify which are the reasons why you do it. 1. NON IMPORTANT REASON; 5 – EXTREMELY IMPORTANT REASON.

Reason behind the use of Modelling	Design Strategy	N	Mean	Std. Dev	Kruskal Wallis
By brief imposition	solution	17	2,06	1,35	.01**
	problem	12	3,17	1,59	
	co-evolution	10	3,80	1,62	
As a way of form selection among design alternatives	solution	17	2,88	1,62	.22
	problem	12	3,50	1,24	
	co-evolution	10	3,80	1,62	
As a way of selecting among identified technical alternatives	solution	17	2,29	1,11	.05*
	problem	12	2,08	1,00	
	co-evolution	10	3,20	1,55	
As a way of studying the articulation of different product components	solution	17	3,12	1,62	.24
	problem	12	3,83	1,40	
	co-evolution	10	3,90	1,73	
As a mean of anticipating problems in subsequent phases of the process	solution	17	2,76	1,56	.24
	problem	12	2,92	1,62	
	co-evolution	10	3,70	1,64	
As an instrument of product dimension gauging	solution	17	3,76	1,60	.76
	problem	12	4,25	,97	
	co-evolution	10	4,00	1,56	
As a product's communicational element	solution	17	3,35	1,80	.99
	problem	12	3,58	1,44	
	co-evolution	10	3,60	1,51	

Table 31 | Descriptive statistics – Reasons to Model 3D along design process vs Design strategy of the Subjects statistic (tested by Kruskal Wallis)

* *$p \leq 0{,}05$* ** *$p \leq 0{,}01$*

As it can be seen in Table 31 subjects with a co-evolution design strategy considered (a) the 'Brief Imposition' and (b) '... a way of selecting among identified technical alternatives' as being more important reasons for using modelling compared to the students with other design strategies.

Furthermore it was also our intention to address the role design softwares have in design process. Therefore the usual softwares used were listed and subjects had to score them according to its degree of importance (question 35) and after identifying its use in the different phases of design process (question 36) Tables 32 and 33 summarize the outcomes of these two questions.

Question 35 – Do you use design softwares and others along your design process? Identify which giving a score between 1 (LESS IMPORTANT) and 5 (THE MOST IMPORTANT).

	Mean	Std. Deviation
Autocad	3,59	1,551
3D Studio Max/Viz	2,64	1,597
InDesign	2,51	1,485
Adobe Illustrator	4,62	,747
Corel Draw	1,33	1,084
Flash Macromedia	1,28	,647
Photoshop	3,87	,923
Solid Works	3,28	1,849
Excel	1,05	,223
Powerpoint	1,56	1,021
Word	2,44	1,273
Project	1,15	,489

Table 32 | Descriptive statistics – Use of Design softwares and others along design process

Table 32 presents us the Adobe Illustrator and the Photoshop softwares as the ones that have higher means in terms of subject's use. However, it is important to say that from the first questionnaire to the second one there was found to exist other software that was intensely used by students: the Rhinoceros design software that was not integrated in the second questionnaire in order to make possible comparisons.

Question 36 - Signalize in which phase(s) of the design process you use those softwares.

Table 33 | Descriptive statistics – Use of Design softwares and others vs design process phases

Softwares	Process Phases		YES	NO	Total
Autocad	Conceptual phase	Freq. %	2 5,1	37 94,9	39 100,0
	Development phase	Freq. %	27 69,2	12 30,8	39 100,0
	Detail phase	Freq. %	30 76,9	9 23,1	39 100,0
	Production phase	Freq. %	11 28,2	28 71,8	39 100,0
3D Studio	Conceptual phase	Freq. %	3 7,7	36 92,3	39 100,0
	Development phase	Freq. %	11 28,2	28 71,8	39 100,0
	Detail phase	Freq. %	15 38,5	24 61,5	39 100,0
	Production phase	Freq. %	16 41,0	23 59,0	39 100,0

INDesign	Conceptual phase	Freq.	9	30	39
		%	23,1	76,9	100,0
	Development phase	Freq.	9	30	39
		%	23,1	76,9	100,0
	Detail phase	Freq.	10	29	39
		%	25,6	74,4	100,0
	Production phase	Freq.	15	24	39
		%	38,5	61,5	100,0
Adobe Illustrator	Conceptual phase	Freq.	24	15	39
		%	61,5	38,5	100,0
	Development phase	Freq.	23	16	39
		%	59,0	41,0	100,0
	Detail phase	Freq.	21	18	39
		%	53,8	46,2	100,0
	Production phase	Freq.	27	12	39
		%	69,2	30,8	100,0
Corel Draw	Conceptual phase	Freq.	3	36	39
		%	7,7	92,3	100,0
	Development phase	Freq.		39	39
		%		100,0	100,0
	Detail phase	Freq.		39	39
		%		100,0	100,0
	Production phase	Freq.	2	37	39
		%	5,1	94,9	100,0
Flash	Conceptual phase	Freq.	1	38	39
		%	2,6	97,4	100,0
	Development phase	Freq.		39	39
		%		100,0	100,0
	Detail phase	Freq.	2	37	39
		%	5,1	94,9	100,0
	Production phase	Freq.	4	35	39
		%	10,3	89,7	100,0
Photoshop	Conceptual phase	Freq.	24	15	39
		%	61,5	38,5	100,0
	Development phase	Freq.	18	21	39
		%	46,2	53,8	100,0
	Detail phase	Freq.	17	22	39
		%	43,6	56,4	100,0
	Production phase	Freq.	24	15	39
		%	61,5	38,5	100,0

Works	Conceptual phase	Freq.	5	34	39
		%	12,8	87,2	100,0
	Development phase	Freq.	22	17	39
		%	56,4	43,6	100,0
	Detail phase	Freq.	21	18	39
		%	53,8	46,2	100,0
	Production phase	Freq.	19	20	39
		%	48,7	51,3	100,0
Excel	Conceptual phase	Freq.	3	36	39
		%	7,7	92,3	100,0
	Development phase	Freq.		39	39
		%		100,0	100,0
	Detail phase	Freq.		39	39
		%		100,0	100,0
	Production phase	Freq.		39	39
		%		100,0	100,0
Powerpoint	Conceptual phase	Freq.	4	35	39
		%	10,3	89,7	100,0
	Development phase	Freq.	2	37	39
		%	5,1	94,9	100,0
	Detail phase	Freq.	1	38	39
		%	2,6	97,4	100,0
	Production phase	Freq.	7	32	39
		%	17,9	82,1	100,0
Word	Conceptual phase	Freq.	20	19	39
		%	51,3	48,7	100,0
	Development phase	Freq.	11	28	39
		%	28,2	71,8	100,0
	Detail phase	Freq.	6	33	39
		%	15,4	84,6	100,0
	Production phase	Freq.	15	24	39
		%	38,5	61,5	100,0
Project	Conceptual phase	Freq.	3	36	39
		%	7,7	92,3	100,0
	Development phase	Freq.	1	38	39
		%	2,6	97,4	100,0
	Detail phase	Freq.	1	38	39
		%	2,6	97,4	100,0
	Production phase	Freq.	1	38	39
		%	2,6%	97,4%	100,0%

A synthesized analysis of the results presented in Table 33 offer us the following conclusions:

> Design softwares are used in all the phases of design process with a special intensity in the technical and detail phases;

> Writing softwares are used mainly in the conceptual phase;

> Softwares of process management are rarely used by the subjects (2,6% - 7,7%);

> Software to support design communication (PowerPoint and Flash macromedia) have also low adhesion on the part of the subjects (from 2,6% to 17,9 %)

Besides characterizing the use intensity and its incidence according to the different phases of design process it was important to explore a few negative and positive implications of the use of these programs. Once again the construction of the offered options was based upon the experience of the researcher as well as in the literature revision. Again here we tried to test the hypothesis that the different design strategies would associate differently with the positive statements about the use of softwares it was found one significant statistical difference (Table 34).

When analysing Figure 34 the first to consider is that the aspects related with communication were the ones that obtained higher mean on the part of subjects.

Question 37 – Relatively to the use of softwares classify the following POSITIVE statements about it. Score it between 1 (DISAGREE) and 5 (AGREE COMPLETELY)

Positive Statements level of agreement	Design Strategy	N	Mean	Std. Dev	Kruskal Wallis
Its use promotes the generation of Ideas (37_01)	solution problem co-evolution	17 12 10	2,85	1,35	0,88
Its use promotes the process of selection of ideas (37_02)	solution problem co-evolution	17 12 10	3,15	1,33	0,73
Its use allows the generation of more alternatives in less time (37_03)	solution problem co-evolution	17 12 10	3,18	1,57	0,27

Its use allows the systematization of design process (37_04)	solution problem co-evolution	17 12 10	3,31	1,15	0,91
Its use improves the presentation aspects of the product (37_05)	solution problem co-evolution	17 12 10	4,64	,707	0,76
Its use contributes to a better overall quality of the design (37_06)	solution problem co-evolution	17 12 10	4,15	1,14	0,91
Its use is essential to achieve good outcomes (37_07)	solution problem co-evolution	17 12 10	3,56	1,33	0,55
Its use allows a faster and clear identification of the weaknesses and virtues of the design (37_08)	solution problem co-evolution	17 12 10	3,44	1,17	0,06**
Its use allows a more efficacious way of communicating the design (37_09)	solution problem co-evolution	17 12 10	4,31	,977	0,28

Table 34 | Descriptive statistics – Evaluation of positive statements about the use of softwares

** $p \leq 0{,}10$

As it can be seen in Table 34 subjects with a problem design strategy considered the positive statement 'its use allows a faster and clear identification of the weaknesses and virtues of the design' as being more important when compared to the students with other design strategies.

Question 38 - Relatively to the use of softwares classify the following NEGATIVE statements about it. Score it between 1 (DISAGREE) and 5 (AGREE COMPLETELY)

Statements	Mean	Std. Deviation
Its use compromises Idea's maturation (38_01)	2,51	1,233
Its use favours the diminishment of idea's exchange (38_02)	2,33	1,132
Its use promotes the lack of control in general design's time management (38_03)	2,44	1,231
Its use eludes the necessity of testing alternatives in a three dimensional way (38_04)	2,82	1,393
Its use favour choices based upon form/aesthetics aspects of the product (38_05)	2,95	1,169
Its use augments the risk that designer assumes wrongly as a study object the drawing peaces instead of the product (38_06)	2,77	1,266

Table 35 | Descriptive statistics – Evaluation of negative statements about the use of softwares

In terms of the negative statements that subjects perceived as being more relevant in the use of design softwares they are: the one related with the overvaluation of the aesthetics aspects of the product and the one that states the elusion of the necessity of trying alternatives through modelling.

There was not found statistically significant differences regarding the way different design strategies are associated with these negative statements about the use of softwares in design processes.

One of the issues related with design process and design cognition that is extensively studied is the iteration in the process. Consequently that was one of the issues addressed in the questionnaire (question 39).

Question 39 - Is it frequent for you to iterate along design process?

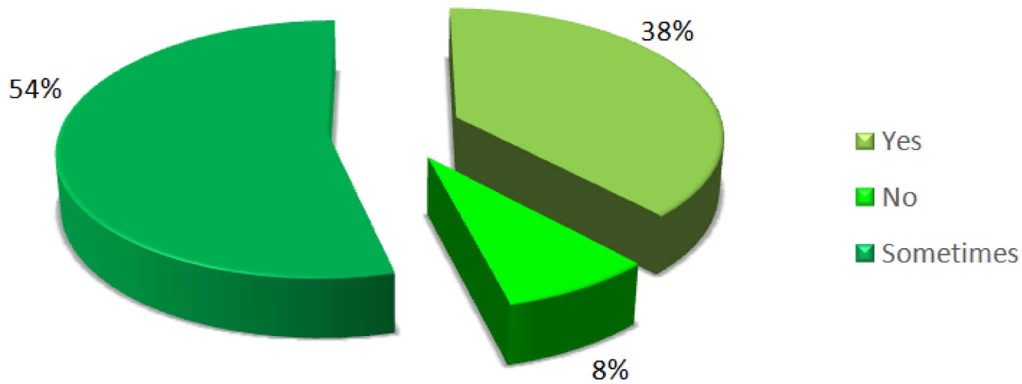


Fig.44 | Frequency of Iteration in Design Process

As predicted and aligned with results from literature iteration is frequent in design processes. In this case a total of 92% of the subjects acknowledge its occurrence. From those, 38% recognize that occurs always and 54% state that it occurs sometimes.

Once more in the questionnaire we posed a question related with time. The aim was to dissect this issue in the most accurate possible way. Question 40 addresses time trying to identify if the time available for design process is perceived as being adequate or not. From that a more deeper analysis was derived relating the perception of available time both with modelling activity (question 32) and with the use of diary (question 30). The aim was to try to understand how these variables relate themselves and if they are independent or not.

Question 40 – Would you say that, in general, the time available for the design process is?

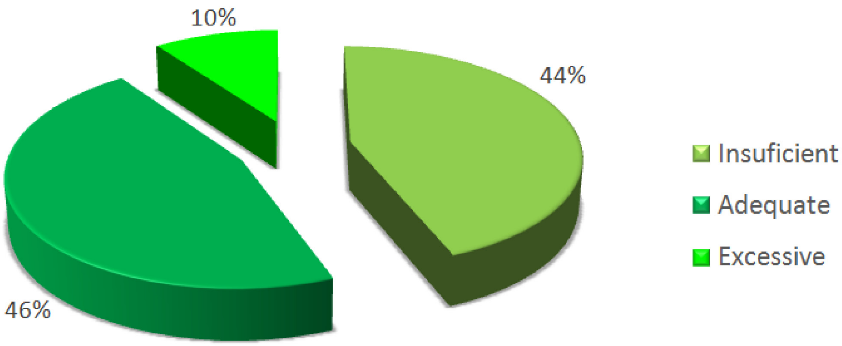


Fig.45 | Evaluation of the time available for the design process

When trying to explore possible relationship between the use of modelling along design process and the evaluation of the available time to be spent in design process it was found that the two variables are independent, i.e. they are not related since Chi-square (1) = 0,762, p=0,390. For that purpose it was also made the crosstabulation of the two questions which is presented in Table 37.

Table 36 | Chi Square test - relationship between the use of 3D modelling and the evaluation of time available for design process

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	,762	1	,383	
Continuity Correction(a)	,244	1	,621	
Likelihood Ratio	,765	1	,382	
Fisher's Exact Test				,465
Linear-by-Linear Association	,739	1	,390	
N of Valid Cases	33			

Table 37 | P32 * P40 Crosstabulation

		Q40		
Q32		Insuficient	Adequate	Total
Yes	Count	10	13	23
	within P32	43,5	56,5	100,0
	within P40	62,5	76,5	69,7
	of Total	30,3	39,4	69,7
Sometimes	Count	6	4	10
	within P32	60,0	40,0	100,0
	within P40	37,5	23,5	30,3
	of Total	18,2	12,1	30,3
Total	Count	16	17	33
	within P32	48,5	51,5	100,0
	within P40	100,0	100,0	100,0
	of Total	48,5	51,5	100,0

It was also tested if there were significant differences between the subjects that considered the time available to design process either insufficient or adequate with the degree of importance attributed by them to a tool such as the diary. It was concluded that the differences are not statistically significant because all the values of significance resultant from the Mann-Whitney[42] test are superior to the reference level of significance (0,05).

	31_01	31_02	31_03	31_04	31_05	31_06
Mann-Whitney U	146,50	145,00	145,50	140,00	140,00	143,50
Wilcoxon W	317,50	316,50	316,50	311,00	311,00	314,50
Z	-,280	-,344	-,323	-,559	-,559	-,409
Asymp. Sig. (2-tailed)	,780	,731	,747	,576	,576	,683

Table 38 | Mann-Whitney Test – relationship between available time evaluation and the use of a Diary

The information gathering and management was also one of the key aspects to be explored through the use of the questionnaire. Question 41 to 47, at different levels aim to gather information about this subject.

Question 41- Do you have the habit of building a 'library' of contents after the information of a finished design process?

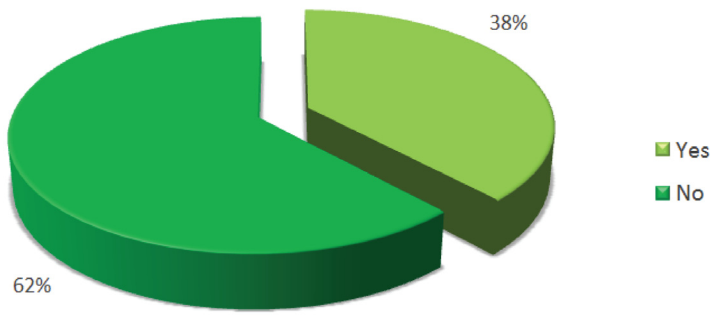


Fig.46 | Creation of a Library of contents

Figure 46 synthesizes the answer to question 41 about the creation or not of a library on the part of the subjects. In fact the 62% are not conclusive since it can still be that the subjects simple store the information in a folder.

One possible way of understanding the necessity of creation such a information system is through the questioning of if subjects have the habit of consulting previous designs (question 42).

42. It was used the test of Mann-Whitney since the comparison is between two groups where the dependent variables are of ordinal type.

Question 42 – It is usual to 'revisit' the concluded design processes?

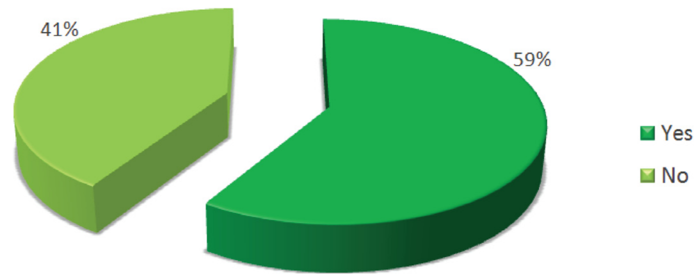


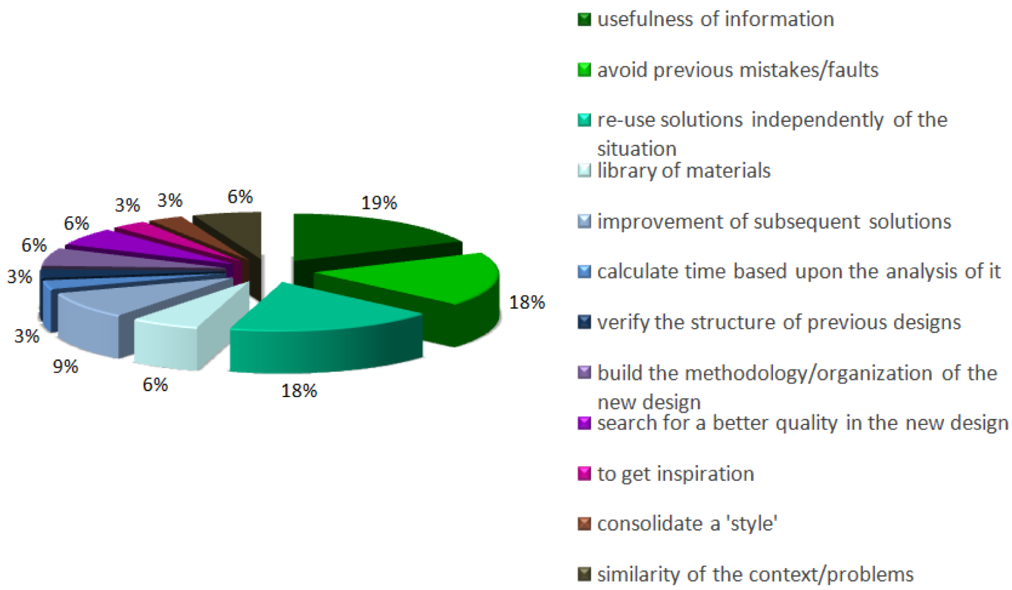
Fig.47 | Revisiting Previous Designs

Figure 47 show us that for 59% of the universe of respondents have the habit of consulting previous designs. Although one can have thought that this percentage should be higher the fact is that several studies recognized designers to have more tendency to explore new information relying less on previous collected one.

For those who gave a positive answer to question 42 it was important to know which were the reasons that made them do it. Figure 48 presents a synthesis of the answers given by the subjects. The fact is that this was one open question. It was made a content analysis and the definition of a few categories that could translate the subjects answers in a reduced organized way. The answers given by the subjects can be consulted in Appendix G.

Question 43 – If yes , which are the reasons?

Fig.48 | Reasons to Revisit Previous Designs



Besides consulting previous gathered or generated information it was also important to collect data related with the use of that retrieved information in new designs. That was done in question 44 which results are show in Figure 49.

Question 44 - Do you normally make use of elements from previous designs to new ones?

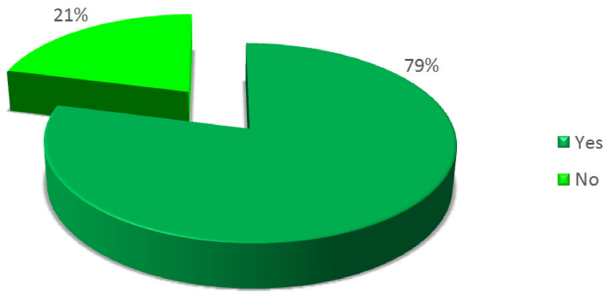


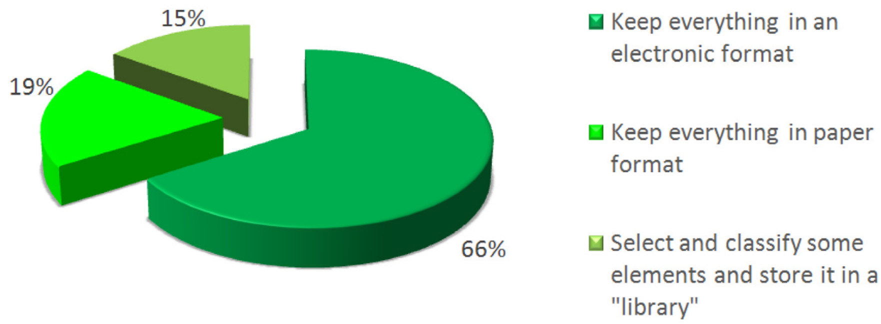
Fig.49 | Posterior use of gathered information

The interesting aspect on these results is that here there is a percentage of 79% of the subjects that have stated that they normally use elements of previous designs in new ones. However in question 42 that asked if subject had the habit to consult previous designs the percentage of positive answers was lower (59%) being even lower the average of those that stated having the habit of building a library of contents (38%). So it seems that there is always some retrieved information stored in the LTM that is effectively used in spite it is not stored in any other form.

The ways used to treat and store information resultant from design processes was also targeted by a specific question (number 45). The results are presented in Figure 50.

Question 45 - What do you usually do with the gathered information of your design processes?

Fig.50 | Gathered information storage



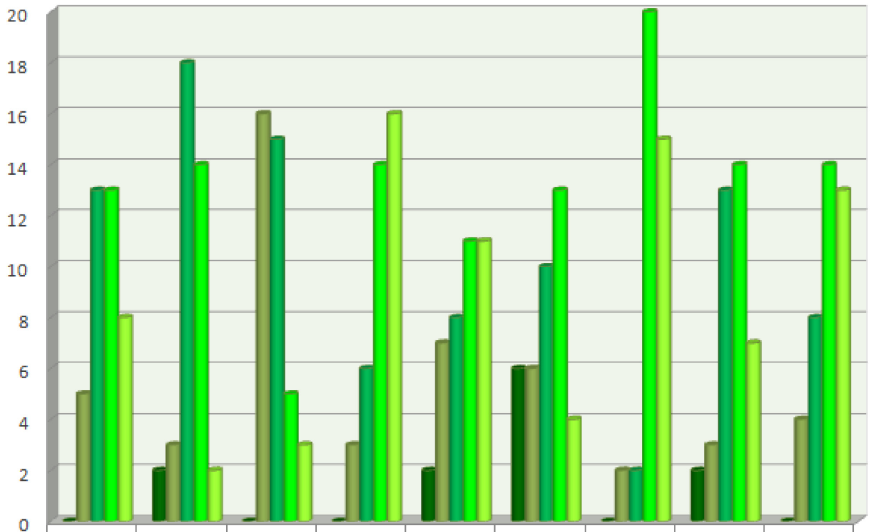
As predicted the majority of the subjects (66%) store the information of the whole design process in electronic format. The ones that make a selection and treatment of the information in deepest ways are in lesser percentage (15%).

This result is a bit contradictory with the one obtained in question 41 and there is no definite reasons to justify it since it was not made later assessment with the subjects regarding this inconsistency.

As previously mentioned this was an exploratory questionnaire. This aspect justifies the inclusion of questions such as question 46 that addresses several issues related with design process ranging from information management to the nature of the brief and its implications.

Question 46 - Classify the following statements according to the scale 1 (COMPLETELY DISAGREE to 5 – AGREE COMPLETELY)

Fig. 51 | Evaluation of statements about design processes



	46_01	46_02	46_03	46_04	46_05	46_06	46_07	46_08	46_09
Completely disagree	0	2	0	0	2	6	0	2	0
Disagree	5	3	16	3	7	6	2	3	4
Somehow agree	13	18	15	6	8	10	2	13	8
Strongly agree	13	14	5	14	11	13	20	14	14
Agree completely	8	2	3	16	11	4	15	7	13

46_01 - To collect information is easy but to treat it is very difficult

46_02 - To search examples of solutions to similar problems reduces the time of creation

46_03 - To pursue solutions is much more important then to structure in an adequate way the problem

46_04 - The process of conception is a constant 'come and going' among the definition of the problem, its context, and the possible solutions that again send us to new reformulations of the problem

46_05 - Problem and solution are two mutable and mobile elements in the creative process

46_06 - The design process must be initiated by the search of existent solutions

46_07 - The design process must be initiated by the problem framing

46_08 - When the brief is very accurate, limiting with exactitude the object to be created it is much easier to manage time

46_09 - When the brief is more free and does not exist a rigorous identification of the constraints, there is a bigger difficulty in time management.

Regarding question 46 it was also tested the hypothesis that subjects with different design strategies would have different evaluations of the statements. There was found one statistically significant difference as it can be seen in Table 39.

Statements	Chi-Square	df	Asymp. Sig.
To collect information is easy but to treat it is very difficult (46_01)	0,218	2	0,897
To search examples of solutions to similiar problems reduces the time of creation (46_02)	0,915	2	0,633
To pursue solutions in much more important then to structure in an adequate way the problem (46_03)	1,614	2	0,446
The process of conception is a constant 'come and going´among the definition of the problem, its context, and the possible solutions that again send us to new reformulations of the problem (46_04)	6,515	2	0,038*
Problem and solution are two mutable and mobile elements in the creative process (46_05)	2,03	2	0,362
The design process must be initiated by the search of existent solutions (46_06)	1,908	2	0,385
The design process must be initiated by the problem framing (46_07)	3,989	2	0,136
When the brief is very accurate, limiting with exactitude the object to be created it is much easier to manage time (46_08)	0,081	2	0,961
When the brief is more free and does not exist a rigorous identification of the constraints, there is a bigger difficulty in time management. (46_09)	2,514	2	0,285

Table 39 | Chi-Square Test – evaluation of statements regarding design process
* $p \leq 0,05$

Table 40 | Tukey's Test – evaluation of statements regarding design process vs subject's design strategy

The subjects categorized as having problem driven agree more with the statement: "the process of conception is a constant 'come and going' among the definition of the problem, its context and possible solutions that conduct us to new reformulations of the problem (m.o..=26,50)" than the ones of the other categories.

Design Strategy	N 1	Subset for alpha = .05 2	 1
solution	17	16,58	
co-evolution	10	18,05	18,05
problem	12		26,50
Sig.		,927	,104

Finally subjects had to answer to question 47 were a few statements regarding the role of the written parts should be classified according to a Likert scale ranging from completely disagree to agree completely. The statement that scored a higher mean on the part of the subjects was the one that says being the written parts adequate to the defense of the concept. The subjects also scored high the idea that the written documents are adequate media to communicate materials and technical specifications.

Question 47 – In relation to the written parts of the design project please classify the following statements giving scores between 1 (COMPLETELY DISAGREE) and 5 (AGREE COMPLETELY).

	Mean	Std. Deviation
They are necessary but complementary to the drawing pieces of the project (47_01)	3,51	1,144
They are essential to the design understanding (47_02)	3,74	,993
They work as a synthesis of the draw ideas (47_03)	3,79	,833
They are adequate to vehicle information about materials and techical specifications (47_04)	4,08	,900
They are adequate to the defense of the concept (47_05)	4,23	,872

Table 41| Descriptive Statistics – evaluation of statements about the written parts

SUMMARY OF SURVEYS

The results on the surveys showed that information management and time management (topics that structured the questionnaire content) were critical elements of the design process. Also relevant was the fact that most of the students describe design process phases in similar ways being more detailed (in terms of the tasks to be developed) in the initial phases and less in the last ones: Detail and pre-production.

Another result of this survey concerns the use of methods/tools to help manage the process. It was found that students mainly do checklists that do not have an effective influence in time and information management.

Furthermore it was concluded that the conceptual phase is the one students get more concentrated on and the one richest in terms of 'events' i.e. blockage, information management; contact with external elements such as peers and teachers.

Finally it was possible to assess to some fundamental issues to be studied through experiments such as the design strategy used by students (problem, solution or co-evolution driven).

1.1.2 Reflection on each one's own Design Process

To understand the way students perceive their own design process is important since it allow us to get information that is relevant in the later comparison to be made with the information gathered from an outside assessment of the student's design process. From that comparison (to occur in the chapter dedicated to discussion and conclusion) we hope to be able to make a good description of design processes in its essential elements.

Being the students perception about their own processes so relevant, a design exercise was developed in the Design Processes Management course, an optional course offered to the students of the 5th grade of the Product Design and Graphic Design Under Graduation courses (the last year of the old curricula). This exercise aimed at getting information on how design students see their own processes. By this way a structured personal assessment about design processes could be acquired complementing the data gathered in the surveys.

Besides that generic goal other objectives were:

> To test the consistency of the student's perceptions gathered in the surveys;

> To enlarge the information about design process perception on the part of the students as their agents;

> The identification of the elements students elect as being structural in design processes;

> The knowledge of the perceived difficulties students had along their design processes;

> The identification of the degree of awareness students have about their own cognitive and design processes.

Individual Work

Title: Design Process - a systematic and critical reflection

Schedule: to be done during the 3 first weeks in one of the 2 hours classes of the course.

A - Work theme - the reflection upon design process made through the critical analysis of a personal example and by the proposal of the improvement of it

B - Methodology: the work is to be developed individually and durin class's time. It must be constituted by two distinct elements: a retrospective analysis of a previous design process and the creation and proposal of a "new process". To do so the student must be deliver:

1. a synthesis model of the studied process - making explicit the different phases of it as well as aspects such the following: used information; constraints taken into account; decision made; swot analysis.

2. a synthesis model of the "new process" that must be adequately detailed.

C - Goals to reach/skills to explore: this is an exercise that as main goals:

1. the reflection upon the personal design processes of each student.

2. the development and consolidation of the analytical, interpretative and critical competences of the student.

D - Evaluation / Criteria
This exercise contributes in **30%** to the final mark of the course Design Processes Management.

a. Content evaluation criteria:
i. Rigour and clarity on the model execution and its explanation;
ii. Capability of clear expression of the reasoning lines that structure the analysis
iii. Ability of correlating the different listed tasks
iv. Ability of proposing and/or integrating other elements/ to perform other tasks that are justified to be necessary to the critical approach;
v. Clear domain of the Portuguece language both in the written and spoken register.

b. Form aspects evaluation criteria
i. Balance in aesthetical, colour, tactile and sound aspects from the part of the elements that form the whole;
ii. Communication ability of the written graphic, tactile and sound elements;
iii. Coherence of the relationship text and form;
iv. Originality on the relationship between text and form;

Fig.52 | Brief of Design Process exercise

The course with the exercise in it was lectured by the researcher. The exercise ran during the first three classes. A brief was delivered to the 32 students [Appendix H]. It stated that students had to describe their own design processes, defining the parameters of their analysis. Preferably the analysis should be presented as a diagram and could be complemented by text. After the deep insight assessment of the process used in one of their past design exercises they had to propose a way to improve their process modelling it again in a diagrammatic way.

All participant students filled in an informed Consent [Appendix I].

After the exercise there was a debrief session with the students in order to collect their impressions about the exercise regarding: a) the difficulties they experienced; b) what they have learned with the exercise.

A short English version of the exercise's brief is presented in Figure 52.

Working with diagrams

The analysis of the design processes exercise is important especially if we take into account that the students should preferably make use of the diagrammatic way of representation. This request has to do with the fact that diagrams as visual representations, are adequate to represent concepts and relations regarding quality, quantity, distribution, subdivision modification and transformation (Massironi, 1982, p.112).

The use of a graphic image to model the phenomena is assumed to be a good research instrument as well as a good vehicle to scientific information. What we get from the diagrams of the design processes of each student is their understanding of a design process in its components, relationship among elements, level of dependence among elements, dominance and subjugation of elements; emphasis and exclusion of elements.

Outcomes of the exercise

The large majority of the students had obvious difficulties to deliver the exercise. According to them it had to do with the fact that: a) they are not used to analyse their own processes and b) to describe them. Furthermore, the expressed preference of presenting the processes in a diagrammatic way was for them an additional difficulty. They asked for an example of what was expected for them to deliver, but they didn't get one. Only 29 students finished the exercise and it is on the basis of their work that the results are presented.

Three approaches were observed on the part of the students:

> A more conservative one, both in formal/ communicational aspects and in content structuring, where students ruled their own model construction according to the familiar phases of the design process, and listed the tasks to be developed, time spent; tools used; positive points and negative points of each phase. This approach was the one who had the preference of the majority of the students (69%) [see Appendix J]. Some of the diagrams were complemented with a descriptive text that contained more details about the issues addressed in it. The reasons to support such option were questioned to the students in a debrief moment. In fact in this debrief the majority of the students confirmed to have had a hard time to describe their own processes. They got fixated in the process phases determined by the brief of the exercise they were analysing. Besides that it was hard for them to identify what could be the determinant parameters in design processes and their role in it. An example of this type of diagram can be seen in Figures 53 and 54.

> A more creative approach (in graphic and content aspects) where students, although recognising the different phases of design process in the way they are used to work it in design studio, made their analysis according to parameters they had found to be essential in design processes [see Appendix K]. In this case 21% of the students presented their own processes with the inclusion of non-literally demanded elements such as:

new parameters of analysis or graphic elements that communicated different dimensions of the process. Also important in this type of exercises is the use of graphic elements to describe almost in 'visual' ways some key issues of the process. An example of this type of approach can be seen in Figures 55 to 59.

> An approach close to a 'story telling' report, very literary and supported by the images and other elements of the design process in analysis [see Appendix L]. The percentage of subjects that adopted this approach was the lowest (10%).

The synthesis of the analysis of the outcomes on this exercise was made through the use of two inductive content analysis grids that are presented in Tables 42 and 43. Data categorization occurred taking into account the results obtained in the survey as well as the literary critics.

The two inductive grids aims at presenting data in a concise and rigorous way trying to reduce the enormous amount of information into categories/patterns of solutions developed by the students.

The first grid offers the summary of the exercise in its structural elements: phases, descriptors used; identified problems; listed methods; proposed reformulations with a general analysis of the outcomes in terms of the model created (its characteristics) and of the written information delivered (see Table42).

The second grid (Table 43) presents the three approaches as a result of the critical and deeper analysis of the information presented in Table 42.

Table 42 and 43 show that the factors that were identified by the students as being more critical along design process were again information management and time management (like it was possible to observe in surveys). However, this exercise also revealed that there are other key factors that students find determinant in the design process: the decision making process is one of these.

Also relevant to mention is that the possibility of representing graphically their own design process gave some students the possibility of expressing in

GESTÃO DE PROCESSOS DE DESIGN

SUBJE	EXERCISE OUTPUT					RESEARCHER GENERAL ANALYSIS	
CODE	LISTED PHASES	USED DESCRIPTORS	IDENTIFIED PROBLEM S	LISTED METHODS	PROPOSED REFORMULATIONS	TYPE OF MODEL	WRITTEN ANALYSIS
S1	Research; conceptualization; development; Final Phase; exam	tasks description; methods/tools	lack of organization and planning; first sketches are hard to make; lack of technical ergonomic knowledge; bad decisions; renders delayed the process; bad time management; lack of motivation; lasyness	internet search; books; sketching; teacher discussion; production office work; softwares: thotoshop, illustrator; indesign; sketchup; autocad; V-Ray	extend the reseach time in order to contribute to better decisions; reduce time of choice of the concept; model earlier in the process to help decision making regarding alternatives; define technical drawings; improve communication elements of the design	conventional - 2 diagrams;	light analysis that did not capture the essence of the process; short information about the process in general
S2	work plan; research; concept; development, presentation, promotion,model	positive/negative aspects; tasks; dates; methods/tools	bad time management; technical concern blocked the process; other discipline's work; lack of software knowledge; hard time concentrating; lack of decision taking...	internet search; books; sketching; teacher discussion; production office work; softwares: thotoshop, illustrator; indesign; autocad;	more detailing programming of tasks;	conventional; 2 diagrams 1- real; 1 ideal; no relation with the object, sequential	short development of the ideal model; ...all to be defined according to the situation; definition of time and tools
S3	briefing; object's choice; research (product analysisand market and technological research); concept study; concept formalization; development and pre engineering; logotype and packaging; final design; prototype	method; output type; strenghs and weaknesses	indecision in the initial choice; research and data treatment; few sketches; quick choice of the idea to develop; lot os computer work, low use of hand designing ;	computer; renders, production office	not done	Conventional; well organized ; divided in two diagrams 1 - synthesis; 1- development (just from the description of the real situation)	effort of summarizing the description; attempt to identify in a clear manner what are the important variables.
S4	context analysis; concept definition; concept visualization;	tasks description; external factors; information management; methods	tiredeness; organizations; other work; language(foreign); idea blockage; expression difficulty	search internet; books and magazines; discussion with peers and professors; sketches	adoption of a process methodology and a reflection upon each design concluded.	conventional; very simple and accompannied with a descriptive text	report type of description that lacks depth.
S5	Analysis; research; concept; development; model	tasks description; postive and negative aspects; methods	lack of material culture; bad selection of the initial m atrix; lack of specific knowledge; time management;	internet; books; InDesign; sketches; illustrator	broaden research; adopt a decision/consequence attitude in the initial phase; avoid design fixation; manage time among phases; predict a time to support umpredicted problems	conventional; 2 schems : real and ideal; no support in design images	supported by a description of the facts in each phase
S6	research; ergonomic studies; concept(creation); development; justification; final result	strenghts and weaknesses	creative blockage; weak research; external factor; bad time management;	sketches, renders	more extense and detailed research; concept - creative process more productive; development of a good product defense	weak conventional diagram ; sequential; no use of the design to support the analysis; very descriptive;	weak; research; inability of isolate variables that interfere ith the process;
S7	research; concpet study; formalization of the concept; development	calendar; task description; negative/positive aspects; resources; outcomes of the phases	problem assessment; difficulties in the selection among alternatives; time management; scarcity of specialized information	other porducts search; Illustrator; books; Rhinoceros; Autocad; peers and professors consultancy; sketchup	not done	conventional; reference to the design; superficial analysis	a context of the exercise is donein descriptive ways
S8	theme choice; pre-research; goals; pre-concepts; selection of a theme; research; formalization; conclusion; presentation	tasks description; methods/tools; resources; difficulties; enablers	dispersion in the choice of the theme; cultural differen ces; monotonie of the technical work; climat influence; language differences; communication barriers	internet search, teacher consultancy; sketching; 3D modeling; photocomposition; autocad, Illustrator; 3D studio Max;	did not made it	conventional; sequential; not use of the design to support the analysis; detailed description	
S9	research; idea generation; attempt/Error; final solution	experiment; knowledge; pressure (parameters just pointed out for the solution)	time management; disperse research; lack of link between research and the concpetual phase; lack of productivity		very creative but not explored in depth.I25		
S10	initial analysis; preliminary research; deep research; research organization; concpet generation; concept definition	tasks description; postive negative aspects; methods	uncertainty; excess of information; excess of ideas and no method to make a choice;	internet; books; brainstorming<<, illustrator; sketches; keywords; renders; journalistic description;	not done	conventional; lack of depth; huge additional information about the design	extensive appendix with the design; lack of ability producing a deep analysis of the process
S11	research; analysis; idea generation; debate; general idea; experiment; general idea 2; final solution	stimuli description; facilitator elements; characteristics-key words in each phase; constraint analysis; decision analysis	tecbhologic access; consumer's mindset	swot; information; schemes; sketches; talks; virtual and physical models	not done	creative especialy in terms of content/descriptors - makes use of a general design process grid of analysis and after presents the design using it;	stimuli: external; rational; emotional; creative; intuittive; affectional; key words in phases: 1) research (choice; variety; specificity); analysis (depth; categorization; reevaluation; comprehension); idea generation: (broathedenss; diversity; ammoubt); debate (context; variety; concentration; communication; dispersion; flexibilty); general idea 1 (manipulation; complexity; quality); experimentation (evolution; make; understand); general idea 2 (complexity; quality; final solution (simplicity; syntesis; communication; quality)
S12	work plan; research; concept; development, presentation, promotion, exam 1 and exam 2	method; output type; strenghs and weaknesses	bad time management; bad conciliation with other work(courses); personal problems; lasyness.	think; observe; sketch; photos; books; net ; production office- sofwares_ illustrator; photoshop; rhinoceros	more and more focused research; more time to concpet creation;use of unblocking processes/methods; more models and with different aims; more iteration in the process;	conventional diagram ; sequential; no use of the design to support the analysis;	enormous ammount of information gathered; difficulty of antecipating subsequent phases; creative blockage have a crucial role;
S13	0	0	0	0	0	0	0
S14	information research/Brief; concpept phase; predesign/detailing; final design	Failure; methods; time/delays	difficulties in defining the goals; teacher's material n ot interesting; lack of interest in the theme; lack of plann ing; most viable concept was uninteresting; dispersion into subsolutions; lack of commitement; late revision of unwanted aspects/elements of the design	online search; images database; skecthes and schemes made in computer; softwares: illustrator; indesign;photoshop; acrobat; model	respond to appointed failures	conventional diagram; description of the tasks to be performed in each phase well done; analysis based on the negative points	
S15	Briefing; choice of the object; first sketches(exploratory); conceptual sketches (materialization); product definition; development; tridimensional object	Input/output - tasks description and questions; methods	some failed ideas in constructive and productive terms; technical problems ; difficulties when modelling the obj ect; time management	computer; hand sketches	search new means of information; reduce time of sketching phases; trust more her own instincts(intuition); less concern with details not neccessary to the scale of work; search new ways of modelling to have reduced time of deliver	conventional diagram; poor in graphic terms and not deep in terms of content ;	lack of ability in identifying the key elements to analyse the process; lack of critical assessement of her work
S16	introduction to product; analysis; research; concpet; development; commercialization; model	chronogram; task definition; description; goals; tools; importance; posture; data that is tranfered; data that is abandoned; methods	umpredicted work or problems; user's not integration in the process	talks and discussions with professors; internet; books; softwares;	generate information new, unique, inovvative; structure the peocess upon decision and information checkpoints;	mixed report and creative model; intensive use of the design to support the analysis	very detailed report that benefited of the ability of synthesis and detection of the key aspects in the process
S17	workplan; initial research; conceptual research; concept study; concept formalization; technical research; development; deliver	calendar; task description; negative/positive aspects; tags - deliver; deliver with failures; not delivered; alterations; necessities along process; methods/tools	hard time management; scarce information; lack of motivation; overlapping of other work; lack of software expertise;	sketching; internet search; local observation; InDesign; Illustrator; reasoning; teacher consultancy; production office; Rhinoceros; Autocad	match the plan of the work with other work from other disciplines; develop information management skills; more rigour to avoid correction in futher tasks; modeling to support development phase; prototype with time to make corrections	conventional; sequential; 2 diagrams . Real and ideal; does not use the design to support the description;	
S18	problem interpretation; selection of priorities; identification of the interest of those priorities; search for analogies in other manifestations; research; idea generation; idea development; selection; development of the concept; model; external evaluation (peers and professors); final object	inputs; inspirational sources; influences ; social interaction; time graph	time management; information management	modeling as a though developer; depth search of images(deconstruction of the objects); exploration of geometric structuring; exploring painting and the impossible persectives...philosophy	early brainstorming; creative diary with checklist; earlier analysis of ideas.		description of t he student "my process is a methodic desorganization" ruled by a constant evaluation; association with the methodic doubt; high quality in the foundational principles of the design process; seduction as a key element; rich analysis
S19	research; pre concepts; presentation; concpet formalization; choice of concept; development; final design; presentation	external influences; attitudes; consequences: positive and negative	resources constraints; climat influence; teacher autocracy; lack of empathy with teacher; cultural differences; routin e and lack of rythm of the classes	internet search;	did not made it	conventional; sequential; does not use the design to support the description	short development of ideas; lack of deepness in the analysis
S20	briefing; data launch; design conceptualization; definition of a preliminary solution; development od the solution; modelling; evaluation	task description; chronogram;	lack of contact with users	library; books; internet search; photoshop; illustrator;	presented a extense description of a design process and its tasks done by another author; reflection on the processes	extensively descriptive and with the structure of a report . Highly supported by the design in its several phases	real process - descriptive in a very egocentric way; ideal process - presentation of a methodology proposed by others.
S21	context; research; formalization of research; concept study; final research; final concpet; final phase; formalization; formal model; improvement; formalization of improvement	method; strenghs and weaknesses	technical and related with the study object; definition of the characteristics of the product; dificulty in get abstracted from its technical characteristics; decisions-form concepts; time management - phase of prototype production	rhinoceros, production office...	focus the research; more revision on the research done; abstract from technical issues while thinking the concept; more rational decision process - exclude parts; direct; consistent; more process pauses; seek an outside view; manage time; do not hesitate in modelling decisions (experiment solutions)	mixed diagram - tries to translate formaly the degree of complexity of each phase; study of the concpet is seen as problematic; execution of the model is seen as well succeded; the other phases are assumed as being regular.	Adds important paralel processes: rest; speak with friends; focus on decision making; It is clearly centred in the Product. Solution driven student.
S22	brief study; product choice; research; concept search; formalization of concept; development	strenghts and weaknesses; methods and tools, inputs and outputs	broaden research; indecision; technical lack of knowledge; lack of time for the concept definition; bad time management in general; lack of software knowledge	internet research; obsertion of other objects; sketching; talks wit teachers, books	not done	conventional and deficiently explored.	Problem driven
S23	research; generate concepts; development; technical drawings/modelling; prototype; product	external variables and industry constraints (general);	information management; lack of sources references; lack of feedback to the gathered images; lack of technical research			symbolic/use of an analogy - poor in graphic terms	the analysis of the diagram suggests being the most problematic phase the one of research - problem/context are hard to approach. The studnt is clearly solution driven.
S24	problem analysis; base program discussion; models; layout of pageas; technical specifications; development; editing	green/yellow/red execution; teacher presence/influence; schedule accomplishment	bad time management; infuence of personal issues; lack of detailing and quality of the final outcomedue to co sts; difficulty in deciding the creative solution	talk and discussion with teacher; modeling; public presentation	consolidate initial research; make a good analysis of resources (costs, time); iteration in a controled way	mixed- report and two diagrams; one that makes an analogy with semaphores and that has a sequential mode and the second one that assumes the process in circular basis that are ruled by a triangle client- designer-resources	the written part is descriptive in the case of the description of the real situation and it is more effective and propositive in relation to the ideal process
S25	brief; concept development; detail; prototype; digital model	information - used; lost; stimuli - positve/negative; task description	delivery of other work; motivation; costs;bad time management; lack of organization	Indesign; Photoshop; illustrator; books; catalogs; internet	reduce information research and better use of it; reduce stimuli in the last phases	creative/descriptive; very clear diagram where it is possible to understand the process in the key elements	synthetic analysis that balances aspects of the process and a didactic information about the design itself.
S26	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0
S28	initial analysis; preliminary research; deep analysis; research organization; concept generation; concept definition	tasks description; methods/tools	information management; selection of alternatives; decision making	internet search; sketching; autocad and illustrator; discussion		traditional diagram; strongly supported in the design (huge ammount of drawings were delivered as appendix)	there was scarce information written... Lots of drawings to explain the process
S29	briefing (3-3); dig up(6-6); research (7-7); concept(22-28); development 14-34); model	actions; support; positive and negative aspects; deliver (output)	bad information management; lack of time to access the market; irrealistic goals; early narrowing of ideas; search of problem and solutions made with lack of support; waste of time with additional research in other contexts; lat e model making; overlapping of tasks; late teacher's input demand ; lack of adequation form concept to production; final execution problems (printing)	thinking; teachers input; experiments; market input ; software programs: autocad; photoshop; illustrator, rhinoceros; indesign;	more rationality in the process; sistematization and choice always supported by a better and adequate information;	conventional, supported by a chronogram; compared chronology of events; very quantified analysis; no connection or support of the design being analysed.	time is a central factorin this analysis; 60 actions are listed; there was a underestimation of time from 47 days it went to 73 days - the gap occured in the concept phase (28 days agianst 22 predicted) and in the development phase (34 against 14 predicted). This is a solution driven student.
S30	aassignment analysis; object search;work planning; research; concept; development; final deliver	constraints; facilitators; inspirational insights; other constraints	colleagues options; cheap object; problem interest; time management;lack of research focus; technical implications; mental blockage; lots of iteration; perfectionism and drawing difficulties; oral communicatio n difficulties;aversion to routine; flack of patience; lack o f knowledge about the producibility degree of the design	informatic tools; friends; conferences; music; cinema	decision making more objective; get out of rational reasoning when entering the concpetualization phase; work on the autotrustness; search different approach perspectives; draw exhaustively; hierarquize better the options; know how to filter and use information;	Conventionall; product image; adds a synthesis diagram	very detailed; short time spent in idea generation although it is a solution driven student
S31	orientation; researches; concept; formalization; development	degree of difficulty(scale 0-5); task description; methods; easiness/hardness	stagnation on the first forms; overlapping of phases; ba d time management;	Thinking; sketches; photos; softwares: illustrator, Indesign, Cad,Rhinoceros, word;V-Ray; production office work; 06-03-2010	new methodology - orientation- problem structuring- generation of alternatives- development	Conventional; well organized ; divided in two diagrams 1 -real; 1- ideal	scarce elements in both diagrams; the real is a descriptive one; the ideal is a generic one with special emphasis on time management and a description of tasks to be performed as well as tools. Co-evolution driven student
S32	Briefing; research; sketching/preliminary ideas; decision making; development; model	chronogram; task definition; description	lack od specialized knowledge; lack of sofware knowledge; hard time with decision-making; problems with pressure;	books search; internet search; peers talks; Indesign	access to client; adoption of a methodology; frame experimenting actions; look for a more holistic perspective of the problem; trust more the intuition and instinct; better choice among alternative solutions;better time managemnt.	extensively descriptive; like a report	descriptive in excess; it is hard to identify the problems, the solutions all the type of possible descriptors... It looks like an oral speech.

Table 42 | Synthesis of the analysis of the design process's exercise (to present in A3 format)

		CONVENTIONAL DIAGRAMS (20)		CREATIVE DIAGRAMS (6)		DESCRIPTIVE (REPORTS) (3)	
		Analysis of the design process (based in previous design)	Proposed design Process	Analysis of the design process (based in previous design)	Proposed design Process	Analysis of the design process (based in previous design)	Proposed design Process
CONTENT	structure	dependent on design brief specification of phases;	structured upon the design phases student uses	not necessarily dependent on the design phases of the brief; more flexible strcture	it can assume a high level of abstraction	extensive description of the process sometimes close to a diary language	descriptive methodology or just a descriptive text that advances ways of improving the experienced negative aspects of the process
CONTENT	parameters/ descriptors	most often used: design phases; task definitions; chronogram; methods; negative/positive aspects	identical parameters making use of the negative aspects to find out solutions to overcome the failures	social interaction; stimuli; cognitive aspects; decision analysis; constraint analysis; facilitators	identical to the analysis of the existent design process	hard to isolate in this 'story telling' process	Conventional, In the cases a methodology ispresented the parameters are the ones addressed in the conventional mode.
CONTENT	level of abstraction from the design	low - the analysis are made based upon the constraints and context of the design process under study	low to medium - some proposal are still dependent on the particular problems found out in the design process that was analyzed	medium to high - analysis is based upon a process but broaden categories are created and inductive thought occurs	mediem to high - normally higher than in the analysis of a 'real situation' - the levels of abstraction are superior	completely dependence on images of the design done	variable - can be dependent or completely independent through the proposal of an existing methodology
CONTENT	more relevant aspects	Regarding content the most relevant aspects are: 1. conventional diagrams convey in a 'literal' way the design process being studied; That apparently constrained the possibility of induction in order to create a more critical assessment of the process. 2. This representation made possible to students to get aware of their own process although it was hard for them to isolate the categories upon which the analysis would be done: 3. The creative approach was done in two ways: content and form. In what content concerns the creativity occurred by the creation of parameters of analysis that were not conventional or found in the existent methodologies; 4. In general it was more succeeded the task of describing an existent process than to propose a new one. That was done either by proposing the improvement of negative aspects previously pointed out or in vague terms, supported by existing design methodologies.					
FORM	representation	sequential scheme; notation of boxes; geometric forms connected through the use of lines, arrows; a color code is normally used to enhance communication and help to isolate and/or group some of the elements	similar to the representation in the case of the analysis of a previous design	intense use of fluid forms; of analogies translating several aspects of the design process	normally it is a natural sequence of what was developed in the analysis of a previous design	the usual use of images done in reports; images complementing the information given in text	written text only
FORM	use of images	low (sometimes there is the use of some images to put in context the 'reading' of the diagram)	non existent	non existent	non existent	extensive use of images that illustrate the descriptive text	non existent
FORM	more relevant aspects	1. The visual representation of the design process in general benefited the communication of those processes; 2. Even in conventional representations it was possible to convey expressively the relationship among parts and the dynamics of the process itself; 3. The creative representations that explored more the form aspects gave some students the possibility of going deeper in their analysis; 4. It was also visible that the students that had more creative approach were the ones that had more ability to engage in inductive thought.					

Table 43 | Main characteristics of the three types of outcomes (to present in A3 format)

Gestão de Processo de Design – Reflexão Crítica e Sistemática

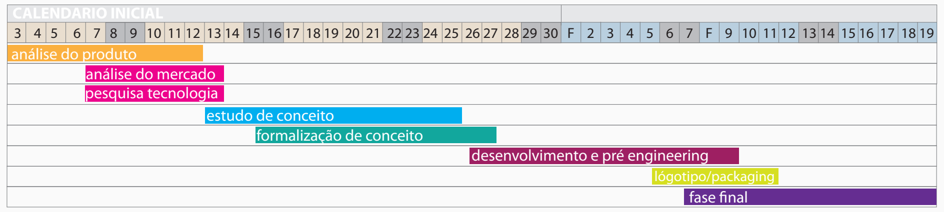
“Interface do produto”

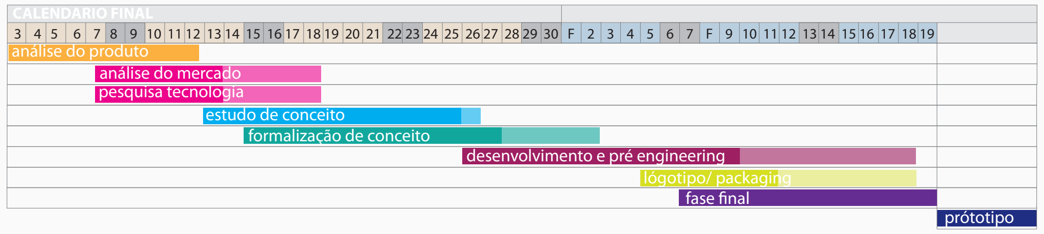
No decorrer da disciplina de projecto, foi-nos proposta a criação de um electrodoméstico que tinha como ponto de partida a escolha de um produto já existente que iria servir de base ao nosso produto. Pretendia-se a identificação e interpretação do objecto através das peças que constituem a essência do seu funcionamento mecânico e/ou electrónico, atrases da decomposição do mesmo, retirando todos os componentes que tenham uma função de cobertura e interface com o utilizador.

Na fase inicial deparei-me com alguns problemas no que diz respeito á escolha do produto a trabalhar, pois tendo em conta que o objectivo seria desmontar todo o aparelho, quis limitar a minha escolha a electrodomésticos velhos que teria em casa. Numa primeira recolha os objectos que seleccionei não me agradavam, tendo mais tarde encontrado um que me agradou recomeçando todo o trabalho do zero.

Devido a esta indecisão quanto ao objecto a trabalhar perdi cerca de uma semana em relação aos meus colegas de turma, e para não perder mais tempo e me organizar segui o concelho dos professores, e elaborei de um plano de execução do projecto, que consistia na divisão do processo de trabalho em fases, e o tempo que a principio iria demorar em cada fase limitando o tempo a cada uma.

Ao longo de todo o processo de trabalho o meu calendário sofreu alterações, tendo no fim do projecto um calendário com tempos diferentes dos inicialmente estipulados.





ANÁLISE DO PROCESSO DO PROJECTO DE DESIGN

	Briefing	Escolha do objecto	Pesquisa: Análise do Produto	Pesquisa: Pesquisa de mercado / Pesquisa de Tecnologica	Estudo de conceito	Formalização de conceito	Desenvolvimento e Pré engineering	Logotipo / Packaging	Final	Prótotipo
desenvolvimento do projecto	- Lançamento do trabalho	- objecto já existente	- História - Público alvo - Análise do produto - Mercado: marcas	- Analogias - Mercado: marcas - Análise de mercado - Análise de materiais - Novos conceitos	- Novo conceito -“O que o público quer” - Esboços - Ideia final	- Medidas gerais - Aspecto final - Estudo de materiais - Componentes necessários	- Desenhos técnicos - 3D e 2D - Renders - Explodidas	- Estudo do logotipo - Cores . Packaging - Marketing/ folheto promocional	- Resumo do trabalho efectuado até então	- Material a usar - Prototipo - objecto - embalagem
metodo		- Recolha de objecto velho em casa	- Pesquisa na internet - Desmantelamento do objecto	- Pesquisa na internet	- Pesquisana internet - Esboços á mão levantada	- Esboços realizados no computador - 3D	- Realizado no computador	- Realizado no computador	- Realizado no computador	- Realizado á mão
entrega			Caderno	Caderno	Cartaz	Caderno	Caderno	Caderno	Cartaz	Maquete 3D
análise + -		- Dificuldade e indecição na escolha do objecto a trabalhar	- Pesquisa e tratamento de informação da 2ª fase na fase de analise do produto, criou alguma repetição nos cadernos entregues		- Realização de poucos esboços - Chegada á ideia final muito rápidamente partido logo para a fase seguinte	- Deixei de lado o lápis e começei logo a trabalhar no computador - Desenvolvi a ideia directamente no computador limitando-me por vezes um pouco - Vantagem de ter noção das medidas reais, logo sei com o que posso contar.	- Devido ao desenvolvimento directo no computador, tinha esta fase já muito desenvolvida	- Primeira ideia resultou bem tendo sido essa e final - Se a primeira ideia resultou caso tivesse desenvolvido mais, poderia ter tido um resultado ainda melhor	- Resumo do resultado final, recolhido da informação tratada até então	- Devido a ter conseguido entregar tudo a horas tive bastante tempo para a realização desta fase -Como nesta fase estava de férias deixei tudo para a última hora tendo o prototipo do produto ficado com algumas imprefeições que devido ao tempo que tive não deveriam de existir.

CONCLUSÃO

Em jeito de conclusão e agora já com algum distanciamento posso dizer que foi um trabalho com o qual não tive grandes problemas, a não ser na fase inicial a quando da escolha do objecto a trabalhar, pois após o ter escolhido não surgiram grandes percalços pelo caminho, tendo sido a realização do calendário essencial a isso, visto que me ajudou a organizar, não me permitindo dispersar e me perder nas diversas fases essenciais á realização do projecto. Apesar de ter prolongado todos os prazos estipulados inicialmente para cada fase, não considero que seja grave pois futuramente vai ser de grande ajuda para perceber onde é que necessito de mais tempo para a realização de um projecto.

Ana Laranjeiro Serrazina nº 6045 D5A Gestão de Processos de Design Docente: Rita Almendra FA_UTL 2008/2009

Fig.53 | Design Process of Ana Serrazina (subject 3; Appendix J)

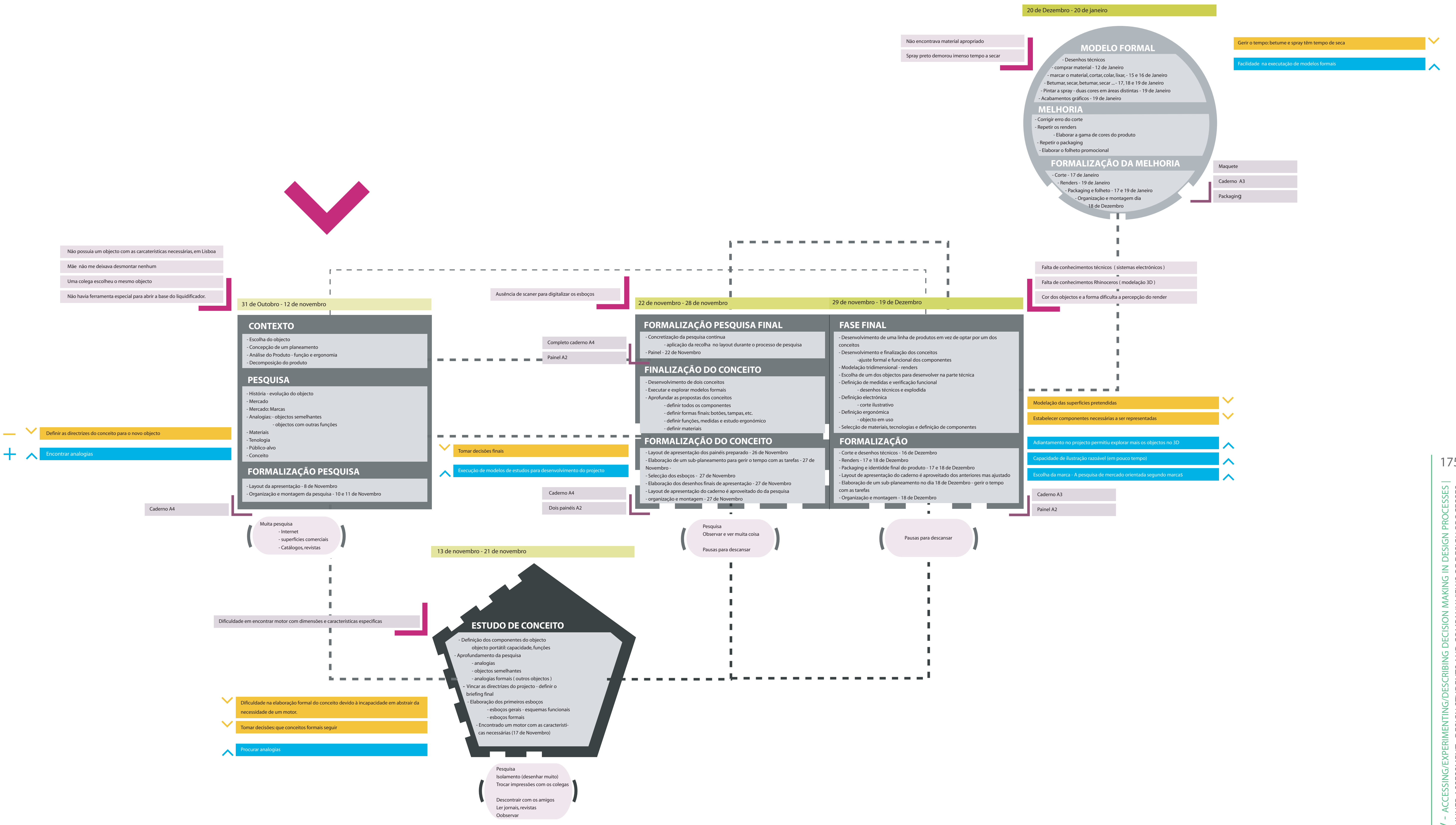


Fig.54 | Design Process of student Patrícia Couto

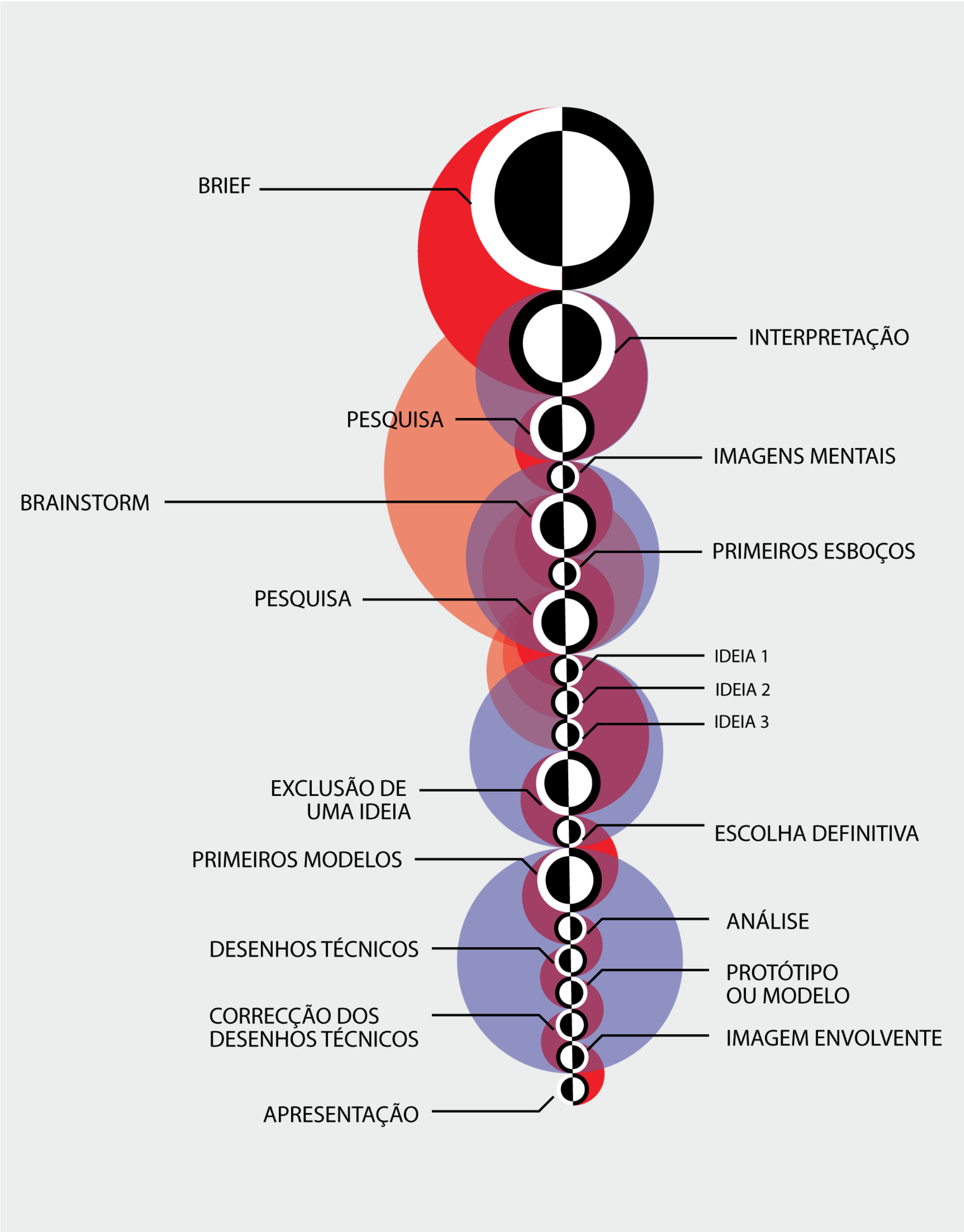


Fig.55 | General Design Process model of Mariana Coutinho (Subject18; Appendix K)

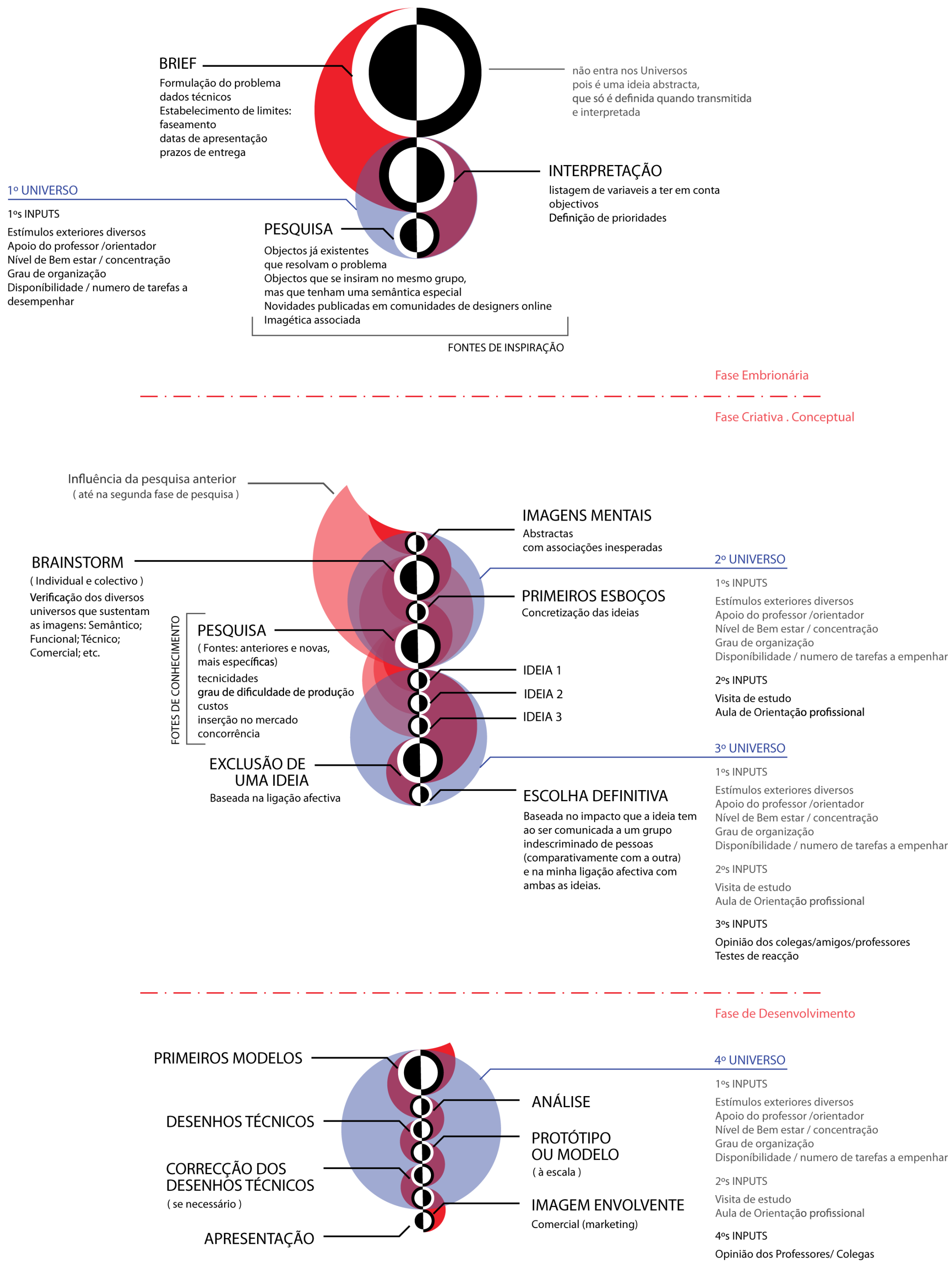
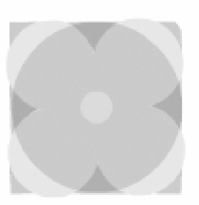


Fig.56 | Detailed description of the process (Mariana Coutinho Subject18; Appendix K)



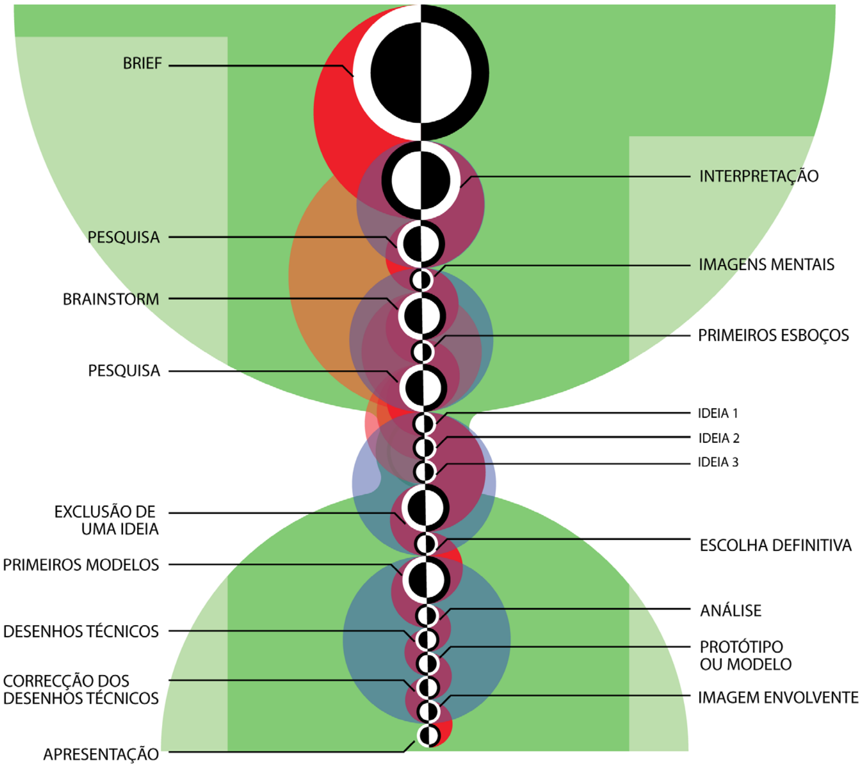


Fig.57 | Analysis of the process in terms of social interaction of Mariana Coutinho (Subject 18; Appendix K)

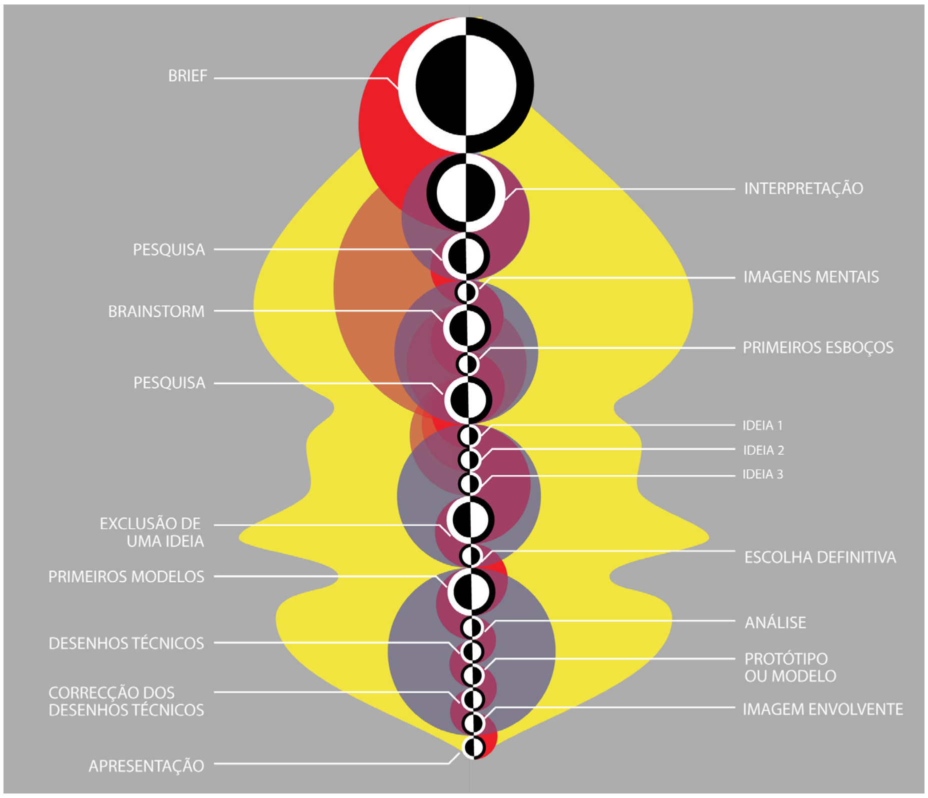
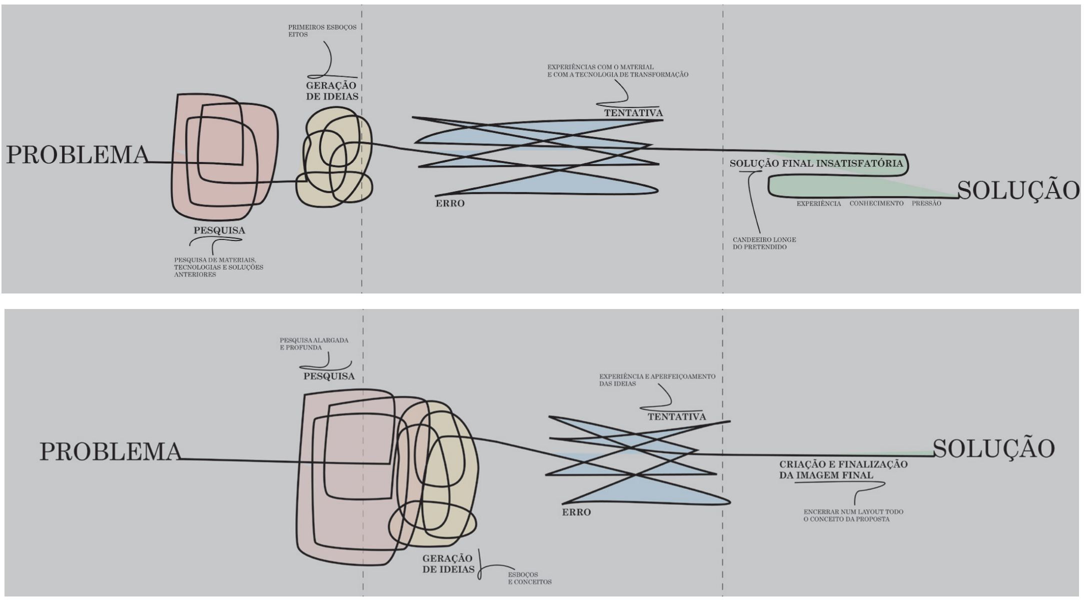


Fig.58 | Process analysis in terms of time spent from Mariana Coutinho(Subject18; Appendix K) more creative ways the richness and the complexity of those processes. Apparently, and according to students in their debrief moment, this way of presenting their assessments of the process worked for them as a facilitator of the reflection process upon not only an existent design process but also upon design processes in general. Regarding the two analyses to be done (a critical assessment of an existent design process and a proposal for a design process) the majority of the students found it very hard to propose an alterative/ improved model. Those who made such a new model did it on the basis of proposing improvements of the negative aspects enclosed in the design process they had to analyse.

Fig.59 | Process analysis and its improvement (David Francisco - Subject 9; Appendix K)



SUMMARY OF THE DESIGN PROCESS EXERCISE

As a special exercise in the course 'design process management' students were requested to make an analysis of their own design process. They had to do it by, preferably, making use of a diagram to represent their process. They also had to propose a reformulation of their process in order to overcome the weak points detected in the existing process.

The Surveys among students and this exercise proposing a visual representation of design process were two methods used to access information about the same subject: (determinants of the) design process.

It was thought that the use of diagrams or any other visual schematic representation would facilitate the delivery of information about the design process. That was because graphic representations, seen as a way of analysing an 'object' could more easily be adopted by these 'visual experts' as a rich mean to proceed to its decomposition in its structural elements and in the multiple and diverse relationship that are established among them.

However, it was noticeable that these students never had thought in depth about their own design process. Therefore, it was visible (especially after the debrief session with them) that through this (learning) experience they became aware of several aspects of the process they never reflected upon before.

Moreover, the results show that the majority of the students had difficulties with inductive thinking. Starting from the description and analysis of a specific design process to ending up with a proposal of a general model to frame design processes was hard to accomplish.

1.2. How industry sees design processes and the quality of the outcomes - based upon the survey made to Portuguese manufacturing industry

The De.:SID research project was created having has one of the main purposes the one of making a diagnosis of the use of Design inside the manufacturing Portuguese Industry. The project was born from the necessity, felt by the researcher, of having data about the Design situation inside portuguese companies since that characterization would be essential to develop the particular study of design processes. It also allowed us to assess the way processes in general are viewed by business practitioners.

The Portuguese Foundation for the Science and Technology (FCT) funded the project that started on the 3rd of September from 2007 and will end in January 2011. The research project is coordinated by Professor Doutor Luís António dos Santos Romão (FA) and it has nine more researchers from the areas of Management, Economy, Artificial Intelligence and Design. Moreover it has two partners: The CPD (the Portuguese Design Centre) and the APD (The portuguese Association of Designers).

Besides the diagnosis of the use of Design in the manufacturing Industry the project will create a software (to be used by the industry) which will allow each company to make its diagnosis, benchmarking and to access to some advise regarding the implementation of an adequate use of Design.

In this thesis we will refer one of the activities of the research project where we had an intense participation. It is the case of the National Survey to the Portuguese Manufacturing Industry that will be analysed in the next pages.

An online survey, addressed to a sample of 1405 Portuguese manufacturing companies, was developed and launched by the De.:SID research project. This online survey was preceeded by an online pilot survey (made to a sample of 60 firms).

The survey sample was representative of the Universe being studied and it was bought by De.:SID to the Ministério do Trabalho (MT)[43].

The questionnaire that was created has six sections: I) General Characterization of the company; II) Perception of the Importance of the Use of Design; III) Identification of the drivers and enablers of Design used by the company; IV) Attitude and action of the company's management towards design use; V) Company's Evaluation of Design Results; VI) Barriers to the Use of Design [Appendix M]

At the end of the process the number of respondents was of 99. The analysis will be presented on this number.

The author's contribution to this De.:SID action was done at different levels: a) the construction of the questions tothe pilot survey; the construction of some of the questions of the survey and an active contribution to the overall design of the questionnaire [Appendix N presents an example of it]; b) an intense participation in the development of the rules for the relationship between questions and the weight of each one in the definition of the degree of design use maturity on companies; [Appendix N] c) participation in the analysis of the outcomes;

43. Labour Ministery.

The descriptive statistics of the online questionnaire [Appendix O] are too extensive. Therefore only a summary of the outcomes will be presented here. The focus of our analysis is on the way companies perceive and evaluate design processes and the quality of design.

In order to understand which variables play a key role in the success of the Business area of companies a first question was formulated in which respondents could rank in order those 'critical factors'.

As can be observed in Table 44, 'Quality' and the 'Design and Technological Innovation' are the factors that mostly influence business success. That is relevant for this research since we have chosen to focus on quality even without knowing that it had such representativeness in terms of business development.

Table 44 | Main Success Critical Factors of the Business area of the companies
(question 10 De.:SID Quest.)

Critical Factors Business	Frequency	%	% Valid	% Cumulative
Quality	25	25,3	27,2	27,2
Design and Technological Innovation	10	10,1	10,9	38,0
Competition	9	9,1	9,8	47,8
Costs / Price	8	8,1	8,7	56,5
Market / Marketing / Brand	8	8,1	8,7	65,2
Services	6	6,1	6,5	71,7
Human Resources / Formation / Qualification	6	6,1	6,5	78,3
Location / Facilities / Equipments	5	5,1	5,4	83,7
Management Strategies / Partnership / Organizational Structure	3	3,0	3,3	87,0
Product / Product Portfolio	2	2,0	2,2	89,1
Client Relationship / Satisfaction / Fidelity of Clients	2	2,0	2,2	91,3
Raw Materials	2	2,0	2,2	93,5
Financial solidity and capacity	2	2,0	2,2	95,7
Eficacity / Deliver time / Velocity to market	1	1,0	1,1	96,7
Production	1	1,0	1,1	97,8
Quality / Price relationship	1	1,0	1,1	98,9
Flexibility	1	1,0	1,1	100,0
Total	92	92,9	100,0	

Furthermore, besides the 'critical factors' that are common to all the companies acting in a specific area of business it is important to consider the 'core competences' which refer to what the firm itself knows to do better than its competitors. The ideal situation is when we have 'what has to be done well' (the business critical factors) aligned with 'what we do better' (the core competences of the firm).

The analysis of Table 45 confirms 'Quality' and 'Design and Technological Innovation' as the core competences assumed by the larger average number of the firms. It also shows that that percentages of both ('Quality' and

Table 45 | Main Core Competences of the Firm (question 11 De.:SID Quest.)

	Frequency	%	% Valid	% Cumulative
Quality	34	34,3	36,2	36,2
Design and Technological Innovation	13	13,1	13,8	50,0
Human Resources / Formation / Qualification	8	8,1	8,5	58,5
Market / Marketing / Brand	6	6,1	6,4	64,9
Services	5	5,1	5,3	70,2
Eficacity / Deliver time / Velocity to market	5	5,1	5,3	75,5
Flexibility	5	5,1	5,3	80,9
Client Relationship / Satisfaction / Fidelity of Clients	4	4,0	4,3	85,1
Product / Product Portfolio	3	3,0	3,2	88,3
Costs / Price	2	2,0	2,1	90,4
Production	2	2,0	2,1	92,6
Location / Facilities / Equipments	2	2,0	2,1	94,7
Financial solidity and capacity	2	2,0	2,1	96,8
Raw Materials	1	1,0	1,1	97,9
Quality / Price relationship	1	1,0	1,1	98,9
Management Strategies / Partnership / Organizational Structure	1	1,0	1,1	100,0
Total	94	94,9	100,0	
Missing	5	5,1		
Total	99	100,0		

'Design and Technological Innovation') are higher than the ones presented in the previous table. That is not unusual since there are several 'business critical factors' intervening at the same time and firms do not dominate completely all the competences at the same level. The combination of all is what might guarantee a good performance in the market, meaning a competitive advantage.

With the answers to these two questions we may assume that 'Quality' and 'Design' are central to business in general. However, it is important to understand how the Industry perceives Design, its presence in firms and the role it can play in business.

A next question was, therefore, what were the associations the firm made with Design. Table 46 shows that 'Innovation' as the strongest association. It also shows the

Table 46 | Factors associated with the term Design (question 12 on De.:SID Quest). N=94

	Average	St. Deviation	Variation Coefficent
Innovation	2,40	1,958	1,23
Product Development	2,17	2,108	1,03
Functionality	1,90	2,120	0,90
Quality	1,89	2,061	0,92
Brand building	1,64	2,026	0,81
Aesthetics	1,55	2,035	0,76
Marketing	1,32	1,930	0,68
Concept Development	1,03	1,799	0,57
Technological Development	,80	1,577	0,51
Cost reduction	,77	1,484	0,52
Trends	,73	1,490	0,49
Research	,49	1,233	0,40
Form Aspects	,38	1,192	0,32
Process	,17	,757	0,22
Sustainability	,16	,794	0,20
Others	,05	,516	0,10

close relationship of Design with 'product development' and 'functionality' (a product centered vision of Design). Nevertheless 'Quality' is also associated in meaningful ways with Design and again we have here a reinforcement of the need to deepen more our understanding of how quality in Design can be worked on.

Also relevant is to notice how distant (in terms of firm's perception) is Design from 'research' from 'Process' and from 'Sustainability'.

In addition to the perception of the firm's concept of Design it was important to understand which were for each company the main drivers of Design. Drivers are seen as reasons for Design Usage inside the companies.

The drivers were grouped according to the categories: Firm; Competition; Clients; Strategy; Industry and Suppliers. These categories were used also in other studies like the one promoted by Designium (UIHA – Helsinki University) and developed under the coordination of Nieminen (2005). On that particular case, of Finnish companies, it was found out that:

"the most important drivers are the maturity and velocity of the industry, customer type, and the size of the company. The less usual design usage is in the industry, the more beneficial it is. Design can be part of solutions that are not typically used in the industry. The experience in design usage affects the intensity of design utilization but also the results. The more experienced design user that the company is, the more difficult the implementation is to copy. It seems that the most important factor for success in design usage is the direct connection between business goals, product strategy and design strategy, as well as the link between brand and corporate identity and design goals". (p.77)

When observing the results in the Portuguese context (Table 47) the drivers that play a key role are, in sequence: the firm's image/reputation; the innovation capabilities of the competitors; the product itself; the strategy of differentiation and the quality of the clients. Apparently there is a main difference in the reasons that drive Design inside the firms in these two different contexts (the Finnish being more mature in terms of the Use of Design), showing that in the Portuguese context the reasons are more restricted to the firm’s sphere of influence and less dependent on the Industry as a whole.

	Average	St. Deviation	Variation Coefficent
Firm: image / reputation	,73	,444	0,61
Competition: innovation capability	,64	,483	0,76
Firm: product	,57	,497	0,87
Strategy: differentiation	,56	,499	0,88
Clients: quality	,53	,502	0,94
Firm: company's culture	,48	,502	1,05
Industry: Product life cycle	,40	,493	1,22
Strategy: Market niches	,39	,491	1,25
Industry: negotiable power of clients	,39	,491	1,25
Industry: type of products	,38	,489	1,28
Strategy: internationalization	,37	,486	1,31
Competition: strategies	,37	,486	1,31
Industry: technology	,37	,486	1,31
Clients: type of clients	,36	,483	1,34
Clients: client’s sophistication	,32	,469	1,47
Firm: competences	,32	,469	1,47
Industry: threat of new competitors	,30	,460	1,54
Strategy: diversification	,27	,444	1,67
Firm: production	,21	,411	1,93
Competition: competences	,20	,404	2,00
Suppliers: certification	,20	,404	2,00
Industry: threat of substitute products	,20	,404	2,00
Strategy: costs reduction	,18	,387	2,14
Suppliers: sophistification of suppliers	,18	,387	2,14
Firm: process	,15	,358	2,40
Firm: Top Mangement	,14	,347	2,51
Firm: firm's dimension (scale of production)	,13	,335	2,63

Clients: certification	,12	,323	2,76
Industry: degree of rivalry	,10	,296	3,09
Industry: maturity	,09	,281	3,30
Strategy: cooperation	,07	,264	3,54
Firm: location	,06	,246	3,85
Industry: legislation	,05	,226	4,24
Firm: Learning	,05	,226	2,24
Strategy: vertical integration	,04	,203	4,77
Industry: negotiable power of suppliers	,03	,177	5,54
Strategy: acquisitions / fusions	,00	,000	

Table 47 | Main Drivers of Design inside the companies (question 13 on De.:SID Quest). N=94

Although the perceptions firms have about Design are important to know, they will be influenced by the actual use of design, by the type of contact they have with it and for how long they have it. Table 48 shows that 30% of the firms use Design longer than 10 years and 27% use it less than 10 years.

	Frequency	%	% Valid	% Cumulative
Less than 10	27	27,3	32,9	32,9
10 to 19	30	30,3	36,6	69,5
20 and more	25	25,3	30,5	100,0
Total	82	82,8	100,0	
Missing	17	17,2		
Total	99	100,0		

Table 48 | Number of Years the Firm uses Design (question 16, De.:SID Quest)

Going deeper in the understanding of the type of use firm's make of Design a question was raised that expresses different levels of maturity in the use of Design. This level of maturity is a concept developed by the Danish Design Centre (DDC) in 2003 and is presented in Figure 60 under the designation of 'Design Ladder' [44].

One of the major challenges of De.:SID research project was to define the parameters which allow us to classify a firm according to this four steps model. Therefore, it

44. According to DDC "The design ladder is a useful 4-step model for grouping companies' design maturity on the basis of their attitudes towards design. The higher a company is up the ladder, the greater strategic importance design has for the

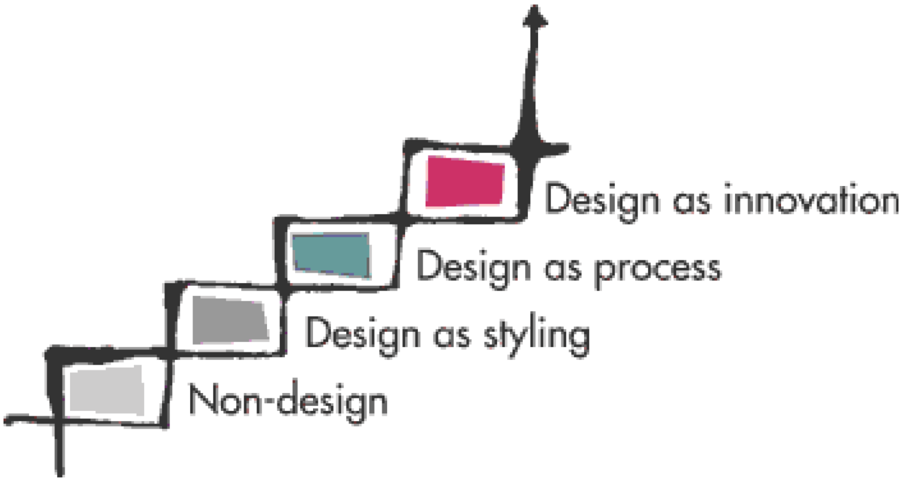


Fig.60 | The Design Ladder (Source: DDC, 2003)

was made a complex study of the relationship between the questions being addressed in the questionnaire and the levels of maturity established by the Design Ladder model. One of the questions that addresses directly that issue is question 15 where firms must indicate the type of attitude they have towards Design. The options of the question are not stated the same way the Design Ladder displays it (see Figure 60). The correspondence between the two (as discussed among the ten researchers of the project after making a literature review) was defined as follows:

> Non-existent activity -> Non Design;

> Occasional Activity/Activity of Modelling/shaping the product -> Design as styling;

> Design as a competitive factor of business/core competence integrating each of the firm's decision -> Design as a process;

> Design as a catalyser of permanent innovation -> Design as innovation.

Figure 61 show us that 42,4% of the firms indicate to be on Step 3 of the Design Ladder; 28,3% are on Step 2 and 15,2% indicate being on Step 4 of the Ladder. However, evidence after data treatment shows that, in general, firms indicate a level of maturity that is higher than what exists in reality (see De.:SID survey Report to be published in the internet address http://desid.fa.utl.pt/).

company. First step: Non-design - Design is a negligible part of product development etc., and any design activities there are fall to professional groups other than designers; Second step: Design as styling- Design is seen solely as relating to the final physical form of a product. This can be the work of a designer, but is usually created by other employees. Third step: Design as process - Design is not a result but a method that is integrated early on in the development process. The production outcome requires contributions from a range of specialists. Fourth step: Design as innovation - The designer works closely alongside the company's owners/management on a complete or major renewal of its business concept." (DDC, 2003)

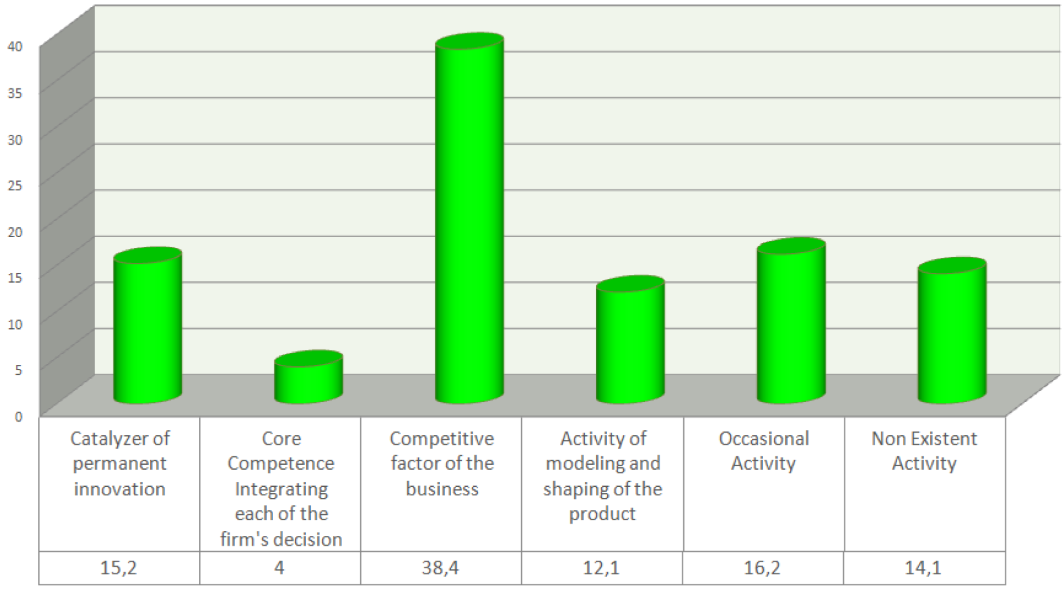


Fig.61 | Characterization of Design Activity (2005 to 2007) – question 15, De.:SID Quest.

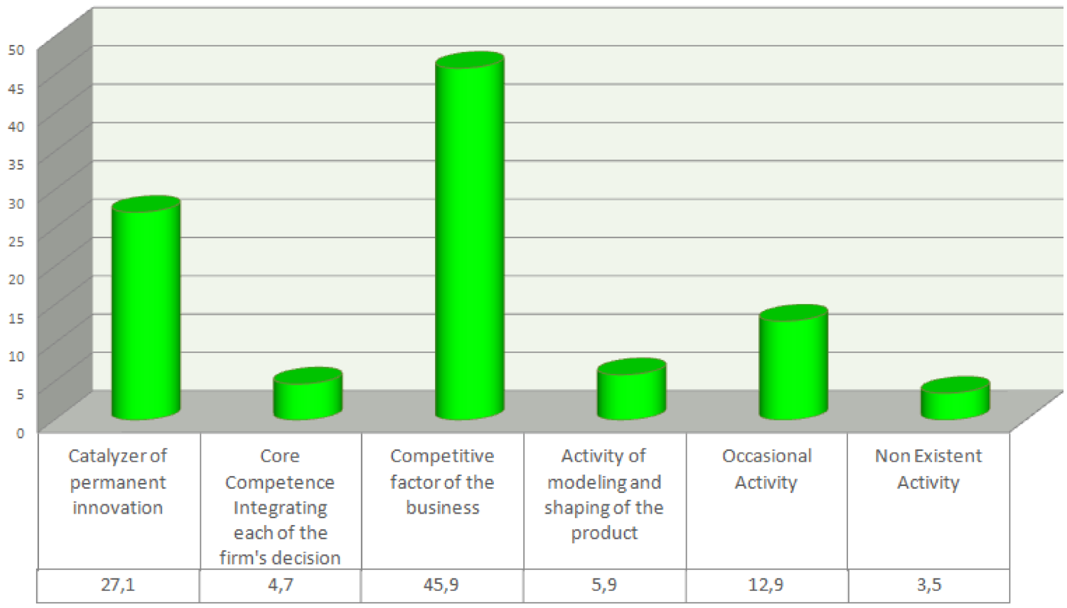


Fig.62 | Characterization of Design Activity (predicted to 2008 to 2010) – question 17. De.:SID Quest.

Additionally it was important to gather information about the evolution in the attitude towards Design firms expected to go through. Figure 62 shows that firms, in general, intend to move up on the Design Ladder.

Deepening the analysis we come to a question that has to do with enabling Design[45] use inside firms. Table 49 presents the results obtained with a question addressing the type of involvement Administration and Management have in the Design Activity.

	Frequency	%	% Valid	% Cumulative
No Involvement	4	4,0	4,9	4,9
Low Involvement - intervenes only in crisis moments	14	14,1	17,3	22,2
Median Involvement - participates in decision making moments	37	37,4	45,7	67,9
High Involvement - permanent	26	26,3	32,1	100,0
Total	81	81,8	100,0	
Missing	18	18,2		
Total	99	100,0		

Table 49 | Involvement of Administration/Management with Design Activity (question 19, De.:SIDQuest.)

The table shows that in the sample of 81 firms that answered the question 47% indicate that administration has a median involvement in Design activities while 32% say that it has a high involvement in it.

Related with the question of the level of involvement of the Top Management in Design is the question about the (evolution in) investment they are willing to do in it.

Table 50 shows that in a sample of 84 companies 54% intend to maintain their current level of Investment in Design while 36% say they aim at a slight increasement.

Regarding the investments made in Design firms were asked to characterize its nature and relative weight. Table 51 shows that the type of investments are divided among the acquisition of tools, other equipments and software (39,4%), the support of Marketing Activities (31,3%), acquiring external knowledge (30,3%) and Education 24,2%).

45. Enablers are issues that companies should consider when implementing design strategies and organizing design usage. Enablers can be further categorized into three parts: design in vision and strategy development, design management, and operative design usage, corresponding to the three level of Design management inside the firms: the strategic, the tactic and the operational one.

	Frequency	%	% Valid	% Cumulative
Strong Reduction	2	2,0	2,4	2,4
Slight Reduction	1	1,0	1,2	3,6
Maintenance	45	45,5	53,6	57,1
Slight Increase	30	30,3	35,7	92,9
Strong Increase	6	6,1	7,1	100,0
Total	84	84,8	100,0	
Missing	15	15,2		
Total	99	100,0		

Table 50 | Predicted evolution of the Investment in Design (2008 to 2010) (question 21, De.:SID Quest.)

Investements in Design	% "YES"
Aquisition of tools, other equipments and software	39,4
Supporting Marketing	31,3
External Knowledge Acquisition	30,3
Education	24,2

Table 51 | Investments in Design made during the period from 2005 to 2007 (question 23, De.:SID Quest.)

Another possible enabler of design use inside the firms is Leadership. For that reason firms were asked to indicate who are the persons/functions responsible for the leadership of new projects of R&D Innovation and Design. Table 52 summarizes the outcomes.

Only 59 out of 99 firms answered the question of leadership[46]. Taking that number as the total we see that projects are lead by a range of functionaries, most frequently by Top Managers (29 %) and less frequently by marketers (8,5%). However, these numbers were found not to reflect exactly what happens in firms. The case-studies performed in the same period that included visits to the firms and interviews with the CEO and other responsible persons from the areas of Design and Marketing shows a different reality: leadership, at least at the strategic level of Design intervention, is done mostly by the Top Management structure.

46. The fact that there are only 59 respondents is directly related with the circumstance that the electronic survey had a mechanism of detecting (after a few central questions were answered) the level of maturity of the firm. As a consequence some firms had to answer only 15 questions; others 37 and the remaining the total number of questions.

	Frequency	%	% Valid	% Cumulative
Top Managers	17	17,2	28,8	28,8
Designers	14	14,1	23,7	52,5
Product Managers	10	10,1	16,9	69,5
Product Engineers	7	7,1	11,9	81,4
Expert (Technicioan)	6	6,1	10,2	91,5
Marketeers	5	5,1	8,5	100,0
Total	59	59,6	100,0	
Missing	40	40,4		
Total	99	100,0		

Table 52 | Leadership of New Projects of R&D, Innovation and Design (question 24, De.:SID Quest.). N=59

The openness firms show towards external entities and the aptitude they reveal to cooperate with those at the level of Design processes is also considered to be a good enabler of Design Use inside the companies.

This question is particularly important for this research since it focuses directly on the relationship firms establish with universities (or research centres).

	Average (Dicotomic Scale "0-1")	St. Deviation	Variation Coefficient	% "YES"
Clients	0,364	0,48	1,33	36,4%
Suppliers	0,293	0,46	1,56	29,3%
Technological Centers	0,242	0,43	1,78	24,2%
Universities	0,202	0,40	2,00	20,2%
Research Centers	0,152	0,36	2,38	15,2%
Others	0,030	0,17	5,69	3,0%
Local Communities	0,010	0,10	9,95	1,0%
Finantial Institutions	0,010	0,10	9,95	1,0%

Table 53 | External Entities involved in the Design Processes (question 26, De.:SID Quest.)N=99

Table 53 shows that from the 99 firms 36,4% declared to have relationship with clients and 29,3% with suppliers, which is common in terms of the dynamics of companies and its stakeholders. Among these external entities the technological centres account for 24,2% followed by the universities with 20,2% and the research centres with 15,2%. The low percentages in general indicate that firms rely mostly upon own resources. The rather poor involvement of the universities makes us aware that much can still be done to strengthen the relationship between university education&research and industry.

The access to the three levels of design intervention inside the firms (strategic tactic operational) was reason for the researchers of De.:SID to design questions addressing specifically each level. One of those is question 31 that tried to isolate the factors that, in the firm's assessment, contribute more to create Value in the Product.

Table 54 | Factors that contribute most to Value in Product (question 31, De.:SID Quest.)N=84

Table 54 shows that 'economic factors' are the most important when creating product Value (65%). It is

	Average	St Deviation	Variation Coefficient
Economic Factors (Cost)	0,65	,478	0,73
Innovation	0,63	0,49	0,77
Atractibility	0,40	0,49	1,22
Ability to suprise	0,36	0,48	1,35
Reliability	0,33	0,47	1,42
Conformity with specifications	0,31	0,47	1,50
Performance	0,30	0,46	1,55
Utility	0,29	0,45	1,59
Security	0,29	0,45	1,59
Durability	0,27	0,45	1,64
Usability	0,24	0,43	1,80
Manufacturability	0,23	0,42	1,86
Ability to adapt	0,19	0,40	2,07
Identify	0,18	0,39	2,16
Simplicity	0,12	0,33	2,74
Universal character	0,11	0,31	2,90
Recyclability	0,05	0,21	4,50
Maintenance	0,05	0,21	4,50
Proficiency	0,01	0,11	9,17

closely followed by 'Innovation' (63%). The aesthetical/ communicational aspects are relevant to firms since 'attractiveness' and 'ability to surprise' score high (40% and 36%). Less influential are aspects related with performance, functioning and manufacturing.

Furthermore the De.:SID questionnaire incorporates a question (Q.35) that is equal to the one presented in the annual survey to Innovation made by the European Community (EC). It is an essential question since it allows us to see if innovation is growing in products and processes either by creating new or by improving existing ones. The question asks if the firm in the years of 2005, 2006, 2007 as introduced new products and processes and improved products and processes.

Innovation rate – New products/New Processes (%)			
	2005	2006	2007
Introduction of New Products	47,5	50,5	53,5
Introduction of New Processes	32,3	34,3	44,4

Innovation rate – Product's Improvement / Process's Improvement			
	2005	2006	2007
Improvement of Products	38,4	41,4	46,5
Improvement of Processes	34,3	36,4	40,4

Table 55 | Innovation Rate – New and Improved Products and Processes.
(question 35, De.:SID Quest.)

It is possible to recognize a consistent growth in both creating and improving products. In what concerns processes the growth is not so linear. It is also visible that Innovation occurs more in products than in processes but it is relevant that the percentages of innovation in processes (both as new or improvement) are around 40% in the year of 2007.

In the De.:SID questionnaire, 'Quality' was also addressed in two questions. One of the questions incorporates the dimensions of quality of the 'Total Product Quality' model presented in Chapter II, section 4.

Design Quality Aspects	N	Average	St Deviation	Variation Coefficient
Customer relationship management	80	3,40	1,635	0,48
Concept*	79	2,99	2,010	0,67
Producibility*	80	1,75	1,579	0,90
Costs reduction	80	1,71	1,678	0,98
Conformity*	80	1,68	1,756	1,05
Operational Robustness*	80	1,29	1,561	1,21
Manufacturing Robustness*	80	1,23	1,501	1,23
Experience	79	1,01	1,489	1,47

Table 56 | Evaluation of some aspects of Design Quality. (question 36, De.:SID Quest.)

*aspects of Quality from Henri Stoll (1999) Total Product Quality Model that were explained to the respondents

The analysis of Table 56 indicates that to firms 'Quality' is determinant in the way it can guarantee the establishment of a good 'customer relationship management' (3,40). It is also noticeable that the quality of the 'concept', which concerns the performance, product features, aesthetic and ergonomic issues (aspects that make the product desirable to the end consumer), is also valued by the firms (2,99). Being so, firms apparently see as fundamental aspects of the Quality those that are directly linked with consumer/customer related issues.

The section of the questionnaire dedicated to the 'Attitude and action of the company's management towards design use' starts with a question about the existence in the firm of someone responsible for having "New Ideas".

Table 57 shows that in 28,3% of the firms designers have that task, followed by the Top managers with 19,2%. When considering the results presented in Table 62 (about leadership of new projects) we verify that the order is reversed but that those are the two professional areas that account mostly for the 'control' of Idea generation and development.

It is also of interest to know if the firms develop design internally or if they make use of external design services or both. Table 58 gives us data about that reality and shows that on a total of 82 firms 59% use both internal and external design services, 31% do Design exclusively

Professionals / Functions	%"YES"
Designers	28,3
President/General Director/Manager	19,2
Product manager	16,2
Any person form any department/Section	14,1
R&D Managers	12,1
Engineers	11,1
Marketing managers	11,1
Quality managers	7,1
Production Managers	7,1

Table 57 | Who has the Responsibility of Having "New Ideas" (question 37, De.:SID Quest.)

inside the firm and 11% use design services hired outside. In principle, if design is a core competence of the firm it should be developed internally. However, there are some services of Design that can, and sometimes should, be outsourced since that has advantages for the firm (for example a multimedia design work to support a product or a brand is something that you can contract outside with consultancies that have the necessary skills and experience to do it).

	Frequency	%	% Valid	% Cumulative
External	9	9,1	11,0	11,0
Internal	25	25,3	30,5	41,5
Both	48	48,5	58,5	100,0
Total	82	82,8	100,0	
Missing	17	17,2		
Total	99	100,0		

Table 58 | Source of Design Activity (question 39, De.:SID Quest.)

With this survey De.:SID researchers also tried to shine some light on the design place inside the firm. In Chapter II of this thesis the organizational diffuseness of design was addressed as one of the problems of Design strategic use on the part of firms.

Table 59 synthesizes the outcomes and it is visible that the departments that are mostly associated with design

Departments/Sections	Average (Dicotomic Scale "0-1")	St. Deviation	Variation Coefficient	% "YES"
R&D Department	,364	0,48	1,33	36,4%
Marketing Department	,343	0,48	1,39	34,3%
Simultaneously to various departments/sections	,232	0,42	1,83	23,2%
Production Department	,131	0,34	2,59	13,1%
Any other situation	,020	0,14	7,00	2,0%

Table 59 | Association of Design Activity to a specific department (question 40, De.:SID Quest.) N=99

Table 60 | Number and education level of persons developing design inside the firms (question 43, De.:SID Quest.) N=72

activity are the R&D department (36,4%) and the one of Marketing (34,3%) which is consistent with the literature review on the topic.

Furthermore it is vital to understand what type of practitioners develops Design inside the firms. Table 60 presents the outcomes on that question.

Level of Education from people working with Design and having Design background				
	Total	%	Average	St Deviation
Basic/high School	33	15,3%	,46	1,100
11/12º year high school	53	24,7%	,74	1,075
Bachelor	17	7,9%	,24	,517
Graduation 5/6 years	98	45,6%	1,36	1,698
Post-graduation	14	6,5%	,19	,547
General Total	215			

Level of Education from people working with Design and having a background from other areas				
	Total	%	Average	St Deviation
Basic/high School	205	55,0%	2,85	9,540
11/12º year high school	67	18,0%	,93	2,210
Bachelor	11	2,9%	,15	,433
Graduation 5/6 years	81	21,7%	1,13	2,169
Post-graduation	9	2,4%	,13	,409
General Total	373			

Table 60 shows that people with design domain specific schooling are low in number (215) than people coming from other areas of knowledge (375). Moreover, from those that does not have a Design Education 73% have low education level (high school). On the other hand, regarding the ones with Design education a percentage of 45,6% of graduate students is responsible for the work inside firms.

The level of qualifications is supposed to be one of the indicators for the low productivity and competitiveness of the Portuguese Economy. Therefore, it is important to attend to these numbers.

Regarding the use of Design it was crucial to understand how Design is used along the *Value Chain*[47].

	Total	%	Average	St Deviation
Concept	40	40,4	50,6	50,6
Development	26	26,3	32,9	83,5
Detail	2	2,0	2,5	86,0
Pre-Production	9	9,1	11,4	97,4
Post-Production	2	2,0	2,5	100,0
Total	79	79,8	100,0	
Missing	20	20,2		
Total	99	100,0		

Table 61 | Design Process Phase where Design starts to be used (question 47, De.:SID Quest.)

Table 61 shows that 51% of the Design processes in firms are initiated in the Conceptual phase while 26% start in the Development phase. As we consider the Conceptual phase a central phase to the success of products (as seen in previous Chapters) it is strange to have so low numbers. At least it raises the hypothesis that part of the firms do not acknowledge the necessity of an early intervention of Design and by doing so they also lose the possibility of understanding the impacts of that intervention.

Besides the issues related with implementation of Design inside firms De.:SID researchers also wanted to get information about the contributions and impact of

47. The Value Chain is a concept from business management that was first described by Michael Porter in 1985. The value chain categorizes the generic value-adding activities of an organization. Products pass through all activities of the chain, and at each activity the product gains some value. The chain of activities gives the products more added value than the sum of added values of all activities.

Departments/Sections	Average (Dicotomic Scale "0-1")	St. Deviation	Variation Coefficient	% "YES"
Product	,43	,498	1,15	43,4%
Brand	,35	,480	1,36	35,4%
Patent	,09	,289	3,18	9,1%
Licencing	,04	,198	4,90	4,0%

Table 62 | Nature of the Contribution of Design to firm's Differentiation (question 48, De.:SID Quest.) N=99

Design in business. Question 48 of the questionnaire does ask directly what the nature was of the contribution Design has done to a firm's differentiation.

Product is the strongest contributor (43%) followed by the brand (35%). Patents and Licensing are marginal expressions of design contributions to a firm's differentiation.

The second question in the section of the questionnaire dedicated to the firm's Evaluation of Design Results addresses quality. This time the aim was to capture possible parameters to measure Design Quality.

Table 63 shows that as a possible Design quality measure firms value mostly the clients/market response and acceptance of the products (35%). Sales, a traditional measure is indicated by 23% of the firms. All the other parameters have low impact. That is not surprising since even for researchers and experts dealing with these issues there are still some difficulties defining the parameters to measure the quality of Design.

More than exploring possible parameters to measure Design quality it was central to capture a firm's assessment of the impacts of their Design Use.

According to Table 64 the 'Firm's Image' has the highest average score as the parameter that is most benefiting from Design Use (4,17). The following items are the 'Communication with Client' and 'Customer's Satisfaction'. This is consistent with the dimension firms value mostly in terms of Quality. Again the aspects of relationship with customers are seen as being significant and this table shows that according to the respondents Design has impact on those aspects.

	Frequency	%	% Valid	% Cumulative
Response and acceptance from market/ clients	23	23,2	34,8	34,8
Sales	15	15,2	22,7	57,6
Product's Adequacy	5	5,1	7,6	65,2
Brand/Firm/Product Awareness	5	5,1	7,6	72,7
Image	3	3,0	4,5	77,3
Quality	3	3,0	4,5	81,8
Clients/Markets captation	2	2,0	3,0	84,8
Innovation	2	2,0	3,0	87,9
Peers Recognition	1	1,0	1,5	89,4
Concept	1	1,0	1,5	90,9
Production Improvement	1	1,0	1,5	92,4
Communication	1	1,0	1,5	93,9
Product Development	1	1,0	1,5	95,5
Introduction of New Product	1	1,0	1,5	97,0
Clients Pannel	1	1,0	1,5	98,5
Design rigour	1	1,0	1,5	100,0
Total	66	66,7	100,0	
Missing	33	33,3		
Total	99	100,0		

Table 63 | Possible Indicators to measure Design Quality (question 49, De.:SID Quest.)

Parameters	Average	St Deviation	Variation Coefficient
Firm's Image	4,17	,971	0,23
Communication with Clients	3,76	,992	0,26
Customer's Satisfaction	3,70	1,120	0,30
Increase in the firm's competitiveness	3,63	1,305	0,36
Increase in the product's Quality	3,61	1,234	0,34
More client's retention and fidelization	3,58	1,146	0,32

Sales Increase	3,53	1,194	0,34
Increase of products in portfolio	3,51	1,474	0,42
Increase in the number of new customers	3,46	1,183	0,34
Increase of Added Value	3,41	1,288	0,38
Entrance in New Markets	3,22	1,420	0,44
Increase in Market Share	3,18	1,219	0,38
Increase in the employees satisfaction	3,07	1,350	0,44
Postivie variation in return on investment	3,04	1,270	0,42
Raise in the profit margin per product/service	2,89	1,362	0,47
Increase in form's productivity	2,89	1,217	0,42
Profit increase	2,74	1,320	0,48
Increase in production's flexibility	2,58	1,268	0,49
Attainment to regulation requests	2,58	1,339	0,52
Environmental impact reduction	2,54	1,390	0,55
Reduction of the complexity of internal processes	2,47	1,311	0,53
Reduction of costs per produced unit	2,39	1,223	0,51
Increase of Employment	2,01	1,205	0,60

Table 64 | Evaluation of the impact of Design Use (2005-2007) (question 50, De.:SID Quest.) N=76

The last section of the questionnaire focuses on the barriers to the Use of Design. Table 65 lists barriers firms assume to be relevant to determine the lack of Use of Design.

	Average	St Deviation	Variation Coefficient
Resistance to Change (business aspects)	2,48	2,15	0,87
High Costs of Design (economic-financial aspects)	2,38	1,97	0,83
Easiness of copying by competition (business aspects)	2,31	2,22	0,96
Lack of R&D activity (business aspects)	2,14	2,20	1,03
Uncertainty regarding the outcomes of Design Activity (business aspects)	2,03	1,97	0,97
High Commercial risks (economic-financial aspects)	2,03	2,03	1,00
Lack of State support (business aspects)	2,00	2,24	1,12
Long Period to return on Investment (economic-financial aspects)	1,93	2,02	1,04

Lack of Time (business aspects)	1,86	1,90	1,02
Week dimension of the market (economic- financial aspects)	1,79	1,88	1,05
Low return on Investment (economic-financial aspects)	1,72	1,79	1,04
Difficulty differentiating Products and processes (business aspects)	1,66	1,63	0,99
Lack of market's information (business aspects)	1,59	1,92	1,21
Ignorance about the opportunities Design creates (institutional aspects)	1,45	1,80	1,25
Scarceness of technical professional external services (institutional aspects)	1,41	1,84	1,30
Lack or debility of the technological infra-structures (business aspects)	1,41	1,84	1,30
Lack of information about Design Technologies (business aspects)	1,38	1,70	1,23
Absence of cooperation with the Designers' Community (business aspects)	1,38	2,09	1,52
Lack of leadership skills on the part of Designers (Business aspects)	1,38	1,70	1,23
Lack of Demand (Institutional Aspects)	1,34	1,45	1,08
Low qualification of employees (economic-financial aspects)	1,34	1,74	1,29
Difficulties in financing (economic-financial aspects)	1,34	1,97	1,46
Lack of Cooperation with other companies (business aspects)	1,14	1,71	1,50
Bad previous experience with Design (institutional aspects)	1,03	1,61	1,56
Standard products (no need of Design) - Business aspects	,97	1,45	1,50
Other barriers	,00	,00	

Table 65 | Global Analysis of the Barriers to the Use of Design (question 51, De.:SID Quest.) N=29

SUMMARY OF DE.:SID SURVEY

De.:SID survey addressing the Portuguese manufacturing Industry was developed by a group of ten researchers including the author. This survey allow us to understand in broaden terms the way business field evaluates the role of Design and designers.

It is helpful in the way it contributes to the description of what 'strategic adequacy' is in the firm's perspective. Also gives light to firm's perception of Design Quality and the way it can be measured.

From a brief analysis of the survey results it is possible to acknowledge that Portuguese firms in general still underestimate the potential of Design as a strategic resource. The use of design in more than 2/3 of the respondent firms has a history of less than 19 years.

Furthermore, designers still operate mostly at the operational level having almost no participation in the strategic level of design's intervention.

The quality of design for these firms is best guaranteed by a good customer relationship management. In addition the Quality of the Concept (as Stoll, 1999 defined it) which refers to the performance, product features, aesthetics and ergonomic issues, is also highly valued by firms.

This result is meaningful in the context of this research since the Concept is by excellence a territory where Design intervention is natural and very intense. However, the survey also shows that only 51% of the firms use Design in the Conceptual phase.

Furthermore, the low level of Design education affects/ denounces the way firms acknowledge Design and its potential role in Business. An upgrade in employees' qualifications could be an important step to boost Design inside firms as a more efficacious resource similarly to what happens in the North European countries (Design Council, 2003, 2008; Designium, 2005 studies).

Finally it is to consider that firms point as the first barrier to design Use the 'resistance to change' which is consistent with the Portuguese cultural trait of 'avoidance to risk' that is so clear in Hofstede Cultural dimensions Index (2001). Another one of the barriers to the use of design mentioned by the firms is the 'uncertainty regarding the outcomes of Design activity'. Curious is the fact that firms consider the lack of State/Government support to Design as being a barrier to its use. In fact, the 'Innovation cause' in Portuguese firms was highly supported by the State and promoted extensively by State organisms and institutions.

Also relevant is the fact that firms consider design to be 'highly costy'. From the above said is clear that is necessary to try to reduce the uncertainty in Design Outcomes. This work tries to contribute to that aim.

2. AN OUTSIDE ASSESSMENT – THE RESEARCHER OBSERVATION AND ANALYSIS OF BOTH STUDENTS AND COMPANY DESIGN PROCESSES

The outside assessment was made both by gathering data regarding: (i) the performance of students along their design processes and (ii) the way companies relate itself with students' design processes. On the following pages a description of the results in both cases will be presented. In the first case the study was done mainly through Design experiments; In the second one experiments were also done in which students and companies worked together.

It is important to acknowledge that it was only after the analysis of the first experiment (a verbal protocol analysis of an individual design exercise) that Decision making was defined as being a central topic in this study. Until that moment the study aimed only to analyze design processes with a focus on knowledge/information management and time management.

In fact as Rehman and Yan (2007, p.170) observed:

"A lack of available life-cycle knowledge is the first reason that designers find it difficult to know the implications of their decisions, made at the conceptual stage, on the product's life-cycle phases, the user of the product and the environment in which the product operates. This is exacerbated by a lack of understanding of complex causal and effect relationships of such knowledge spanning these different life-cycle phases".

The observation of Rehman and Yan is consistent with what was found in the literature review. Another consideration is that the outcomes of the survey done with students reinforced the idea that time management and knowledge management were central issues in Design Processes especially at the conceptual phase.

A first experiment was developed with design students from the 5th year of the Product Design Course. In the next section the experiment will be explained in detail.

2.1 An experiment with design Students - Lisbon/Delft Verbal Protocol Analysis – Individual Exercise

The main goal of doing an experiment was to identify how the macro and micro structure of student's design methodology is thought and put in action, how are decisions taken and which are the critical points of the process (the ones that will conduct to relevant changes). The experiment was designed similarly to the one developed by Christiaans (1992) in his study on creativity in design among a group of Delft University Design students [Appendix P].

The assignment came out from this study (1992, p. 108-109), which was later on also used in Dorst's study on the operationalization of Schön and Simon paradigms in their study of design processes (1998). Using the same assignment in our study was important since we

Assignment

(This assignment was presented to 10 design students in an experiment developed by Christiaans (1992) and also to 9 designers by Kees Dorst (1998)

The Producer - Lemmens Inc.

Lemmens Inc. is a manufacturer of plastic trays and buckets. The factory has 40 employees at present, spread over 10 injection-moulding machines, an assembling dividion, and a small instruments division. Most products are injection-moulded; small amounts of special runs are also produced by vacuum forming, or roto-moulding (contracted to another firm).
Lemmens manufactures is own small product-range, aiming at the institutional market.
Futhermore, it is supplier to, for example, Curver PC. The intention of Lemmens is to extend its own product-range in the next few years, and to decrease the supply.

The Brief

Company XP is interested in the reformulation of one of the trains it owns since the nineties, the SM90. This was a revolutionary design at the time since it allowed accommodating one more passenger per row (2+3).
Because of the growing number of people travelling a new refuse system (waste bin + cleaning tool) for the passenger's compartment is to be considered.
In answer to this brief the current supplier of the refuse system made a new proposal which after consideration was not accepted by XP. Next, XP conducted a survey among passengers and cleaners as to the functioning of the current refuse system; moreover, they investigated the kind of waste in the bins.

On account of this study XP decided to invite Lemmens Ltd., among others, to make concepts for a new design. The director of Lemmens Ltd., and the product manager of the XP have already discussed the situation.
Lemmens Ltd. takes the view that supplying such a product gives an opportunity to increase its profile within the market.
You are engaged as free lance designer to design one or more designs to XP. This afternoon you will have a meeting in which the following concepts will be discussed:

- A Basic solution
- Main solutions for realization
- Idear behind the design
- Drawings
- Costs estimation

Fig.63 | Assignment sheet of paper. (transcribed)

wanted to compare the results obtained by students with different education backgrounds and to observe the role different curricula play in the outcomes of design processes. The exercise was evaluated by a group of six persons including design teachers, engineers, representatives of a company similar to the one presented as a client in the brief and representative of a firm similar to the one presented as a producer in the exercise's brief.

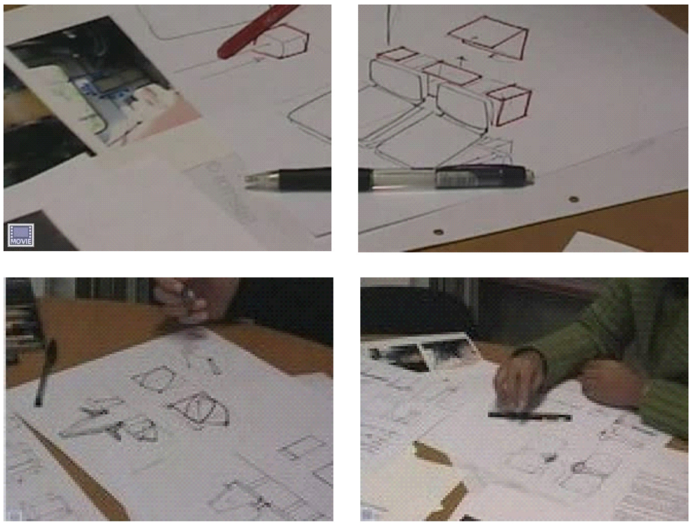


Fig.64 | Images of the Experiment (protocol L)

The analysis of the experiment will be done in two phases: a first one where information access and use was considered the main topic to be studied; a second one that takes decision making as the most relevant topic to be studied. That is due to the fact that with the first approach we come to the conclusion that decision making study was crucial.

Moreover, besides the experiment done with Portuguese students there was also the opportunity to compare it with the results from the Dutch experiment made by Christiaans (1992). The analysis of the data gathered with Portuguese students was deep and highly time consuming. Therefore, the comparison with the Dutch students was made only between the best, the worse and a medium outcome.

Since the experiment was very rich in information we decided to also present the analysis of all the Portuguese protocols as an autonomous experiment.

2.1.1 The experiment with Portuguese design students (Protocol L)

Protocol L was conducted in 2007/2008 and its subjects account for 13 students from the last year of the Design course at Faculdade de Arquitectura da Universidade Técnica de Lisboa.

Method

The protocol was videotaped and had an assignment that proposed the creation of one or more concepts of an industrial object – a litter-disposal system in the train - that called for the integration of aspects such as ergonomics, construction, aesthetics and business. Each design student had to perform the task individually having an alloted time to the experiment of two hours. Each of the students signed an informed consent before starting the task. [Appendix Q]

Being a Verbal Protocol experiment subjects were requested to think aloud during the process of solving this design problem. Prior to the experiment they made a preliminary test [Appendix S] with the thinking-aloud method that had the duration of 10 minutes where they tried to solve aloud a cryptarithmetic puzzle (Newell and Simon, 1972).

The experiment had an information support system [Appendix R] that was only used at subject's demand. Information was separated by topics and presented in cards that were handed by an experimenter that was present in the room. The information was presented in simple and summarized ways (see Table 64).

After the experiment the students had a debrief moment, a short interview, that included four questions:

1) How do you evaluate your performance?; 2) Which were the perceived difficulties of this moment?; 3) The information you had at your disposal was enough?; 4) The existing information Yhe one that was offered for you to use) was enlightening? [Appendix T]. The videotapes were transcribed and translated to English [Appendix U].

Data was then coded according to the encoding system [Appendix V] developed after the first analysis of all the protocols. This analysis took into account not only the information asked for and used but also the activities developed, time spent in each activity, reflections made and decisions taken.

The coding of the protocols was done both by the researcher and an independent judge. See Fig. 67 for

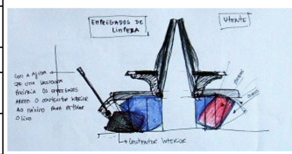
Time	verbal expression	basic encoding	encoder's observation and comments	type of reflection reflecting about the experience of use and possible problems... Identifying one...	decision taken	writing/ Sketches
00.36.46	...that is to say... This doesn't have to open that much!	reflecting		advancing an argument to sustain the idea... revising the support system	FDre4	
00.36.52	(back to sheet 1)	sketching	sketch 11		FDs31	
00.36.57	...if this opens...	reflecting/sketching			FDs31 / FDre4	
00.37.07	...the seat... is separated... where the arm holds...	sketching			FDs32	
00.37.37	...the chair...	sketching			FDs32	
00.37.43	(looks at images on card 2)	sketching			FDs32 / FDI2	
00.37.46	... I would like to understand where it is arrested but I think it is down below	sketching			FDs12	
00.37.51	... a thing of this kind...	sketching			FDs12	
00.37.57	...of course with the ergonomics forms... like this...	sketching			FDs11	
00.38.03	... Therefore... It has here a wedge...	sketching			FDs11	
00.38.10	...that is being filled (uncovered) by this arm... so...	sketching		assuming a blockage in the process (trying to fight it with sketching)	FDs11	
00.38.18	... and now?...	sketching			FDre7	
00.38.41	...I do not know...	sketching			FDre7	
00.38.45	...I have blocked...				FDre7	
00.38.52	... I have blocked...				FDre7	
00.38.56	...I am only drawing... I don't know what to do....	sketching			FDs11 / FDre7	
00.39.05	.. can it be a design of seats????	sketching			FDs2	
00.39.13	... I am trying to do the garbage bins integrated...	sketching			FDs2	

Fig.65 | Excerpt of a transcribed/ translated and coded protocol

an example of double coding. The level of agreement was in average of 73%. When there was divergence in the encoding a third judge (an experienced researcher) established the final coding.

The evaluation of the quality of the students' work based on the written transcripts was done by the jury composed by six members. The protocols were delivered to them in an arbitrary order. They had access to the transcribed protocols where it was identified the order of drawing making [Appendix W]. They also had copies of the drawings produced by each student (with the sequence numbered) [Appendix X]. Furthermore, they had a document where evaluation criteria were defined and the scale and weight of criteria could be filled in for each of the protocols [Appendix Y].

The criteria were: Feasibility; Creativity; Prototypicality; Strategic adequacy; Quality of communicative interaction; Decision making process (see Glossary). Jury members had the possibility of attributing different weights to each of the criteria elements.

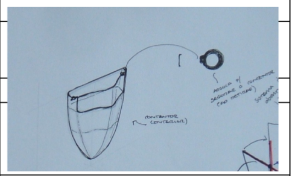
01.30.08	... It will be seen, yes it will... It won't be seen the container... It will be visible only from here... So...	reflecting		FDre4 / FDs3	EDre74/EDs13	
01.30.32	... Can I try here this pencil?....	geting material/s ketching	**sketch 34**	FDg2 / FDs3	EDg2/EDs13	
01.31.49	... This here... It goes like this...	geting material/s ketching	grabs a black pen	FDg3 / FDs3	EDg3/EDs13	
01.32.20	... I am... Exact...	sketching		FDg3	EDg3	
01.32.32	... I am here thinking that... The container has the same form that one of the external bin... It must have... So it can after be incased...	reflecting/sketching		FDre9 / FDs31	EDre73/EDs11	
01.32.47	... So that after it can incase inside... Of the external box isn't it?....	reflecting/sketching		FDre9 / FDs31	EDre73/EDs11	
01.32.53	... I was just thinking... How is it that it after... Can be redraw... Exactly...	reflecting		FDre9	EDre1	
01.32.50	... This ... Is seen... From the side (sketch 30)... Is is a lateral view...	reflecting/sketching	sketch 30	FDre4 / FDs31	EDre9/EDs11	
01.32.56	... At the bottom it can have a little handle... Here on the side... Inside... But... Hold on...	reflecting/sketching		EDre71 / EDs13		34
01.33.16	... But... Hold on... That this here does not go until the end... I draw it in the wrong way...	reflecting/sketching		EDre71 / EDs13		
01.33.23	... This goes that way... Until.. Until... Here... Ok...	reflecting/sketching		EDre71 / EDs13		
01.33.37	... So... Like this...	geting material/s ketching	grabs black pen	EDg3 / EDs13		
01.33.54	... This is the container...	reflecting/sketching		FDre4 / FDs31	EDre71	

Fig.66 | Excerpt of a Protocol – example of double coding

After the jury assessment on the protocols the results were processed. [Appendix Z]. Figure 67 presents the evaluation of three protocols by all jury members. The scale to be used was 1 to 10. The number in each cell represents the score the jury member gave to that particular criterion multiplied by the weight that criterion has in the whole evaluation system.

It was also assessed the inter-rater reliability of the jury members. The Intraclass Correlation Coefficient (ICC) is a measure of the reliability of measurements or ratings. Average measures were used meaning that this Intraclass correlation Coefficient (ICC) is an index for the reliability of different raters averaged together.[48]

Table 66 shows that the level of agreement between the jury members is highest for Prototipicality, Quality of communicative interaction and Decision making process. Creativity reveals the lowest agreement level, an unexpected result because both Amabile (1983) and Christiaans (1992) get high agreement on this criterion when judging products. The low agreement in our

48. McGraw KO, Wong SP (1996) Forming inferences about some intraclass correlation coefficients. Psychological Methods, 1:30-46. (Correction: 1:390). Shrout PE, Fleiss JL (1979) Intraclass correlations: uses in assessing rater reliability. Psychological Bulletin, 86:420-428

SUBJECT 4

	LSR	ECR	ALS	JAP	JRM	ARJ
Decision Making Process	1,2	1,75	0,48	0,75	1,05	0,7
Feasibility	1,2	1	0,5	1,6	1,2	0,7
Creativity	2,1	0,6	1	0,6	1,2	2,1
Prototypicality	0,5	0,6	0,8	0,9	0,8	0,35
Strategic Adequacy	0,4	1,05	0,54	0,6	1,75	1,05
Quality of the communicative interaction	0,9	0,6	0,72	0,6	1,05	2,1
FINAL SCORE	6,3	5,6	4,04	5,05	7,05	7

SUBJECT 5

	LSR	ECR	ALS	JAP	JRM	ARJ
Decision Making Process	0,75	2	0,72	1,05	1,05	0,8
Feasibility	0,8	0,8	0,5	1,6	1,05	0,8
Creativity	1,2	0,8	0,8	0,8	1,4	2,1
Prototypicality	0,4	0,4	0,8	0,9	0,9	0,4
Strategic Adequacy	0,3	1,35	0,9	0,9	1,5	1,05
Quality of the communicative interaction	1,05	0,7	1,08	0,9	1,2	2,4
FINAL SCORE	4,5	6,05	4,8	6,15	7,1	7,55

SUBJECT 6

	LSR	ECR	ALS	JAP	JRM	ARJ
Decision Making Process	1,5	1,75	0,96	1,2	1,05	0,9
Feasibility	1	0,8	0,3	1,2	1,05	0,8
Creativity	2,1	1,2	0,8	1,2	1,4	2,7
Prototypicality	0,6	0,7	0,7	1,05	0,7	0,4
Strategic Adequacy	0,7	0,9	0,54	1,2	2	1,2
Quality of the communicative interaction	1,35	0,8	0,9	1,05	1,35	2,7
FINAL SCORE	7,25	5,9	4,2	6,9	7,55	8,7

Fig.67 | Excerpt of the evaluation by the 6 judges of three Protocols.

	ICC
Decision Making process	,764
Decision Making process (weight)	,717
Feasibility	,653
Feasibility (weight)	,559
Creativity	,355
Creativity (weight)	,255
Prototypicality	,889
Prototypicality (weight)	,872
Strategic Adequacy	,658
Strategic Adequacy (weight)	,684
Quality of the communicative interaction	,806
Quality of the communicative interaction (weight)	,803

Table 66 | Intraclass Correlation Coefficients as measure for interrater reliability

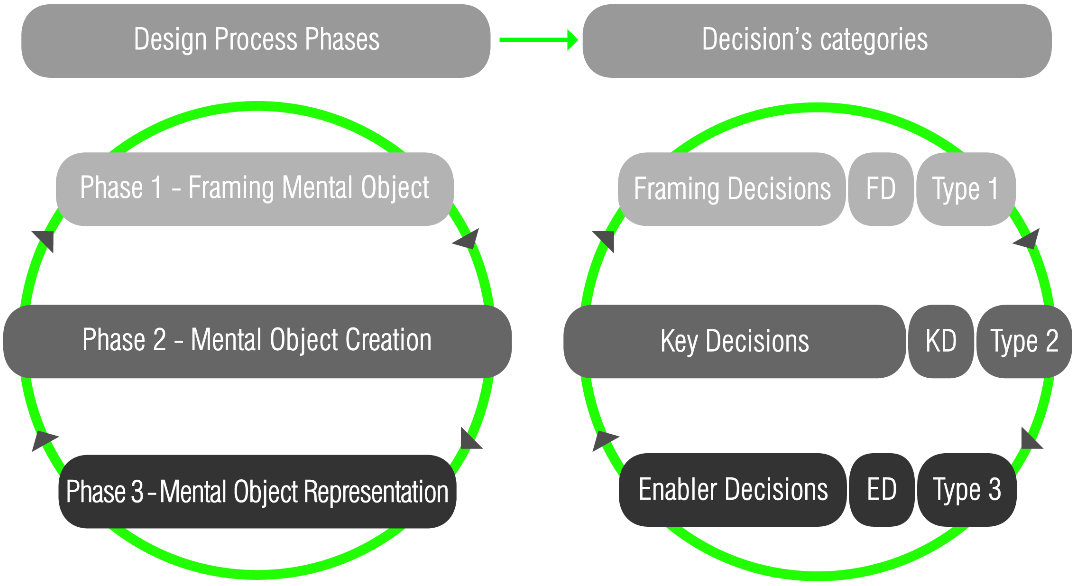
study might be due to the fact that judges come from different knowledge domains (from design to business), while the fore mentioned authors make use of judges with homogenous domain expertise.

Data analysis

Because of the exploratory character of the experiment the analysis of the protocol data will cover several aspects. In a first analysis we will observe:

> the existing information students ask for during the design process;
> the non-existing information asked for;
> the type and number of drawings;
> the locations in the train chosen to place the waste system;
> the time students take before starting to sketch;
> the time until the first Key Decision if any;
> some observations about the Solutions;
> the Jury evaluation.

In a second analysis the focus on the decision making process examines the kind of decisions taken by each



Phase 1 - Typically PROBLEM and SOLUTION co-evolve;
Phase 2 - Typically designer is focused in the PROBLEM;
Phase 3 - Typically designer is focused in SOLUTION;

Fig.68 | Decision Nature categories (Almendra, 2007)

subject during the design process. before the analysis of the verbal protocols a first decision model was developed (see Figure11, Chapter II) based upon the following observations:

> Progress in the process can be made through decision making as a conscious and explicit action but also through reflection, that can lead to natural selection of alternatives and evolution in the process.

> How persons take decisions, the relation with design moves along the process, and the factors influencing the decisions and moves are key aspects of this study.

The critical observation of decision making along the exercise suggested that there were different kind of decisions and after identifying its particular characteristics (along the protocols videos observations) we defined it into three categories:

> Framing Decisions - decisions made during the period when a designer mentally 'frames' the object/solution;

> Key Decisions - those made on moments when the (preparation of the) product creation occurs;

> Enabler Decisions - signify mental object representation instants.

These categories are presented in Figure 68 where a correspondence between the design process phases and the decision categories is made.

It is essential to explore a bit further the definition of these three categories.

Framing Decision is a decision that is taken aiming to create a mental image of the context and overall framing of the problem.

Key Decision is one that results in a move in terms of Design process (the way Goldschmidt defined it in 1996). It is a decision that is critical for the progress of the entire design and it can refer to the generation of a partial or entirely novel solution. Key decisions are the result of the synthesis of information that enables the person to have a mental "big picture" of the "solution to be constructed". In that way they act as drivers of the process.

Enabler decision can be understood as routine decision in the sense it keeps the process moving in the direction key decision points out. These are decisions that facilitate the execution of the key decision in its operational practical aspects. Enabler decisions are those that occur in a context of predicted or controlled results (where the designer knows what is expected to happen).

All types of decisions can be expressed either in verbal or graphic terms.

These Categories were used to define the encoding system that is activity based. The code system has a first level of tagging that corresponds to the type of decision (FD –framing; ED- enabling; KD – key) and a second level of coding that has to do with the activity (a – asking information; r – reading information; l – looking images; g – getting material; w – writing information; m – modelling; s- sketching; re – reflecting). Finally, on a third level of encoding numbers are used to identify in each of the subcategories the content being addressed (client; users; employees; producer; ergonomics; technical; constructive; aesthetics; costs; constraints; current solution, other solutions etcetera…).

As mentioned previously all the thirteen protocols were transcribed, translated and encoded by two people. All of them were also scored by the aforementioned Jury.

Several analyses were done with the gathered information.

2.1.1.1 First Analysis of the Portuguese protocols

Table 67 summarizes one of the analyses done where we took into account: the Jury evaluation; the existing demanded Information; the non existent information demanded; the type of drawings; the number of drawings; the locations chosen; the time students took to start sketching; the time until the first Key Decision and some observations about the Solutions.

From the analysis of Table 67 some conclusions can be mentioned:

A - regarding sketch activity time:

> In five out of thirteen (38%) the first sketch initiates the Key Decision moment meaning that the framing decision occurred by means of reflection (either speech and/or written);

> The average time lap between the start and the first sketch is 12:37 minutes; but this changes to 30 minutes if we consider sketching driven by the "mental solution", i.e. the Key decision;

B - Regarding information seeking behavior

> All subjects (excluding the one that denied the problem) demanded card 1 and 2 - images of exterior and interior of the train (including the existent bin with general measurements);

> The less demanded information (38,5 % of subjects asked for it) is the one concerned with card 4 (passengers opinions) and card 7(company views of the problem and possible solutions;

> From the eight subjects that had access to card 6 (types of garbage) 75% developed a solution incorporating the concepts of re-use and recycling.

	Scores	Existent Information (DEMANDED)								Non Existent Information (DEMANDED)	drawings/sketches																					
											other bins	existent/proposed bin						interface drawings		detail sketches		contextual drawings (existent and proposed)		nº draw	locations					time to sketch		
	(average)	1	2	3	4	5	6	7	8			plant	lat/front plant/ lat	frontal view	lateral view	section	perspective	interface/ users	interface employees	technical detail	constructive sketch	integration object	plant/ lat/location		the same	floor	seat	seat/ wall	hall	1st	1st kD	observations
Subject 1	4,64	x	x	x		x		x	x	material; emptying aid system; images of the bin open and interaction; dimension(ergonomics) technical drawings of the train;			X			6		X	X	X	X	2	1	**9**	X					23.24	29.35	(all general - object included in context) - existent and proposed... Focus on the train - comprehension of the context
Subject 2	7,13	x	x		x	x	x		x	technical drawings of interior; ergonomics	2	4		1	3	4	4	2	X	5	X	2	X	**27**			X			14.10	20.03	priviligees the sections and the understanding of how the object will work...
Subject 3	5,34	x	x	x	x	x	x		x	technical drawings of existent bin/train; ergonomics			X			X	2	X	X	8	3	X	4	**17**			X			33.23		searching drawings, exploring tecnhical possibilities **recycling principle**
Subject 4	5,84	x	x	x	x	x			x	technical drawings of existent bin/train; ergonomics; other objects made by lemmens			2		3	1	7	0,5	0,5	1	3	2	1	**21**			X			05.05	10.57	balanced intervention - using all types od drawing... **newspaper division**
Subject 5	6,03	x	x	x		x	x			technical drawings of existent bin/train; ergonomics; images of other trains	1	4	1	4	9	1	6	X	X	5	X	2	3	**36**	X					11.10	25.23	stucked to the same form from the beginning- lack of interface drawings
Subject 6	6,75	x	x	x		x	x		x	materials; technical information about the seats				2	3	2	13	1	2	4	X	3	1	**31**			X			03.26	36.25	balanced search that lacks the constructive aspects; concern with final presentation; 1 concept since the beginning **newspaper division**
Subject 7	7,01	x	x				x	x		interior remodeling		3	1		5	2	11	2	1	1	7	1	1	**35**	X					09.20	16.46	one solution; very systematically folowed, search balanced in terms of sketches done; **recycling principle**
Subject 8	5,8	x	x										X		1	2	11	4	1	1	X	1	X	**21**		X	X			05.25	01.04.45	2 solutions; 1 preferred from the beginning; complete lack of proportions;
Subject 9	6,45	x	x	x			x		x			1		1	6	X	15	1	1	2	X	5	X	**32**	X		X			13.59	37.28	2 solutions - both developed; no construction details and scarce technical ones (no sections) **newspaper division**
Subject 10	6,4	x	x	x	x	x	x	x	x			3		1	2	2	15	X	X	1	X	2	3	**29**	X					11.40	11.40	one solution **(recycling)** followed since the brginning; no constructive or technical drawings, no interface design
Subject 11	5,01	x	x	x					x			1	5	2	2	2	11	2	1	1	X	8	3	**38**				X		04.20	11.01	one concept - 2 locations; very superficial no technical or constructive solutions
Subject 12	3,13	0	0	0	0	0	0	0	0															**0**								denial of the problem - complete rsctructuring of it - a communication campaign will teach passengers to be better citizens taking care of his garbage and not needing to have a bin inside the carriage
Subject 13	6,06	x	x					x		refused proposal	2			3	2	X	8	1	X	1	X	3	X	**20**	X				X	02.13	27.52	2 solutions - **recycling principle** - one preferrred one more deeply defended; lack of interface drawings and technical and constructive solutions
Subject 14	5,39	x	x	x	x		x	x	x	technical drawings of the seats; Technical drawings of the bin; newspaper and magazines supports; ergonomic studies			1	1	4	X	7	X	X	1	X	3	X	**17**	X		X			16.53	01.03.18	1 solution - modular 2 locations **- recycling principle**; no technical and constructive sketches no interaction ones also
Sub total																							**average**	**23,79**							**12,37**	**average of time to 1st sketch**
TOTAL		**13**	**13**	**9**	**5**	**7**	**8**	**5**	**9**														**median**	**24**	**7**	**1**	**7**	**1**	**1**		**11,1**	**median of time to the 1st sketch**
																							average (excluding 12)	**25,80**							**30**	**average of time to 1st sketch towards a solution (KD)**
																							median (excluding 12)	**25,62**							**27,50**	**median of time to the 1st sketch towards solution (KD)**

Table 67| Analysis of the Protocol L (Information; Type of Drawing; Time to Sketch; First Key Decision; Type of Solution)

C - Regarding the solutions developed

> 8 subjects developed one or more solutions for one location only: 1 subject made a solution that occupies two locations; 3 subjects presented two solutions (on two cases one of which was clearly dominant); one subject developed an interchangeable solution (works both in the seat and on the wall);

> 8 of the subjects developed a solution that includes re-use or recycling concepts; 5 of them went to the recycling concept; 3 of them proposed the newspapers separation from garbage;

> In terms of location: 7 subjects adopted the existent location; 4 subjects saw the seat as a substitute place; 1 subject saw the seat as a complementary place to the existent one; 2 subjects saw the seat as another solution; 1 subject adopted the floor space in front of the seats; 1 subject found the wall of the train's hall as the solution.

D - Regarding the Sketching

> The average number of drawings is 25; The student with poor results only made 9 drawings and always generalist ones, meaning that the design made are not focused on the object itself but in its general shape in relation to its context.

> The perspective of the object (both the existent and the proposed) is the more frequently used type of drawing done;

> Drawings of an 'interface' either with employees or with users are scarce;

> Sketches focusing on details are more used to specify technical details than to explain constructive ones;

> 'Contextual drawings' to illustrate both the integration of the object in the space or to study the location of seats and paths inside the train were done by the majority of the students;

> 23% of the subjects felt the necessity of drawing other types of bins as part of the process of creating a new one for a different context.

> The student that scored high in the exercise made intensive use of sections and technical detailed drawings to explain her solution.

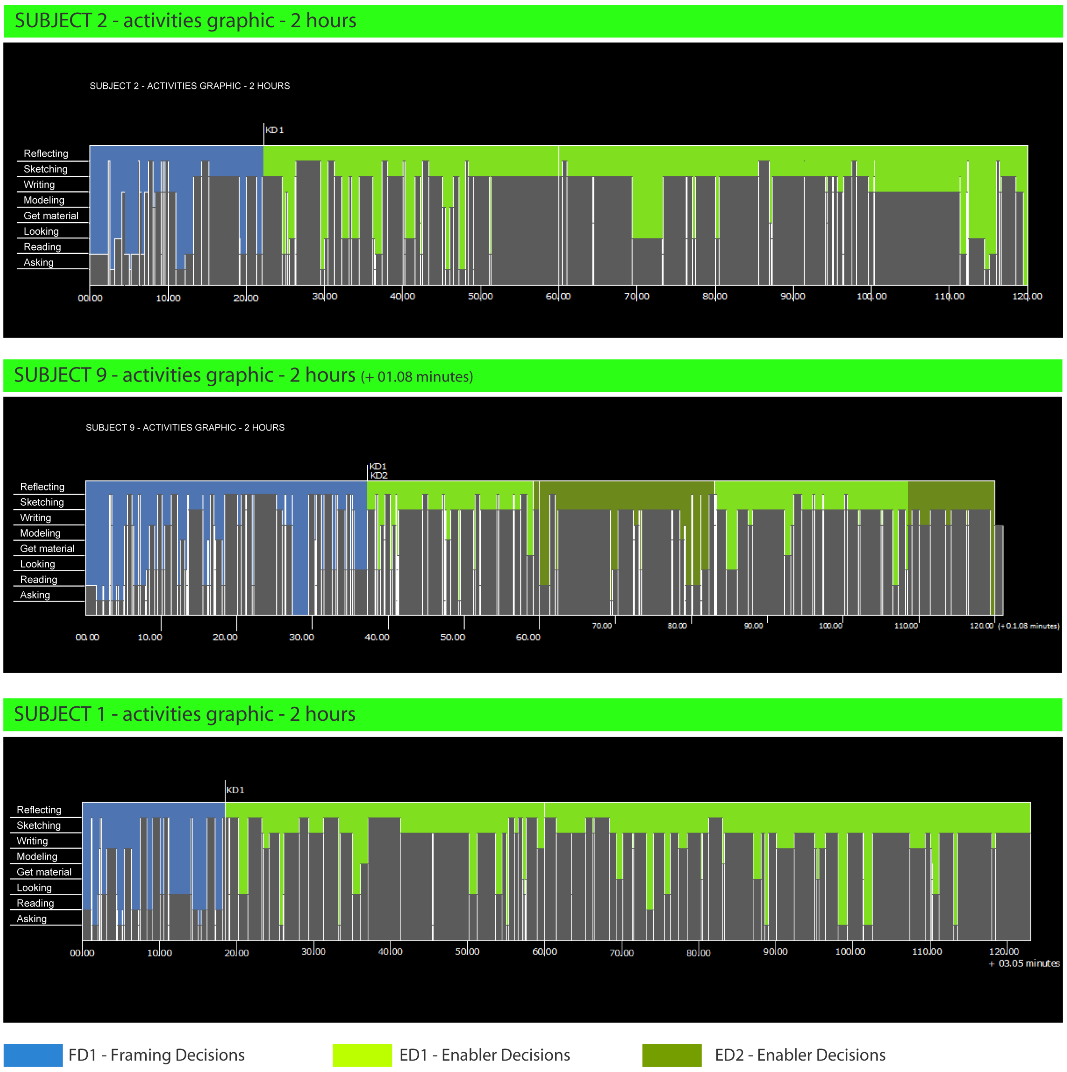
2.1.1.2 Second Analysis of the Portuguese Protocols

In the sequence of this first analysis a deeper one was made similarly to the ones done in other studies like the one of Christiaans (1992) and Dorst (1998).

This second analysis was activity based and included the design of graphics in which time spent in each activity was taken into account. The new element introduced in these graphics is the inclusion of the decision categories we had established (Key, Framing and Enabler).

As an example of what was done we present Figures 69, 70 and 71. The first one shows the graphics of the best a

Fig.69 | Protocols L2 (Best); L9 (Medium) and L1 (Worsed) – activities and decision making general analysis (Framing,Key and Enabler Decisions). See in detail figures 70 and 71



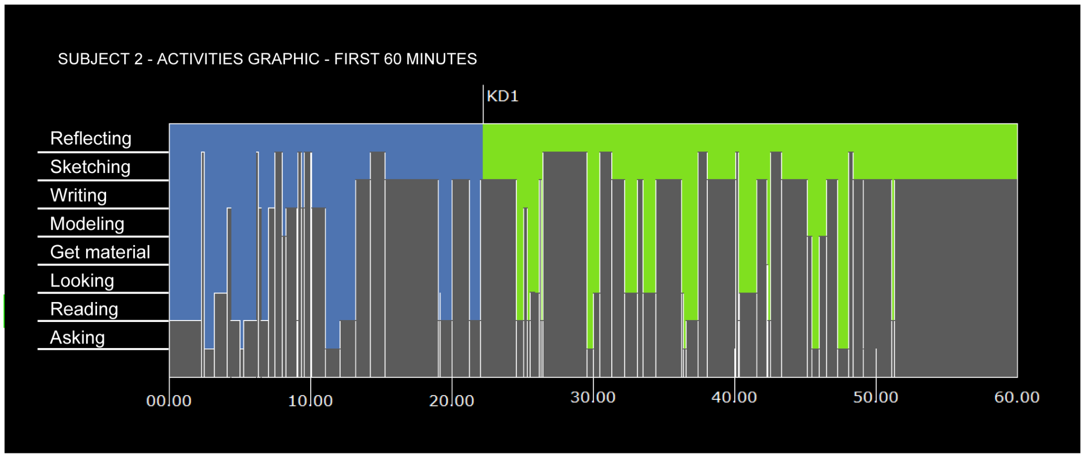
medium and the worse solutions according to the Jury of the exercise. Figure 69 and 70 refer to the best one and the medium one in detail.

This type of analysis makes it possible to graphically assess the diversity in the design process in terms of time spent in each activity as well as the general development of the different types of decisions taken by the students. However, it still lacks the possibility of showing the differences in content of the decisions taken.

Therefore, we tried to develop a new way of graphically exposing the protocol's design processes. That was done

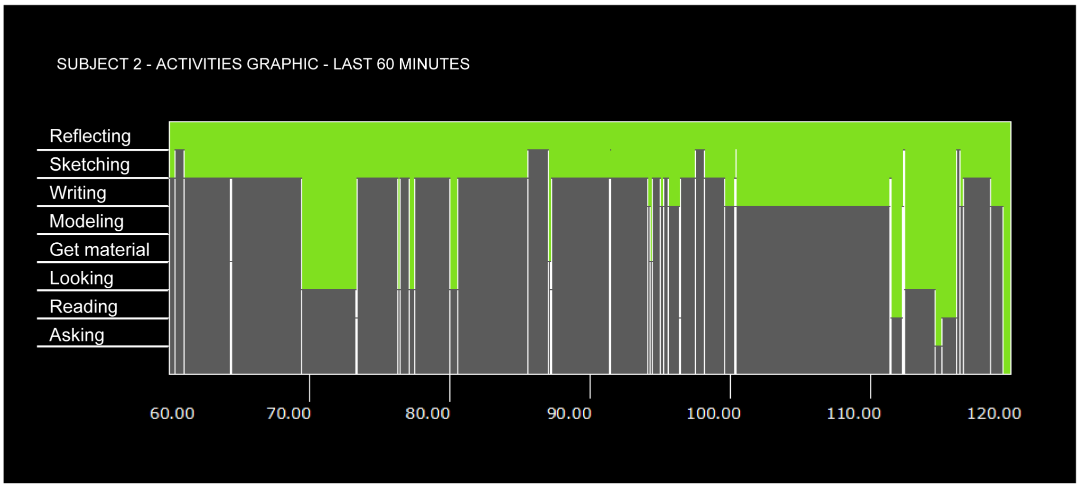
Fig.70 | Protocols L2 (Best); – Activities and decision making in detail during 2 hours.

SUBJECT 2 - activities graphic - (1st 60 minutes)



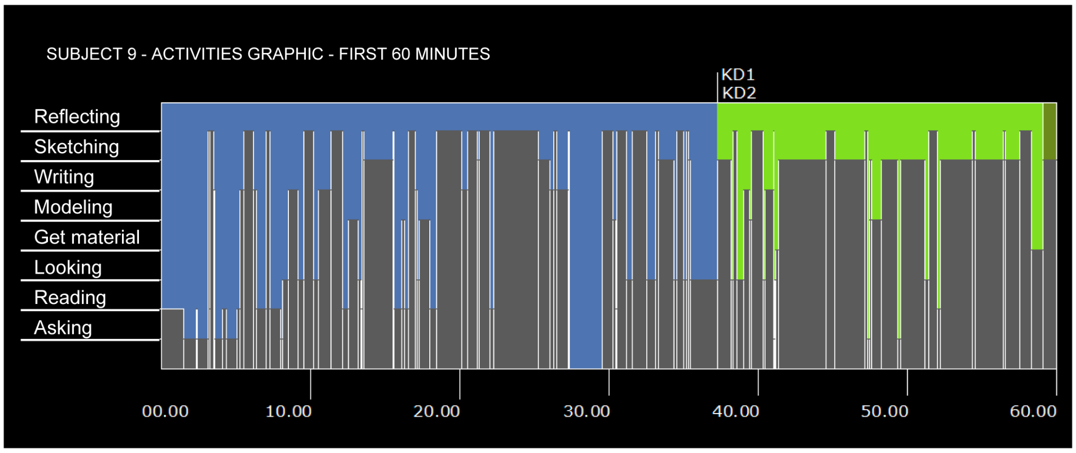
FD1 - Framing Decisions   ED1 - Enabler Decisions

SUBJECT 2 - activities graphic - (2nd 60 minutes)



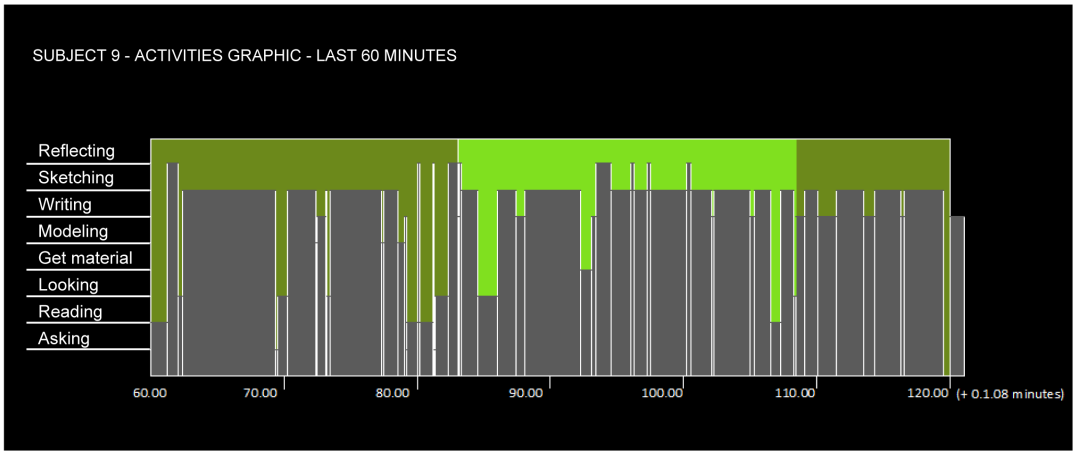
ED1 - Enabler Decisions

SUBJECT 9 - activities graphic - (1st 60 minutes)



FD1 - Framing Decisions | ED1 - Enabler Decisions | ED2 - Enabler Decisions

SUBJECT 9 - activities graphic - (2nd 60 minutes)



ED1 - Enabler Decisions | ED2 - Enabler Decisions

Fig.71 | Protocols L9 (Medium); – Activities and decision making in detail, during 2 hours (the 2 green tones correspond to the 2 solutions developed)

for all the Portuguese protocols [Appendix AA]. However, since we decide to compare the Portuguese protocols with the Dutch ones that analysis will be presented further ahead in this thesis.

Finally it is relevant to say that the debrief moment reinforced the impression that students have difficulties managing information and taking decisions. Another finding from the debriefing was that two students experienced difficulties with the Think aloud method. That is one of the constraints of using this method taken for granted by the researcher since the positive aspects of its use overcome the less positive sides.

2.2 Comparing Portuguese (L) with Dutch (D) Protocols

The decision to compare the Portuguese protocol study with the Dutch one (conducted by Christiaans in 1992) had to do with two reasons: 1) to compare and somehow validate the outcomes; 2) to understand if the differences in design education curricula would be strong determinants in the outcomes;

2.2.1 A short overview of Design Education at FA.UTL and FIDE.TUD

In 2007 the Design programs at the Faculty of Architecture of the Technical University Lisbon (FA.UTL) in Portugal were restructured according to the Bologna declaration. The transformation was radical since the Design programs changed from 6 years bachelor (5 +1 internship) and 2 years master to 3 BSc and 2 years MSc. In the previous programs the weight of science and social sciences was stronger than in the new programs. Nevertheless, they remained divided into the traditional design areas of product design, communication design and fashion design, each with their own master program.

The experiment in Portugal was done with Portuguese students from the 'old' program previous to the restructuring.

Design Education at the Faculty of Architecture (FA.UTL), is ruled by a 'proximity culture' since it accounts for an average of 30 students per year in the bachelor course, 20 students in each master course and a total of 145 PhD students. Classes are taught in Portuguese. The students are mainly Portuguese but in the last 10 years due to the mobility programs such as ERASMUS, there is also a presence of foreign students (before in the 4th year of the program now in the 1st semester of the 1st year of the master course) coming from schools in Europe (mostly Italians, Dutch, English, Eastern European) and in Brazil.

The Portuguese students also go abroad within the ERASMUS program (15 in total per year; 2 per year with Delft) during 6 months (1st semester) and some during 1 year.

The Faculty of Industrial Design Engineering of Delft University of Technology (FIDE.TUD) in the Netherlands on the other hand is the largest Design Education institution in the world with about 380 freshmen per year in the bachelor course and more than 300 students per year starting in the masters courses. The number of PhD students is around 70. In response to the Bologna declaration, the TU Delft introduced the Bachelor-Master degree system in 2002. It has a curriculum model of a three years bachelor program and a two-years master program. The language in the bachelor is Dutch while the three master course programs are in English. Therefore, in the master course there is a tradition of a multicultural student population coming from all over the world since the number of foreign students has increased to 78 in 2009. Moreover, the number of exchange students is increasing, from 30 in 2005 to 55 in 2009. Since 2005 TU Delft has a stable number of 2 exchange students per year from FA-UTL.

TU Delft has joint Master programs with METU, Turkey and KAIST, South Korea.

In Table 68 the content of all different programs is translated into averages spent to one of three areas: (1) specific for that program (including technology, materials, drawing), (2) human/social theory, and (3) business.

In first glance there are no relevant differences between the two programs except for the Masters courses in Delft. However, the bachelor at FA.UTL had changed its curricula reducing the weight of human/social theory courses, reinforcing the domain-specific knowledge area as well as the business one. Also to notice that the master's programs are structured differently. At FA.UTL they are a 'natural' extent of the bachelor course through an increment of specialization contents, and do maintain a broaden approach to Design while at FIDE.TUD there are two specialization masters in design fields that have a key importance to the markets/business.

Research as part of the design education curriculum in the two Institutions has quite a different weight. In the

	Faculty of Architecture - TU Lisbon				Faculty of Industrial Design Engineering - TU.Delft			
PROGRAMS	BRANCH OF DESIGN	STRUCTURE OF CURRICULA			BRANCH OF DESIGN	STRUCTURE OF CURRICULA		
		SPECIFIC (includes technologies, materials, drawing)	*HUMAN/ SOCIAL/ THEORY*	*BUSINESS*		SPECIFIC	HUMAN/ SOCIAL/ THEORY	BUSINESS
BACHELOR (3 years)	*DESIGN* average of 30 students/year	70%	17%	13%	*IDE* average of 100 students/year	70%	15%	15%
	FASHION DESIGN average of 30 students/year	81%	9%	10%				

	Faculty of Architecture - TU Lisbon				Faculty of Industrial Design Engineering - TU.Delft			
MASTER (2years - 1 for dissertation)	*PRODUCT DESIGN* average of 20 students/year	71%	19%	10%	*INTEGRATED PRODUCT DESIGN* average of 100 students/year	80%	10%	10%
	COMMUNICATION DESIGN average of 20 students/year	75%	11%	14%	*DESIGN FOR INTERACTION* average of 100 students/year	65%	30%	5%
	FASHION DESIGN average of 20 students/year	75%	11%	14%	*STRATEGIC PRODUCT DESIGN* average of 100 students/year	10%	30%	60%
PHD (at least 3 years) - 145 students since 2006	*DESIGN (1 curricular year) * the remaining 17% can be done in optional courses from all types* 145 students since 2006	25%	58%		*DESIGN (no curricular year. Courses are optional up to 15%)*	-	-	-

Table 68 | Bachelors, Masters and PhD at the two Faculties

new programs FA.UTL only has an optional course on design research (3 hours per week/42 semester) offered to the three masters. Furthermore, the first semester of the second year of the master courses is dedicated to research related disciplines. The PhD program is research oriented and the courses support the execution of philosophical/theoretical thesis.

Regarding the attention given to research in the Delft education programs, both bachelor and master programs have compulsory courses on this topic. Two of the MSc courses, Design for Interaction and Strategic Product Design have a clear research focus as expressed in the number of courses on this area. Delft doesn't give compulsory courses to PhD students; contrary to Lisbon. PhD's can choose their own courses.

Table 69 gives an overview of numbers, themes and nature/focus of both master dissertations and PhD theses at FA.UTL and FIDE.TUD measured in the period from September 2005 to September 2009.

The FA.UTL MSc and PhD students show clearly an attraction to theoretical and historical topics. Particularly in the PhD projects two lines of research are emerging: inclusive design and sustainability design. Taking the Portuguese industry's maturity into account one can

Table 69 | Master Dissertations and PhD Theses at both Institutions from 2005 to 2009

Themes Focus	FA. TU. Lisbon						TU.Delft				FA. TU.Lisbon	TU.Delft
	MASTER DISSERTATIONS (72)						MASTER DISSERTATIONS (935)				PhD THESIS (in progress) 64 of 145 have theme defined	PhD THESIS
	TOTAL	PRODUCT 21	COMMUNICATION 29	FASHION 12	INTERIOR 8	PUBLIC SPACES 2	TOTAL	INTEGRATED PRODUCT DESIGN	DESIGN FOR INTERACTION	STRATEGIC PRODUCT DESIGN	64	69
Historical	12	0	7	4	1	0	0				9	
Theoretical	18	8	7	2	1	0	0				10	1
Object Analysis	5	3	0	2	0	0	450	356	78	16	5	5
Case Study	4	1	3	0	0	0	5	2	1	2	5	2
Author/ Designer	2	0	1	0	1	0	2	2			1	
Inclusive	10	2	3	1	3	1	60	31	24	5	4	5
Sustainable	1	1	0		0	0	79	50	7	22	9	7
Management	8	4	3	1		0	96	2	2	92	4	4
Interaction	5	1	2	1	1	0	62	10	49	3	2	5
Innovation	1	0	0	0	0	1	36	2	1	33	4	
Cognition	4	1	1	1	1	0	49	7	29	13	3	20
Research	0	0	0	0	0	0	28	8	12	8	1	*
Methods	0	0	0	0	0	0	65	10	17	38	1	17
System Analysis	2	0	2	0	0	0	3	2	1		6	3

observe that the areas being more intensively studied at FA.UTL have a hard time to be immediate accepted by companies. The pHd students are clearly more tuned to the innovation and management areas. However, it is also the goal of research to anticipate the 'world needs' and to propose ways of better assessing problems and actions.

FIDE.TUD shows another picture. Apart from the huge amount of master dissertations (935 in the period 2005-2009), the focus on designing objects is outstanding (48%). Other important topics such as management and sustainability are following at great distance. The differences in focus between the three master courses are according to what they promise: interaction, cognition (emotion, perception) and inclusive design are clearly linked to Design for Interaction, while management and innovation are typical subjects for Strategic Product Design. As we see later on, most of the projects stem from industry itself and apparently are the relevant topics of that period. For the Delft PhD's cognition and methods are the two topics mostly studied.

Bridges between Education and Industry/Business

To address the relationship between design education and industry/business is to consider the context of it, i.e. the design role at national level, the firm's degree of maturity in design's use and the country's design policies. The role of design at a national level is crucial to the definition and strength of the relationship between education and industry. There exists some information compiled in rankings, but the 2009 report made by Moultrie and Livesey about Indicators of International Design Capabilities makes a rigorous assessment of this topic by means of collecting and comparing data on key indicators of design to define national capabilities. Those types of studies, we believe, are essential to support a systematic approach to this issue. The analysis includes the study of: a) enabling conditions such as national policies, strategies, institutions and endowments; programs that promote design to both business, particularly small and medium sized firms, and the general public; b) inputs/ capabilities: the development of human capital relating to design, including design graduates, designers in the workforce and those working in the design sector; c) outputs: intellectual capital generated as a result of design activity, including design registrations, trademarks and design awards; d) outcomes: reflecting the impact of the output on the overall economy (2009, p.16). It is interesting to notice that although TU Delft is a reference worldwide in design education (serving as an example to several education programs such as the ones of Designium, 2003 and of Design Council,2007) the Netherlands does not appear in the top of the Design competitive level rankings. That has probably to do with the lack of a national policy and of a consistent and regular study of the relationship between design investment and design outcomes in terms of the economy vision.

TU Delft education's success in the area of design is clearly related with the effective and consistent relationship it has with industry and service companies. That relationship is part of its distinctiveness and it rules the way programs are structured and research units establish their lines of research. In Table 70 differences between TU.FIDE and FA.UTL regarding internal and external factors are presented.

In contrast, FA.UTL has not an established relationship with industries. This relationship only happens in an episodic way, in the old program in the last two years of the 6 years course and with the new programs in the first year of the master course. The design studio teacher is the person who might establish contact with a firm, either with a real design brief or with a fictional one. In those cases the company will only appear at the beginning of the process and at the end, participate in the evaluation of the outcomes. Students also have contact with firms in the way that they participate at least in one contest per year (in the last years) launched by a firm that is integrated in the design studio program.

Note: This analysis of the two Institutions integrates a paper (that has as a co-author Prof. Christiaans).[49]

49. The paper will be presented at the 12th International Conference on Engineering and product design Education (EP&DE 2010) organized by the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway in partnership with the Design Education Special Interest Group (DESIG) of the Design Society and the Institution of Engineering Designers (IED). The conference will be held on the 2-3 September, 2010.

	Internal Factors	External Factors			
Schools	Background	Country design policy	Degree of maturity in the use of design* (design ladder)	Global Awareness of the design in the country (rankings)	Attitudes towards design and research
TU Delft	Engineering/ expert approach	Design as a strategic resource	Medium High in the majority of the companies	'Dutch Design' is a player in the busines and academic world	Companies and education have a consistent and natural relationship and it is assumed as a win-win situation
FA. TU Lisbon	Arts/ Humanistic approach	Design is part of the innovation strategy in a very diffuse way	Low - most of the companies use design as styling	There is no awareness of a 'Portuguese design' although there are several Portuguese designers contributing to the 'good design' all over the world	Education understands and tries to establish the bridges; companies do not have that culture of collaboration; the links occur not in regular basis

Table 70 | Comparison of the two education systems and context.

* The design ladder is a useful 4-step model for grouping companies' design maturity on the basis of their attitudes towards design. The higher a company is up the ladder, the greater strategic importance design has for the company. See Chapter IV, section 1.2 of this Thesis.

2.2.2 Comparing the two protocols focusing on problem structuring and information access in the design process

The aims of the first comparison study was the identification and comparison of the manner both Portuguese and Dutch students facing the same design problem in their design processes: 1) required information, 2) the nature of the information; 3) the occasion of its request; 4) the moment of use; 5) the possible relations between information required and decision making, and 6) the possible connections between information use and design moves along the process.

The analysis presented here integrated a paper (in co-authorship with Christiaans) presented in 2008 at the P&D Design08 Conference in São Paulo, Brazil [Appendix AB].

Information Access and Use in Protocols L and D

In both protocol studies information about various aspects of the brief and solution directions were available only at request by the subject. Each 'bit' of information was offered on a card. For an overview of cards see Table 71.

The nature of the information differs in both cases being rather complete and complex in D protocol and highly simplified in L protocol. The reason for this reduced information in the L protocols was to test the assumption that access to less and more simplified information might have a significant effect on the results of the experiment in terms of quality criteria …. This will be addressed later in this study.

The time allotted to the experiments was 2½ hours for D protocol and 2 hours for L protocol. The time reduction in L protocol was made taking into account two main issues: the focus of the assignment is on designing a concept and the amount of information offered has been significantly reduced.

Besides being rather different in number and complexity we can observe that the kind of information asked for and the sequence during the process differ per student; with the exception of the start-up information as we will see below.

Furthermore, in both groups there is a clear division between information asked for and used to structure the problem, and the one asked for and used to problem solving (Restrepo, 2004).

Information seeking, selection and focus

There are evident links between information requirement and decision-making. Information can open new paths of research for the solution but also serves the purpose of evaluation and/or confirmation of the existing hypothesis. That was visible in the case of information related with 'other solutions'. However, it is important to notice that not all information available was demanded and from the information required some was not used.

In the available information the one related with the images of the interior of the train, and with the current bin were the relevant ones, and they were asked for by all the subjects in both experiments. This type of information in almost all the cases made students to explore alternative locations to the object that later boosted the generation of ideas, further developed in terms of shape and functional/constructive aspects.

As was said before, some information requested showed to be ignored or not valued along the process and in the development of the solutions. That occurred in both D and L groups where information related with the producer and the railway company had a low (visible) impact on those that consulted it.

Also important to mention is the role of information created, the one that results from reflection either on information asked for or from retrieved information or even new one. This 'new information' becomes more visible in the form of new ideas but it is not fully used in most cases since some of those ideas get lost in the process. However, this effective reflection upon information is the one that unblocks solution generation.

In a few cases information created had its origin during sketching being the reason why we mention it as one of the key factors in design processes' decision making.

In general, in both cases "Problem structuring occurs mainly in the beginning of the design process, but also reoccurs periodically as the design activity progresses." (Christiaans and Restrepo, 2004, p.2). The 'structuring information' serves the purpose of creating 'the big picture' that helps defining the space of decision: being a kind of mental representation of the solution that will be further developed by means of drawing it. The 'problem solving information' is the one of enabling that mentally represented solution, and here the information is fundamental to verifying and evaluating the ideas/concepts in formal, technical and constructive aspects.

Table 71 | Information available on demand in both protocols.

● Information demanded but non existent

Information cards	Info asked	Information cards	Info asked
PROTOCOL D	(10)	PROTOCOL L	(14)
C Technical aspects			
C.1. Production			
C1.1 Production techniques vs costs			
C 1.2 Lathe			
C 1.3 Milling-machine			

C 1.4 Die Set-up			
C 1.5 Die mould			
C 1.6 Design for Assembly			
C 2 Tension and Rigidity			
C 2.1 Angular Rotation and retardation			
C 2.2 Snap-connections			
C 2.3 Break			
C 2.4 Tensile and Bending Stress			
C 2.5 Torque: rigidity and maximum tension			
C 2.6 Torque stress: formulas cross-sections			
C 2.7 Moments of inertia			
C 2.8 Elongation			
C 2.9 Friction			
E Ergonomics	3		
E 1 Operating Forces			
E 2 Compatibility			
E 3 DINED I (anthropometric data)			
E 4 DINED II			
E 5 pushing and pulling forces			
E 6 Compensation factors to clothing			
E 7 Body strength and age			
E 8 Pedal forces			
E 9 Reaching			
E 10 Maximum lifting and carrying capacity			
E 11 Lifting			
K Costs	1		
K 1 Production techniques vs costs			
K 2 Costs computation model			
K 3 Injection moulding costs: the mould			
K 4 Vacuum moulding costs: the mould			
K 5 Injection moulding: costs per hour			
K 6 Vacuum moulding: costs per hour			

M Materials	3		●
M 1 General properties			
M 2 Plastics			
M 2.1 Chemical resistance			
M 2.2 E (bending)			
M 2.3 E (pulling)			
M 2.4 Properties			
M 2.5 Maximum temperature			
M 2.6 Subassemblies			
M 2.7 Rules for designing in plastics (2x)			
M 2.8 Mechanical properties			
M 2.9 Costs/ Kilogram			
M 2.10 strength (bending load)			
M 2.11 Strength (pulling load)			
M 2.12 Processing Techniques			
M 2.13 Heat resistance			
S Environment			
S 1 Requirements	5		
S 1.1 Requirements NS			
S 1.2 Analytic technique of product use (2x)			
S 2 User Trial			
S 2.1 passengers	10	Card 4 – users/passengers	5
S 2.2 Cleaners	10	Card 5 – Cleaner comments	7
S 2.3 Contents of bins	10	Card 6 – Types of garbage	8
S 3 Client	4		
S.3.1 Producer	3	Card 7 – production Company	5
S 3.2 NS		Card 8 – The railway Company	9
S 4 Train Situation		Card 2 – images of the interior of the train and of the litter bin	13
S 4.1 sizes current train interior (2x)	10		●
S 4.2 Wall construction current trains	3		●
S 4.3 sketches for the new train interior (2x)	3		●
S 4.4 SM 90 : the new local train	10	Card 1 – external images of the train	13

P Product Information			
P 1 Existing Ns – refuse bins	6		
P 1.1 Exploded views	8		
P 1.2 Turn-over movement			
P 1.3 Technical drawings (3x)	6		
P 2 Design for new refused bin NS (3x)			●
P 3 Examples of litter bins (15x)	6	Card 3 – other solutions(3)	9
P 4. Emptying the bin			
P 4.1 Emptying tool	6		●
P 4.2 emptying: the procedure	5		
S Hinges (6x)			●
V Vandalism	3		

Also important to notice is what Christiaans and Restrepo (2004, p.2) observed "…that there are differences in the way designers approach the design assignments, describing it sometimes in terms of abstract relations and concepts (problem oriented) or descriptions of the possible solutions (object or solution oriented). These differences seem to influence the information seeking-behavior of designers, their tendency to become fixated as well as the output of the design process."

Information demanded and used to structure the problem

According to Restrepo (2004) information accessed during problem structuring refers more to users, the company and the environment in which the product is used, requiring much more active interpretation and manipulation before it can be used than the information normally required for problem solving.

Both in Protocol D and Protocol L after reading the assignment (which included some clues about possible information to be asked), subjects started with problem definition through exploration of the situation. In the available information the cards related with the images of the interior of the train, and with the current bin were the relevant ones, and they were asked for by all the subjects in both experiments.

This type of information in almost all the cases concurred to explore alternative locations to the object that later boosted the generation of ideas, further developed in terms of shape and functional/constructive aspects.

In Protocol L the information related with 'other solutions', when asked for, served mainly the goals of opening new paths of research for the solution, evaluation and/or confirmation of the existent hypothesis.

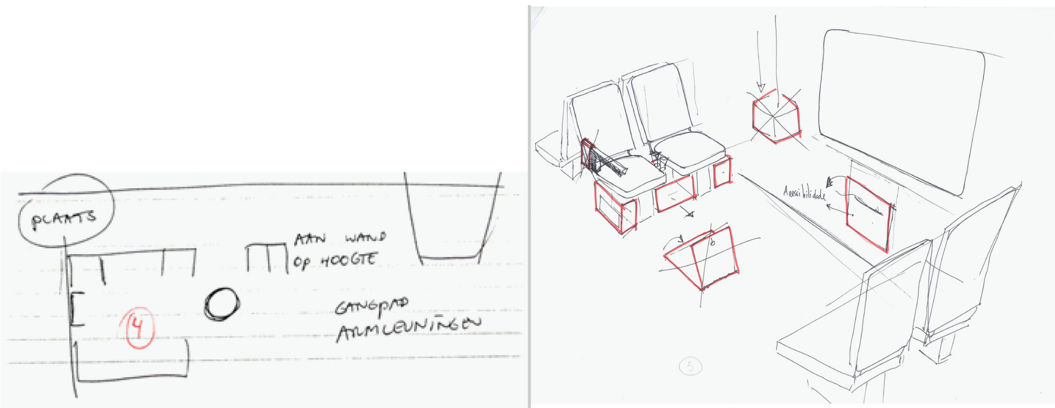
In both D and L design processes information related with the producer and the railway company had a low (visible) impact on those that consulted it.

In the following Figures 72 to 78 a comparison is presented of the sketches in subsequent stages of the design process.

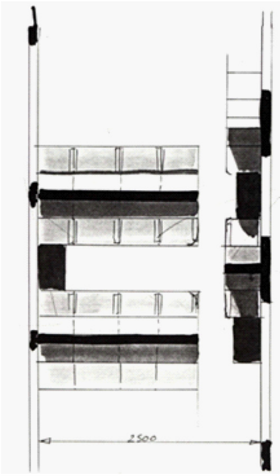
Information asked for and used to solve the problem

The type of information accessed during problem solving is according to Restrepo (2004, p.12) more related with manufacturing conditions, properties of materials, functional characteristics, formal aspects etcetera. In fact, ergonomic information as well as the one about the bin use and operation gave origin to formal and technical, operational and constructive design moves as well as an evaluation of the bin location.

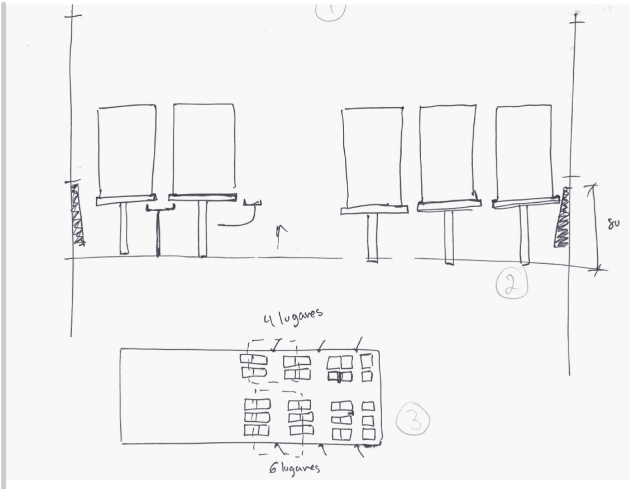
Fig.72 | Exploring possible locations of the bin



Protocol D (14) Protocol L (3)

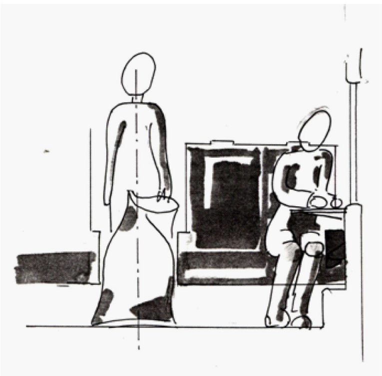


Protocol D (9)

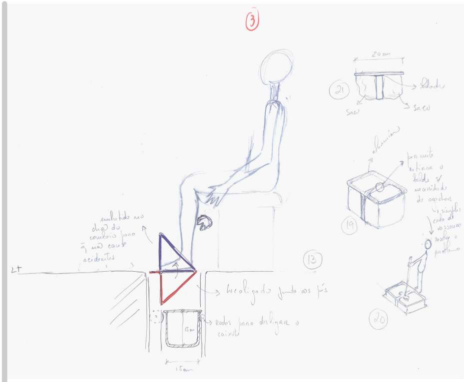


Protocol L (8)

Fig.73 | Understanding the space/ environment/context



Protocol D (9)



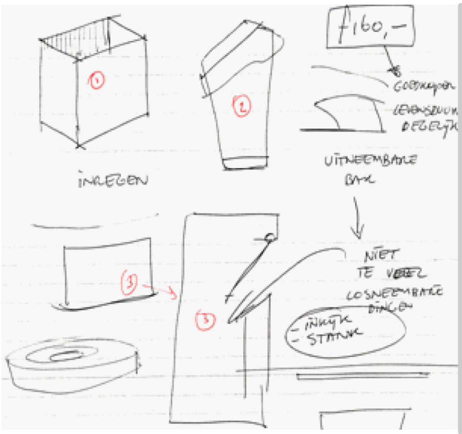
Protocol L (8)

Fig.74 | Operating the solution – passenger and cleaning employee

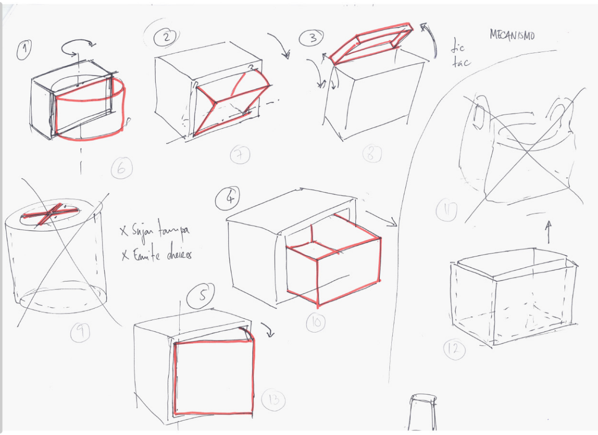
The information regarding the type of garbage, especially in Protocol L where it was asked for by 62% of the subjects, generated in all cases the idea of separating the garbage. This separation is a clear determinant of the final concepts that are distinguishable from the others who were not informed by that data.

The solution – a new piece of information / the transformed information

The solution or solutions presented are in itself a new piece of information that deserved special attention on the part of the subjects involved in both protocols.

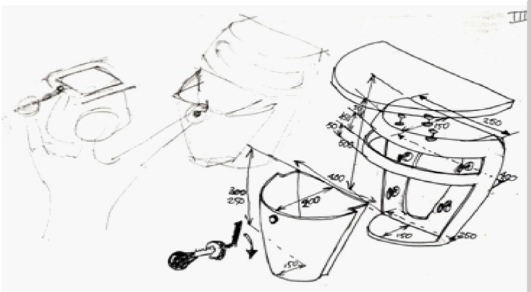


Protocol D (14)

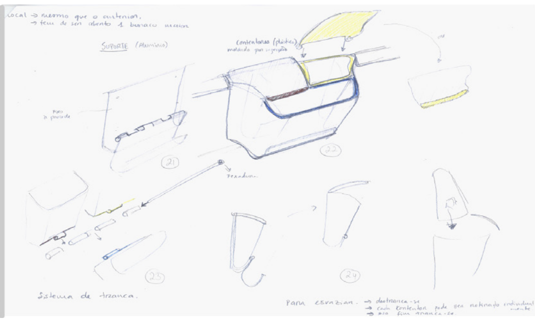


Protocol L (3)

Fig.75 | Exploring possible opening systems for the bin

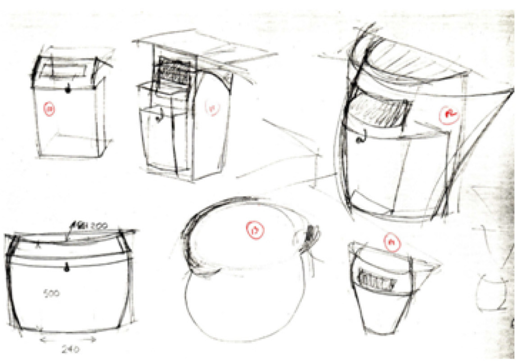


Protocol D (3)

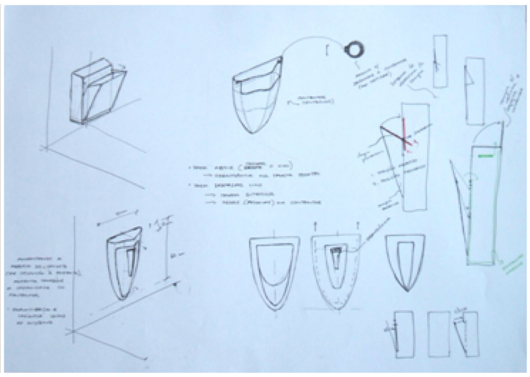


Protocol L (7)

Fig.76 | Constructive and functional approach



Protocol D (3)

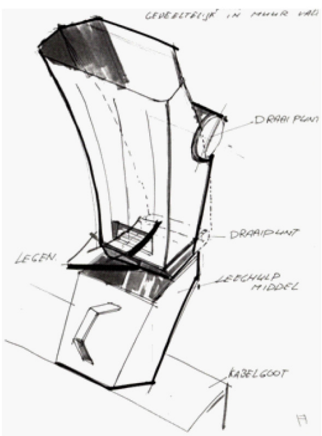


Protocol L (5)

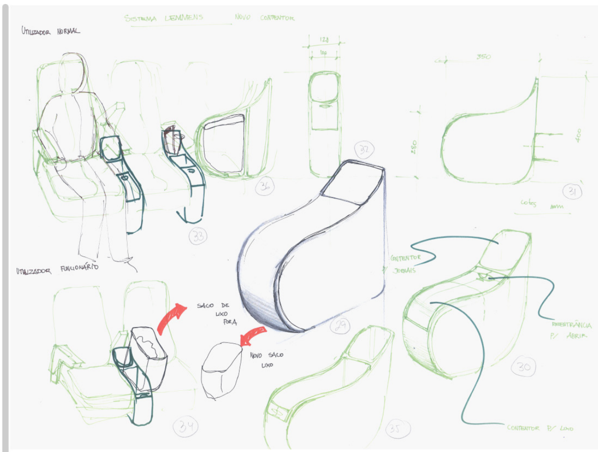
Fig.77| Searching the form

Information was presented both in drawings and texts that aimed to summarize in a very efficacious, appealing way the solution proposed. In fact, almost all the subjects along the experiment gave notice of their concern about their performance in terms of final presentation alluding to their inability to draw, the poor communicational capabilities of their sketches and of the composition and arrangement they made of it. Therefore, it is important to underline that there is a very accurate conscience among the design students that their solutions in themselves must be very clear and consistent pieces of information and that it is suggested by the analysis of their verbalization that their efficacy depends heavily on representation skills either mentally of physically through drawings and modeling.

Fig.78 | Presenting the concept – creation of new information



Protocol D (2)



Protocol L (6)

2.2.3 Comparing the two protocols focusing on Decision Making

As previously said the original focus of both studies was on knowledge and information management. However, the observation of the protocols made clear that decision making was a crucial topic to assess.

That was the reason to conduct a comparative analysis of decision making in both the Portuguese protocols (L) and the Dutch ones (D).

Protocol study D was undertaken in 1992 and included both 2nd-year and final-year students from the Faculty of Industrial Design Engineering at Delft University of Technology (Christiaans, 1992). For the purpose of this study we only compared the work Delft developed by the 10 final-year students (3 female and 7 male). They were selected out of 75 students on the basis of their average marks for the design courses (at least a 7 out of 10). Protocol L was conducted in 2007/2008 and its subjects were 14 students (11 female and 3 male) from the last year of the Design course at Faculdade de Arquitectura da Universidade Técnica de Lisboa. From the class of 17 they volunteered in the project. In this thesis due to the complexity and extent of the analysis we only present the comparison for the best, a medium and the poor results in both cases.

The analysis presented ahead integrated one paper presented at a Design Conference and a Design Journal article and had the co-authorship of Prof. Henri Christiaans.[50]

The aims of this particular study were the identification and comparison of the way senior design students in both groups take decisions, the relation with design moves along the process, and the factors influencing the decisions and moves.

For that purpose both verbal protocol analysis studies (VPA) were analyzed on the basis of activities and decision-making moments described in terms of reasons behind it and goals intended to be achieved through it.

By studying the decisions made during the process and the factors that influence those decisions we hope to

50. The paper was presented at ICORD 09 [Appendix AC] and was published in a book and the article was published in the Journal of Design Research (2009) [Appendix AD].

get a more detailed view on the effectiveness of the decision making process in terms of quality of the end result. The issues addressed by this study regarding the decision-making process were: a)the characteristics of the decision-making process in design (framing-key-enabling); b)the process of decision-making related to the generation of ideas and the quality of the final result; c)the relationship between decision making and 'design moves'; d)the role of different types of decisions; e) the relevant factors influencing the decision process (knowledge/expertise, external information, sketching).

Concerning the analyses done in the Delft protocols workshop Cross (2006) highlights those that '…reinforce the importance of a concept as marking a key point in the process' (p. 70). This 'key point' is what we refer to as a key decision. Furthermore the analysis developed by Günter et al. (1996) is also important to mention. Their analysis of the design process has three main stages: clarifying the task, searching for concepts and fixing the concept, the two first ones being covered by our framing decisions category and the last one corresponding to the enabler decisions. In his analysis of the Delft protocols Cross (2006) also recognizes the occurrence of a bridging concept between problem and solution that '…synthesizes and resolves a variety of goals and constraints; and it occurs during a 'review period' after earlier periods of more deliberately generating concepts and ideas' (p. 70). This review period in this study corresponds in some cases to the end phase of framing decisions or even to a period of time where in the protocol graphics framing decisions alternate with enabler decisions, mostly of reflecting nature ones as it is observable in Figures 79 to 84.

In addition to this Cross (2006) claims the 'appositional' nature of design reasoning that is characterized by the development of function and form in parallel rather than in series, being a neglected aspect in almost all design process models. This is clearly observable in both protocols that display - as Cross (2006) mentions it - an '…exploration and identification of the complex network of sub-problems in practice (that) is often pursue by considering possible sub-solutions. In practice, designing seems to proceed by oscillating between sub-solution and sub-problem areas, as well as by decomposing the problem and combining sub-solutions' (p.78).

Within that perspective key decisions, according to our encoding system, are taken when bridging occurs among partial models of the problem and solution that have been constructed side-by-side. In the words of Cross (2006) it is a 'bridge' that recognizably embodies satisfactory relationships between problem and solution. '… the recognition of a proposed design concept as embodying both problem and solution together (…); it is neither one nor the other, but a combination which resolves both together and allows either to be focused upon' (pp. 78-79).

For the purpose of this analysis it was created a graphic's layout that allowed to establish the precise moment of each decision along the process, its nature (that is described in the encoding system) and the way it contributes or not to the proposed solution that is related with a key decision (orange for the first one; red for the second one). Idea generation (purple color) also makes part of this graph that allows a visual perception of the density of decision type and of the decision flow per activity.

The examples we will show try to enhance the diversity and uniqueness it is possible to find in design processes. Although the analysis was done for the entire time of the exercise we will only present graphics of the first hour. The complete analysis integrates Appendix AE.

Next, when presenting cases with the best and the most poor results it was found useful to add two more cases on the basis of the following criteria: for the Delft protocols we added a female subject with a medium score (while the other two Delft subjects were male); from the Lisbon protocols the added subject also had a medium score and developed two solutions, in an alternate mode.

2.2.3.1 Analysis of both Portuguese and Dutch Poor, Best and one Median Protocols

'Poor results' – Protocols D1 (male, average rating=5.7) and L1 (male, average rating= 4.6)

Protocols D1 and L1 were, according to the jury, the ones that had the lowest average and median rating. Their similar results have complete different processes behind. However, they show a striking similarity by not succeeding in processing information and in idea generation.

As we can observe in terms of decision-making (see Figure 79) subject D1 has an expressive density in columns related with asking and reading information that is not sustained by reflection on information. This indicates a lack of information processing and subsequent application.

Subject D1 was unable during this period to formulate a key decision displaying only framing decisions that gave no origin to idea generation. On the other hand in Protocol L1, Figure 80, we can observe that not much information was asked for (and from the one asked the focus was on the train and its interior being the rest ignored); less decisions were taken, and there was a fixation to an idea that boosted a reasoning in a circular way. It is also to be considered the negative reaction both subjects had to the brief.

Subject L1's immediate reaction was to propose two contrasting solutions, one that had serious implications for the train structure and layout and another one, defended until the end, that consisted of augmenting the capacity of the existing bin by stretching it to the floor. It was clearly a strategy of opposing extreme solutions to benefit the one that was more realistic. At first sight subject L1 shows a quick idea generation followed by a period of sketching and reflecting activities. However, when analyzing the contents of those activities we come to the conclusion that the subject is fixated in circular reasoning as is clear from the fact that (1) his sketching is not meant to search for ideas but sticks to the same statements, and 2) the reflections made are a repetition of statements in favor of the option he came up with.

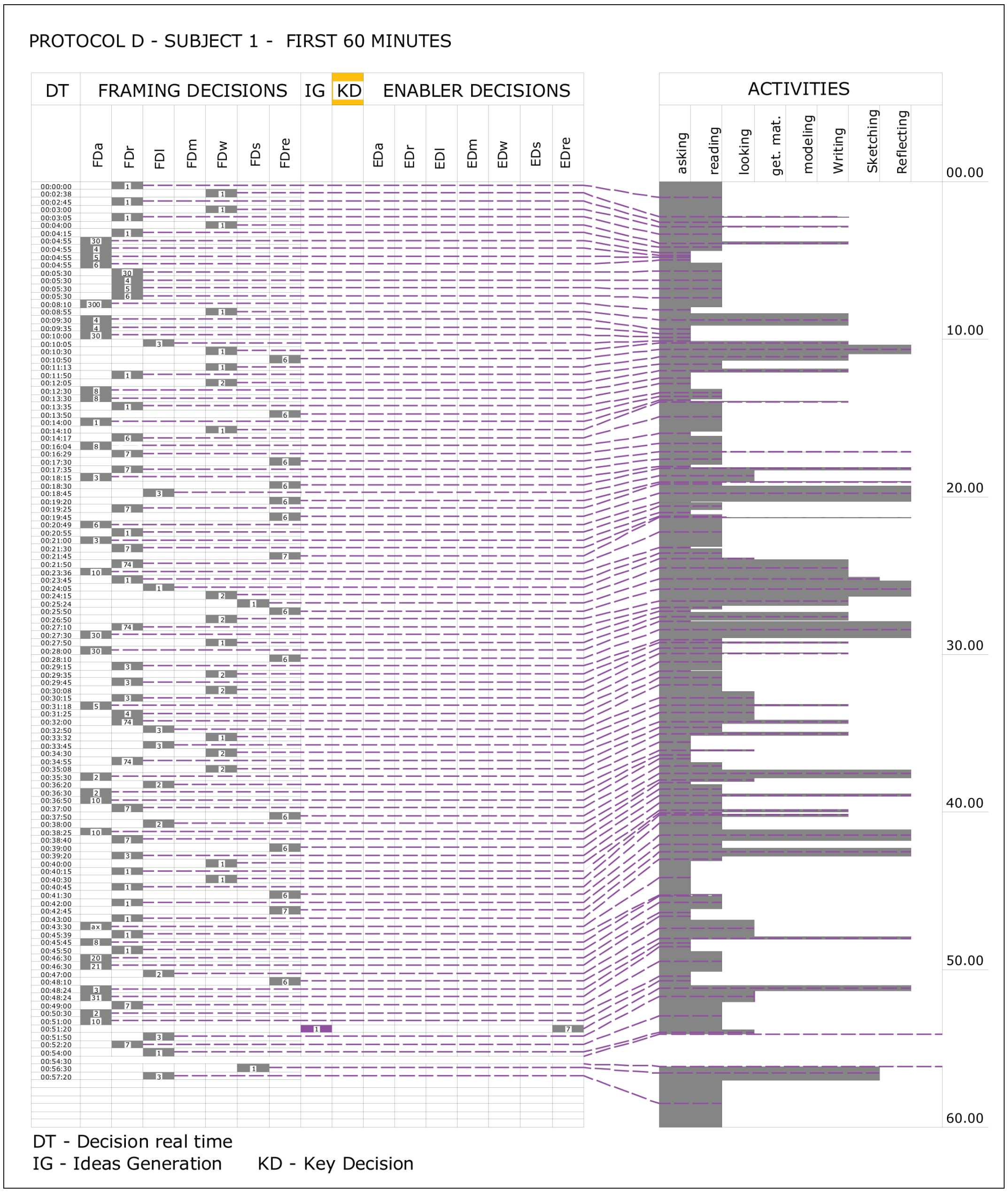


Fig.79 | Protocol D1 – first 60 minutes

Taking a closer look to subject D1's performance whose approach is radically different; he is 'obsessed' with information gathering in a systematic but not reflective way. The information asked for covers all the aspects involved in the exercise – it goes from information about the train, passing through information regarding the interior of it, other solutions, types of garbage, current solution in all details, producers information, employees complaints, technical issues and mechanisms. His first idea is generated after 51:50 minutes but this idea is

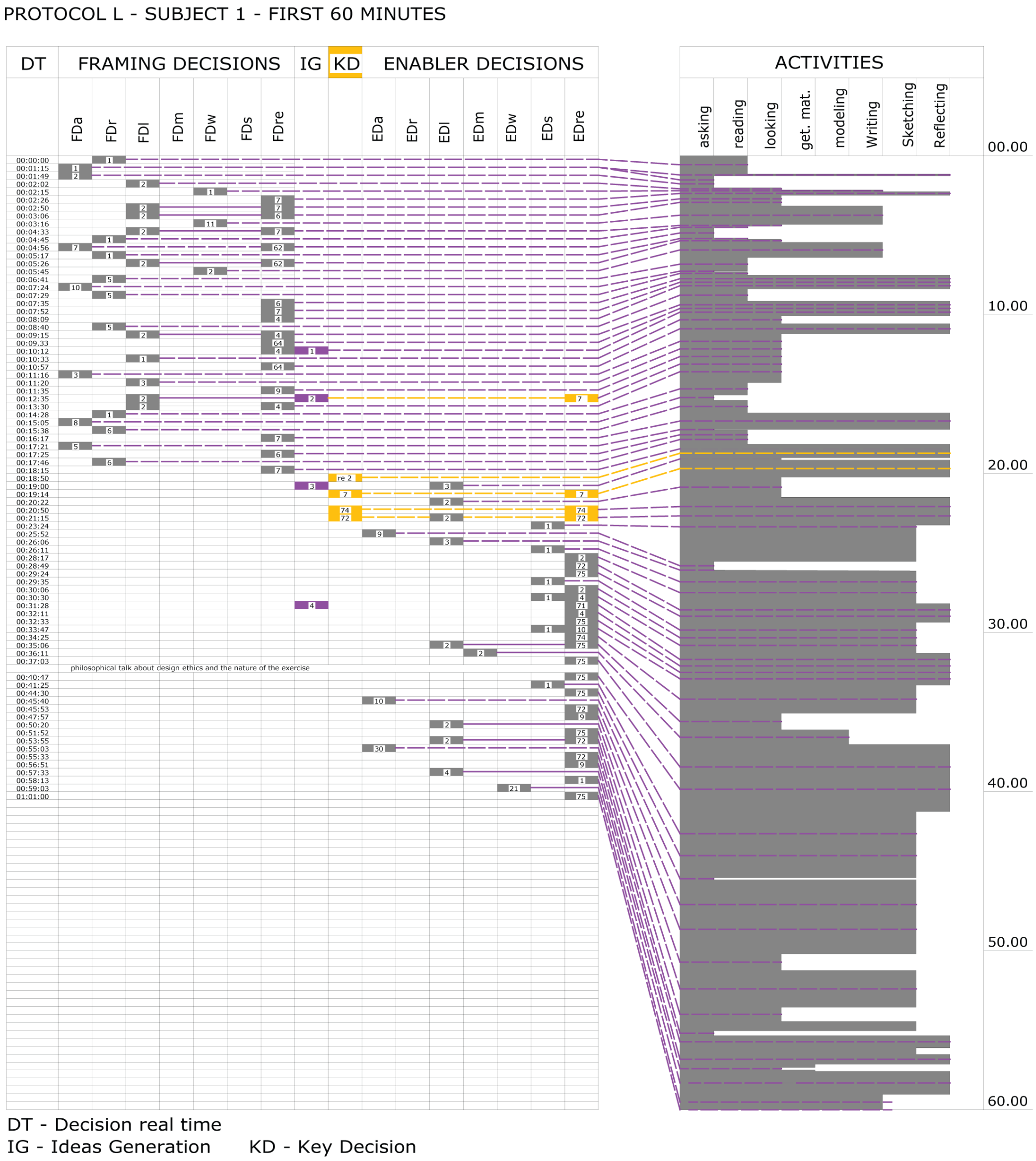


Fig.80 | Protocol L1 – first 60 minutes

abandoned and not linked with the final solution he developed.

Subject L1 on the contrary has a quick gathering information moment, after about 18 minutes where he asks information about the train, the interior of it, technical issues, other solutions developed, producer's data as well as employees' complaints; but the only information taken into account is the one presented of the train itself and the interior of it. In fact, minute 18:00 is the moment when his third idea is generated and where his key solution appears to remain until the last moment.

Enabling actions were mere drawing reinforcements of his circular speech expressed in only nine sketches made during the 2 hours. (While 25 sketches is the average of sketches done in all L protocols). Among these nine sketches five were dedicated to copying the existing solution, both in sections and in one perspective.

'Best results' – Protocols D6 (male, average rating=8.5) and L2 (female, average rating=7.1)

Both high rated protocols display an intensive reflective dialogue – subject decides, reflects/evaluates upon decision, and decides again. Each activity is developed having the reflection mode as the dominant activity. The activity itself must apparently have a complementary role in this analysis: not the reading by the subject is important, but what he is reading, the selection that he makes of it (decision) and the way that selection is consistently propagated along the process in order to contribute to the final solution.

Also important is the nature of those reflecting decisions that have a clear applied goal – most of the decisions are related with the idea generation process and its materialization in its multiple aspects from technical aspects to ergonomic and aesthetic ones.

Subject D6 has a clearly defined period of brainstorming – an idea generation moment to expose a novel possible concept (33:50–38:30 min.) that serves not only the purpose of finding new paths but also as an evaluation moment to previous ideas, some of which partially integrated in the final solution.

On the Lisbon side subject L2 displays a strategy of continuous monitoring. Tests of her ideas that occur as 'extensions' to previous ones through sketching and modeling where functional aspects pay a key role. The detailed comprehension of the object and its feasibility and easiness to use are central in the design.

Giving a brief description of the subject's performance we observe that D6 spent his first half hour on framing decisions but his first Key decision can be traced back to minute 11:55 when he generates his first idea. That one

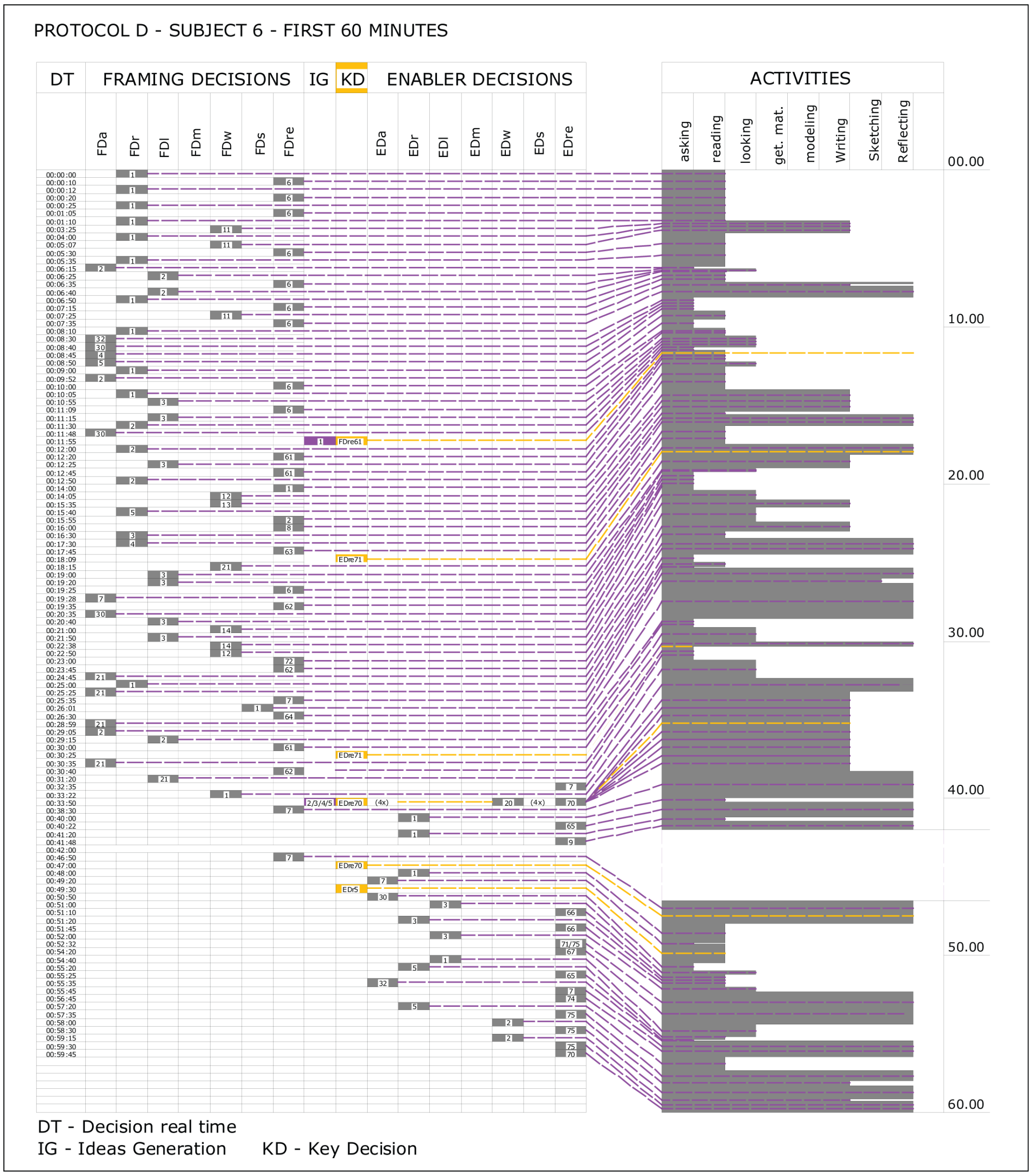


Fig.81 | Protocol D6 – first 60 minutes

combined with other ideas later on in the process gives birth to the final solution. That idea was generated out of framing decisions that related to:

> Reading the assignment;

> Reflections made upon information asked for that had to do with the current solution, the list of requirements, the interior of the train, users' opinions and the employees' complaints.

The moment of enabling the solution was born from the consolidation of one object that integrated three previously generated ideas that were put together.

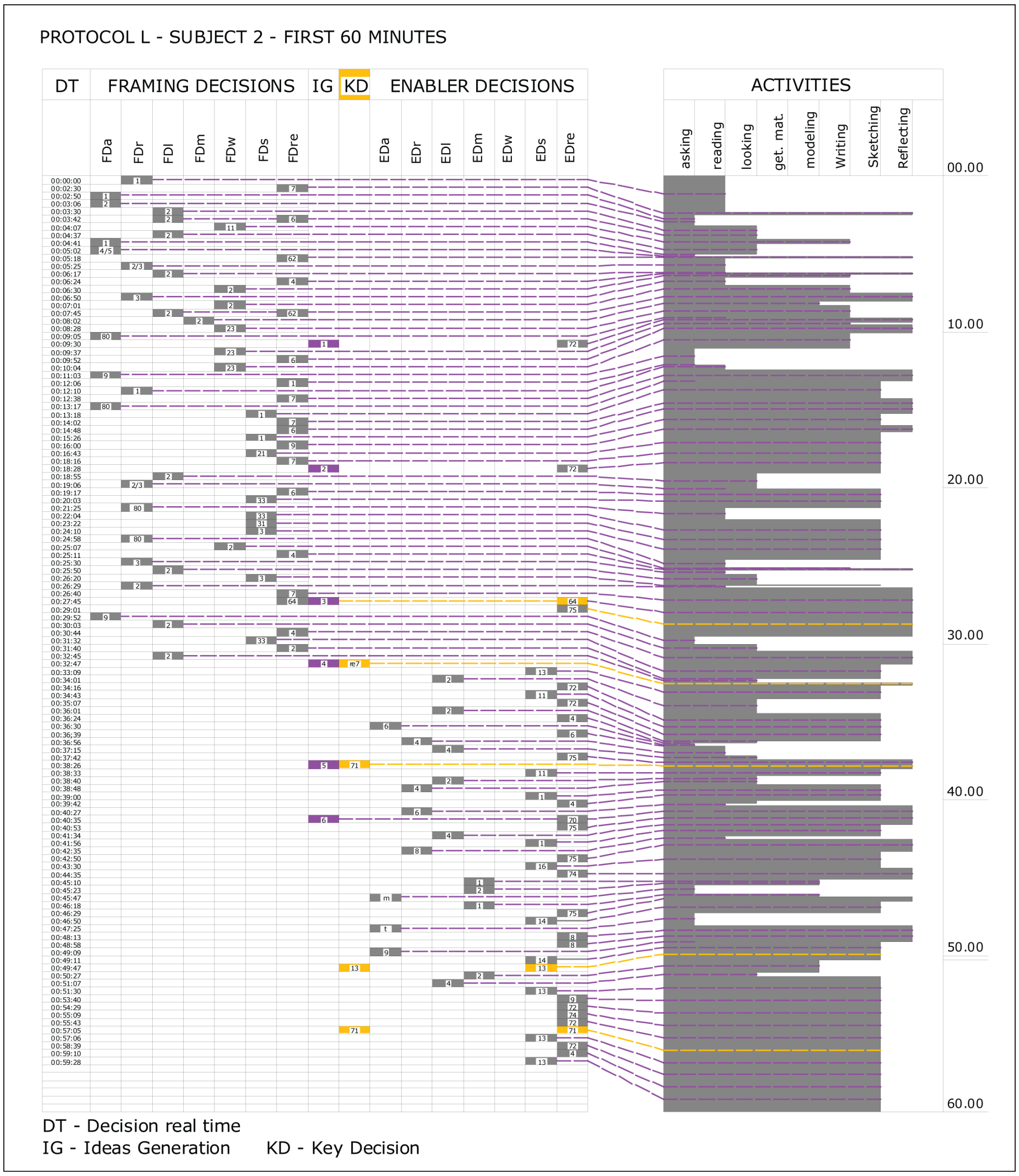


Fig.82 | Protocol L2 – first 60 minutes

This phase of enabling is characterized in D6's case by:

> Reduction of asking activity (he was concentrated on his thoughts, information and sketching)

> Intensive reflection activity related to generating a new system, parts of the system and on analyzing his own ideas regarding possible solutions to employees' complaints, company data integration, costs control and also ways of presenting the final solution.

Regarding subject L2, she also took half an hour period of framing decisions that, when compared to D6, is more diverse in terms of the activities performed. It goes from gathering and analyzing information about the train, users, employees' complaints, producers and ergonomics to looking at the images, writing her reflections and data collected.

We can trace back her Key decision up to minute 27:45, the moment of her third idea generation phase that would be further developed.

In the L2 case the enabling moment was also a very intensive and holistic way in that she reflected on the new system in general as well as on both its technical aspects, constraints evaluation, ergonomics and on her own ideas' potential, types of most effective representations and means of presenting the solution.

However, and when compared to D6 this process was deeply linked with sketching as being an action-reflection way of design thinking. On the other hand, D6 declared in his debriefing that he was used to visually imagining situation, objects, context and ideas. Representations were made in his head, not so much on paper.

Also to mention that modeling was important for her in the overall process of enabling the solution.

'Median results' – Protocols D9 (female, average rating=6.7) and L9 (female, average rating=6.5)

Both Figures 85 and 86 illustrate protocols that had an medium rating in quality terms.

D9 developed a single solution was Figure 84. During the first hour of work her main concern regards the issues of the location of a bin and the emptying tool for the cleaners. Although we can trace back the final solution to decisions made in this first hour, at that time she has no solutions for those issues yet. The number of decisions made was also reduced due to reflection moments either during sketching or as a means to evaluate information.

In subject L9's protocol (Figure 85) the rhythm of the whole process is quite impressive being very dynamic and intensive.The subject decides very early in the process to develop at least two possible solutions and works on both in an alternate mode but continuously

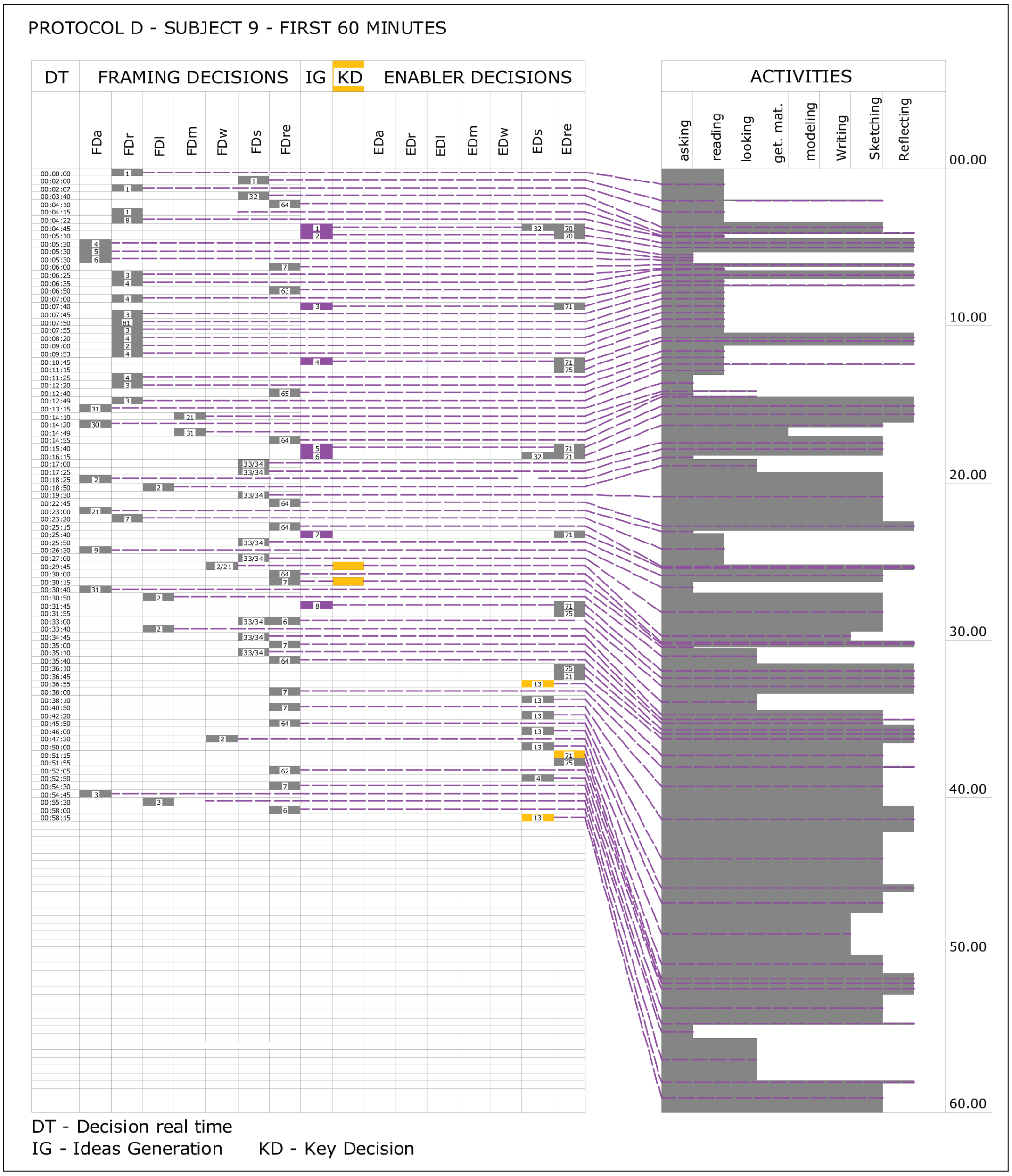


Fig.83 | Protocol D9 – first 60 minutes

using the comparison between solutions for one concept as a refinement tool for the other and vice versa. When compared with both low and high rated cases we can observe in these two subjects that some information is both processed and applied, and that idea generation and the follow up of some of the ideas towards a solution indeed take place. However, at the end of the more than two-hours session both subjects do not meet the phase of presenting creative solutions that integrate in a balanced way the perspectives of all stakeholders involved (client, passengers, cleaner employees). From

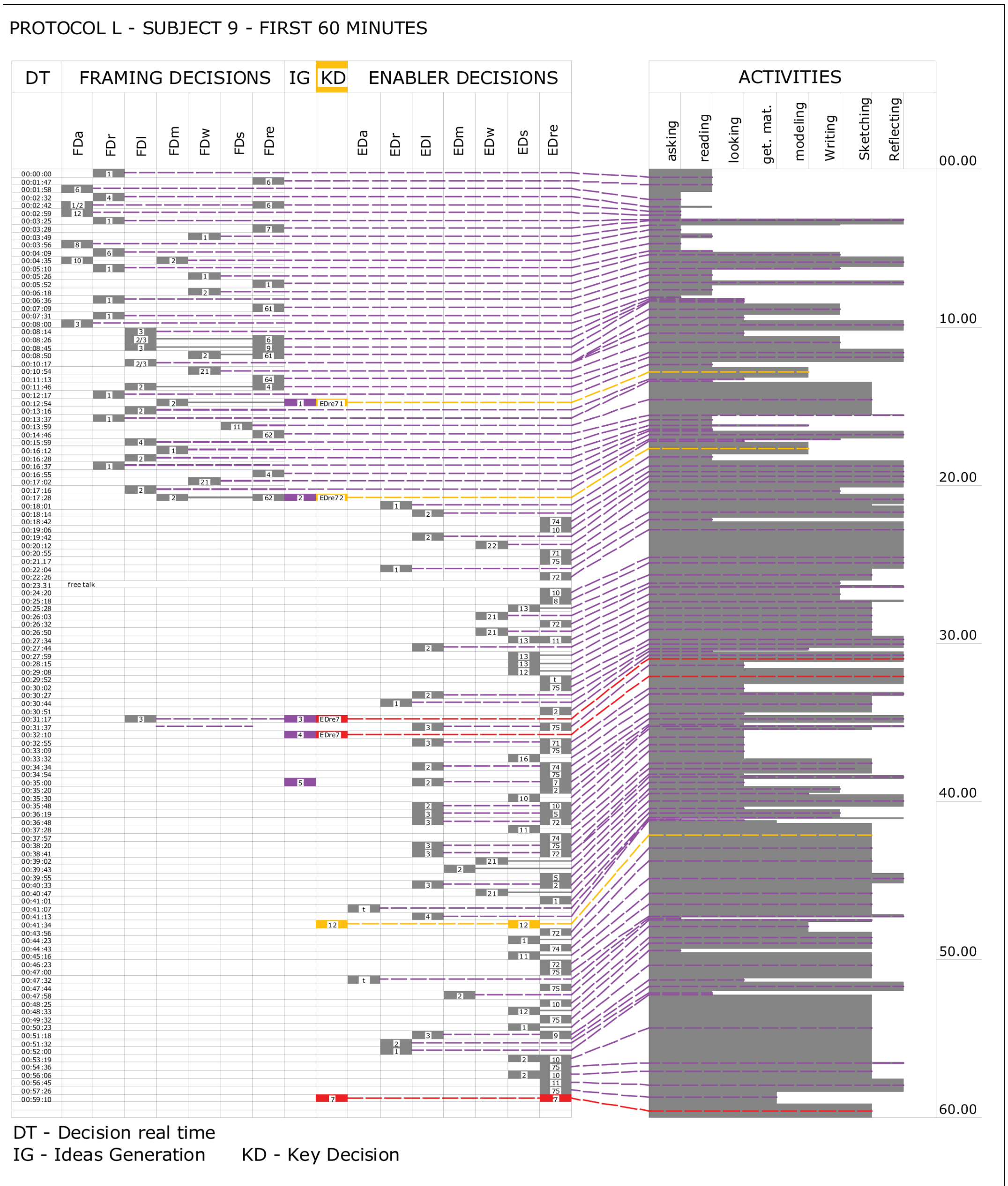


Fig.84 | Protocol L9 – first 60 minutes

the accurate analysis of the verbal protocol contents we found out that the design process itself dominates the development of the design solution.

Worth noticing here is the fact that subjects based their work upon a chosen focus (a single perspective) diluting the importance of other interrelated factors. In D9's case the cautious approach of the student plays a role in this result and in L9's case the self-imposed commitment to present two final solutions caused a kind of 'running against time' attitude that did not promote deep reflection along the process.

2.2.3.2 How is the process of decision-making related to the generation of ideas and the quality of the final result?

Reflecting on the foregoing analysis of the decision making process and looking for the 'logic' behind the ideas generated we like to highlight some findings. First, we can conclude on the basis of, for example, the L2 protocol (see Figure 81) that not only radical shifts of perspective characterize the generation and materialization of an idea in design processes. By means of manipulating the idea, exploring it deeply in an attempt to expose its self-potential and relational potential one can enter a 'creative leap' that in the words of Cross (2006) '…might be no unexpected dislocation of the solution space itself, but merely a shift to a new part of the solution space, and the 'finding' there of an appropriate concept' (p.65). That is, according to Cross, what characterizes creative design as exploration rather than search.

Cross's idea of '…creative design being the apposite proposal of a concept which embodies novel features for a new design product' (p.65) presents us the creative cognitive act in design similar to '…building a bridge between problem requirements and solution proposal' (p.66).

Subject D6's protocol, where it is evident that each activity is preceded and followed by a reflection moment, formulated in operative terms, is a clear example of an undergoing creative construction' that involves problem and solution as the dynamic and interdependent parts of the 'engine' driving the process.

What is observable from the analysis of D6's exercise is that his accurate and critical attitude towards the task 'under construction' made it possible for him to question problem and solution settings in an evolutionary interdependent way, entering a dynamic design practice that is recognized by Dorst and Cross (2001) as being more '…a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces' - problem space and solution space. In creative design, the designer is seeking to generate a matching problem-solution pair, through a 'co-evolution' of the problem and the solution' (p. 434).

Relationship with design moves

The study conducted by Goldschmidt (1996, pp. 75-76) identifies what she calls 'critical moves' i.e. '…one which has a relatively high number of links to other statements that succeed it'. In spite of the fact that she does not identify the key decision moments her linkograph work clearly shows that there exists some statements that have a high number of 'fore-links' i.e. subsequent statements that build onto, or refer back to, those statements.

This path of related statements is also identified in our figures where decisions that contribute to the final solutions are marked; either they are technical enabler decisions or reflecting enabler decision that reinforces or confirms a path or marks an inflection of direction.

In both D and L protocols the most significant moves have do to with the decision to change the location of the litter disposal system. The new placement of the object determines the re-arrangement of all the constraints and variables of the problem and also defines a change of paradigm that corresponds to a key decision. The pieces of information that contributed most to the need of finding a new place for the object were: images of the interior of the train that shows the actual location of the bin and that makes problems of capacity/dimensions evident to the designers, reach and interference with passengers' space/commodity and information about types of garbage – that especially in Protocol L lead to the idea of separating the garbage and thus finding a place that can support that feature.

SUMMARY OF THE EXPERIMENT WITH DESIGN STUDENTS – INDIVIDUAL EXERCISE

This individual exercise allowed us to make an active study of the way students: a) access and use information along the conceptual phase of the design process; 2) develop their own decision-making processes in that conceptual phase of design.

The assignment in the Lisbon protocol was the same as the one used in studies by Christiaans (1992) and Dorst (1997). Because of this we had the chance to compare the Delft protocols with the Lisbon protocols and to analyze similarities and differences along design processes.

The method used was the Verbal Protocol Analysis (VPA) that implied the videotaping of all subjects that had to think aloud while developing their design processes. The protocols were then transcribed, translated to English and encoded according to a code system based upon decision making categories developed by the researcher. These categories have their origin in the literature review as well as in the critical observation of the protocols. The coding system relates to the nature of decisions with the activities being undertaken by the students.

To assess the quality of the outcomes a Jury was created. It was composed by design teachers, engineers, and business representatives. They had made their judgments based in the transcribed protocols and the drawings made by the students. They score each protocol according to defined criteria and using a sale from 0 to 10. The weigh of each criterion was to be established by each jury member.

The students also had a debrief moment were they could express their opinion about the method used, the difficulties they experienced along the exercise and the adequacy of the information given as a support to the design process.

In comparing the Delft and Lisbon protocols is is important to notice that these two different group of students have distinct education backgrounds since the Dutch curriculum has a substantial presence of technical disciplines while the Portuguese ones have a less technical and more humanistic curriculum. For that reason the information at their disposal was significantly different in terms of complexity and quantity, with the amount of information offered in the Delft Protocol being more complete and complex in technical and technological terms and that in the Lisbon Protocol much simpler and generalistic.

Regarding the first study on information access and use one of the findings we can address is that in both cases the gathering of information by itself does not guarantee the best results in terms of solution. The best solutions occurred when reflection upon information was made in such a way that it gave occasion to the generation of significant design moves. Another finding is that results of both groups are very similar in terms of the type of concepts generated and quality criteria. It suggests that in the conceptual phase it is possible to formulate consistent concepts without having access to very sophisticated information.

In our second part of the study on decision making we found out that the analyses provided by graphics based upon decision-making provides a better understanding of the dialogue between problem and solution, envisioning the complexity of the process compared to conventional graphics illustrating activity-based approaches.

Another finding was that design decisions related to product form and manufacturing processes are evidently more often listed in a conscious way than development decisions that control the progress of design process.

Considering now the protocols studied in a more strict view there is a kind of primary 'Pattern logic' approach to the problem that goes as follows: more passengers imply more garbage that implies a bigger bin or smaller ones in more quantity (capacity prevails as a criterion). This implied in almost all the cases the 'reduction' of the solution to a bin instead of a completely different system; a system that should also be influenced by the evaluation of existent solutions as well as by information that integrated the specific company's information available.

The analysis of both protocol studies allows us to conclude that decisions that 'made a difference' i.e. that implied key decisions and design moves, were almost always linked with: a) location –that is linked with garbage volume (the most common subject's 'control constraint'), b) passengers' use of garbage and movements inside the train; b) types of garbage – that influence dimensions and therefore location. Especially in L protocols there was a prevalence of the recycle concept even when ergonomics, usability, interface with users and employees and costs were affected giving strength to the idea that 'the principle overcomes the constraints'.

2.3 - The CLIMAR Experiment - a Group Design Process linking Design Education with Business

This particular study is a descriptive approach to design processes as decision-making ones. To support the experiment to be done 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 [Appendix AF]. Furthermore, a Decision Making Model was developed based upon the experiments and activities performed previously (see Figure 85).

This experiment, similarly to the previous one, gave origin to a paper that has as co-author Prof. Henri Christiaans, which was presented at the Conference IASDR 09, Seoul, 18 – 22 October, South Korea. [Appendix AG].

The experiment was done with the thirty two design students (teams of 5/6 each) from the 5th year of both Product Design Program and Communication Design Program that also have made the exercise about design processes reported on 1.1.2 of this chapter.

The students had to solve a design problem suggested by a Portuguese Light Company, CLIMAR, Sistemas de Iluminação, S.A. [Appendix AH].

Decision making in design processes is on our point of 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.

The overall aims of this study was to understand: a) if a descriptive framework would allow us to describe, understand and better implement decision making along design processes; b) to assess if the creation of a decision making supporting tool to designers would facilitate decision making in the design process.

2.3.1 The Decision Making Descriptive Model

The descriptive model of decision making is presented in Figure 85. It equates decision making at three different levels that are highly dependent on information/ Knowledge management and Idea generation. They are:

a) a macro level - as depending on:

> (1) *Design Strategy* that as Christiaans and Restrepo (2004) mentioned can assume two 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; and solution oriented when from the beginning there are descriptions of the possible solutions. On the base of these authors' findings and after the analysis of the previous experiments and actions we decided to include a third category, the *integration oriented* one that has to do with a design strategy that alternates from problem to solution in the way the concept of co-evolution is proposed by Dorst and Cross (2001). Moreover, we have changed the denomination from being 'oriented' to being 'driven' since it seems more appropriate to use this term.

> (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.

b) an intermediate level , including *Decision Nature*, that was defined according to 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 micro level – where decision making is defined according to the following descriptors:

> (1) Decision Strategy, where we can find three distinct strategies: a non-compensatory rule based strategy

meaning that, as defined by Rothrock and Yin (2008), 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 etcetera.

> (2) Mode of Decision that has to do with the dynamics of groups in terms of decision making including three types: 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; Autocracy, 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.

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 (1992) 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.

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.

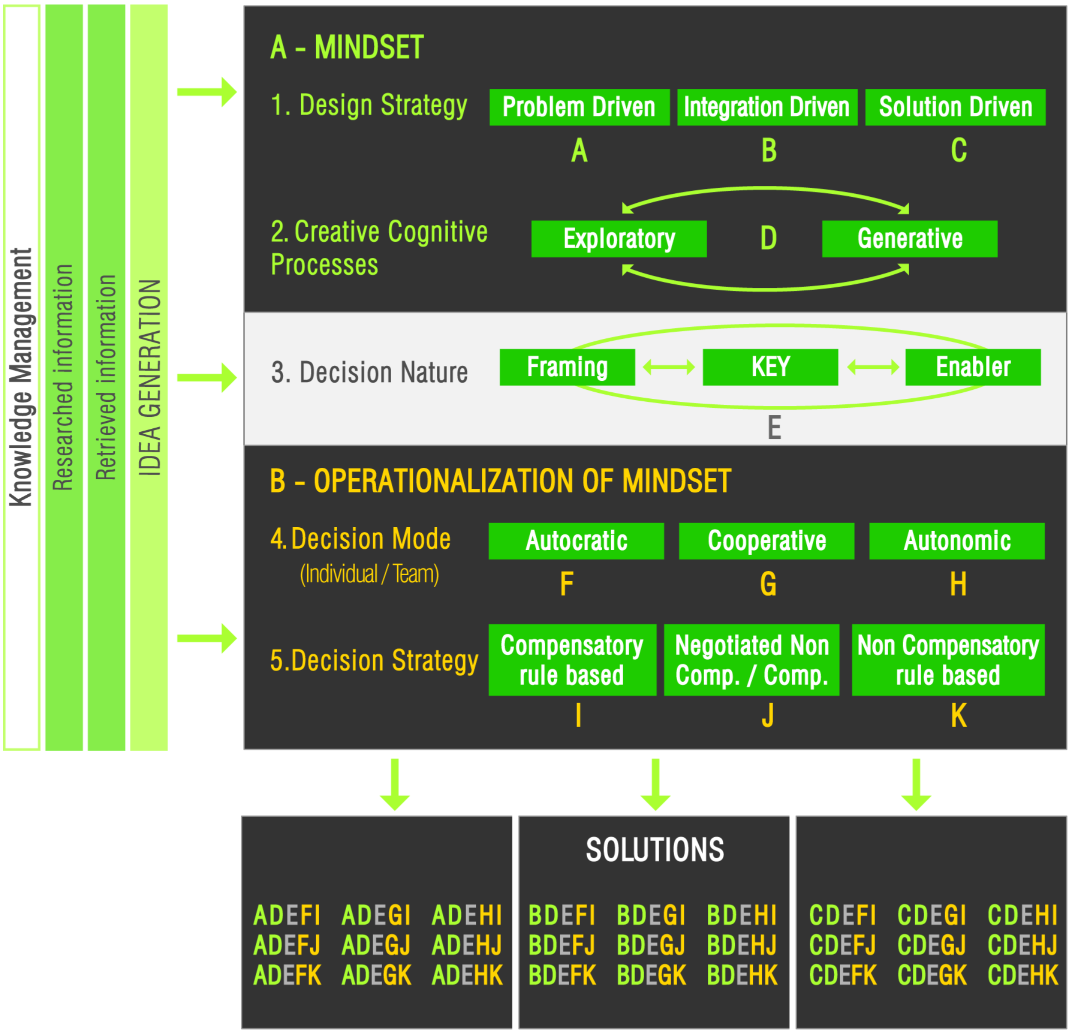


Fig.85 | Decision Making Descriptive Model II – From Mindset to Solutions (Almendra, 2009)

2.3.2 The DMTool

DMTool is a folder created in Excel (meant to be developed as an 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,

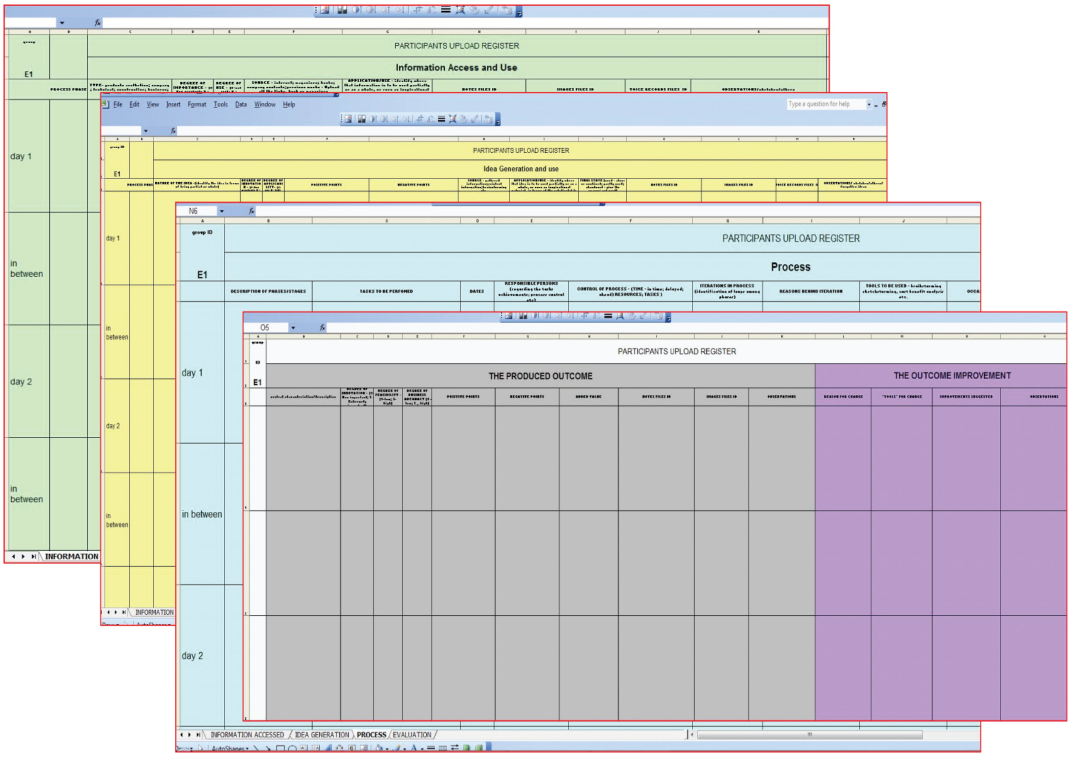


Fig.86 | DMTool layout: information, idea generation, process, evaluation

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 86).

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, on the other hand, 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.

2.3.3 The experiment

All groups received the same assignment from the Portuguese Light manufacturer named CLIMAR, Sistemas de Iluminação SA. The Challenge was named by the company as 'Concept Hall 09'. The assignment proposed 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. [Appendix AH]. The groups had to develop the work during five weeks having the real possibility of working two times a week during at least two hours. Previous to the sessions the students went to the Company, visited all the facilities and the factory and had the opportunity to have a presentation of the Brief made by the CEO of the company, the managers of Design Department, the Marketing manager and a Designer. The program of that visit to the company (sponsored by the company) can be seen in [Appendix AI].

2.3.3.1 Method

As previously said the experiment was done with thirty two (32) final year students from the 5th year of the Product Design Program and of Communication Design Program at the Faculty of Architecture of the 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.

Six groups were composed, four groups of five students and two groups of six 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 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 domain area: an equal number of product design and communication design students. Next, people of both design domain areas were at random placed in one of the six teams. Finally, the two Erasmus students were at random appointed to two groups.

Out of the three experimental (E) and the three 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. The remaining experimental (E3) and control (C3) group were observed by an assistant (a PhD student) that monitored them along the sessions making a register of the sessions making use of the created DMTool too. [Appendix AJ].

During the session and also in between them the groups had the chance to contact a person of the company that would answer their doubts. They also received information about the company, its products, producing methods and tools materials and costs.

A pre-and post-test was also part of the study. The pre test was the survey made to the students; the post test was an audio recorded short interview [Appendix AK] made with all groups regarding the experiment and the use of the tools (for those who had used it).

The group solutions were evaluated by a jury of eight persons composed of two design teachers, one architect, two representatives of CLIMAR, one light engineer expert and two light magazine directors that used criteria established by the researcher along with the company representatives [Appendix AL].

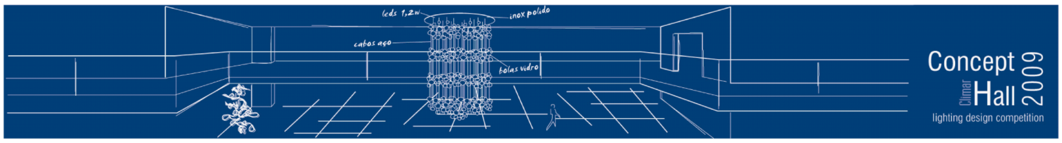
2.3.3.2 Procedure

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 implemented during the classes of the *Design processes management* optional course that had the researcher as a lecturer.

All teams had to elect a leader that was shortly 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: An electronic diary register of all sketches, images and written documents produced along the process and a screen record book to keep record of those moments that the groups worked outside the studio hours (this device only records the work developed in computer) [Appendix AM].

Regarding the evaluation two sessions were made (one in Lisbon one in Aveiro). In it the Jury member had the opportunity to view and score the group proposals (see Appendix AN). The detailed evaluation can be seen in [Appendix AO]. After the evaluation each Jury member also made a qualitative evaluation of each of the six designs [Appendix AP].

A brief analysis of Table 72 shows that the evaluation made by the jury was not consensual assuming high score divergences for the some design depending on the jury member voting. Also to notice 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.



	STACK (group C1)	OZ (group C2)	D'LIGHT (group C3)	DUB (group E1)	YORU (group E2)	GLITNIR (group E3)
Prof. Fernando Moreira da Silva	17,75	17,05	12,9	16,4	18,35	14
Prof. Henri Christiaans	16,9	13,6	9,6	10,3	17,6	10,4
Drª. Cátia Fernandes	14,97	15,06	13,14	13,37	16,66	13,86
Arq. Eduardo Souto de Moura	15,15	11,6	11,6	11,6	12,65	17,9
Eng. Fernando Silva	14,4	13,4	13,2	16,9	15,3	18,3
Sr. Jorge Passos	12	9,25	11,55	14,95	8,75	16,8
Paul James	17,25	15,15	14,65	15,2	16,65	15,5
Eng. José Sucena	15,45	13,05	11,85	11,45	15,85	17,25
Total	123,87	108,16	98,49	110,17	121,81	124,01
Average	15,484	13,520	12,311	13,771	15,226	15,501
	2º	5º	6º	4º	3º	1º

Table 72 | CLIMAR Experiment - Synthesis of Jury Evaluation

2.3.4 Experiment analysis and findings

2.3.4.1 In terms of the DMTool use

Teams that had to work with DMtool used it at the end of the sessions and never as a facilitator along the process. Two of the groups did it electronically [Appendix AQ] and one did it manually (printed the excel sheets in a large format and fill it in during the sessins). However, the awareness of the issues addressed and the analysis 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 scrutiny of the generated ideas (their potential and limitations). This 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 the researcher has recommended its use at the end of each session since otherwise it could hamper the natural fluidity of the teams´ reasoning and creative process.

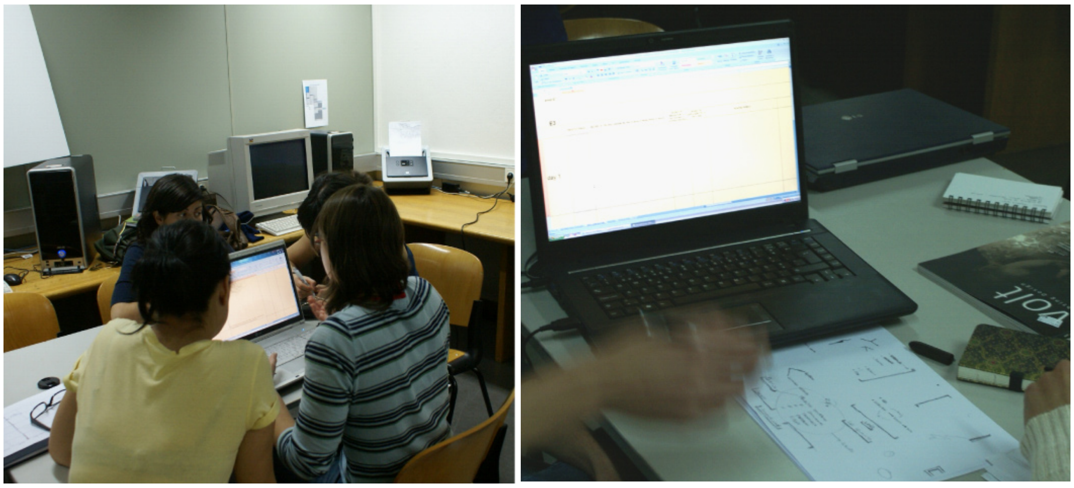


Fig.87 | Using the DMTool (source: author)

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 groups, although the groups placed in first and third in the prize ranking had used 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 would be 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.

2.3.4.2 In terms of Decision Making Descriptive Model analysis

The use of the Decision Making Model to assess the experiment and its outcomes was done to perform the analysis of the information gathered along the design process.

C2 - 23 April 2009

time		speach	REFLECTIONS	DECISIONS	nature decision	mode decision	decision strategy	decision behaviour	decision evaluation	supporting INFORMATION	IDEAS	creative process	Images(only video)
				blue - process; pink - problem/context; purple - product/solution	FR - framing; K Key EN - enabler	H - hierarchy CO - cooperation; A - autonomy	A - non compensatory; B - compensatory		see document			**E - Exploratory** - (contextual shifting; functional inference; hypotesis testing); **G - Generative** (analogical transfer; association;retrieval; synthesis)	
0:01:01	s1	first let us plan, let us do here... Design planning...		to make a plan	FR	cooperation -used to define the approach to the problem - issues are negotiated and the facilitator does it WITH people; 2. some degree of autonomy might occur in next sessions since tasks are being delegated to all members.	B	the group decision behaviour clearly displayed 2 behaviours: a)pursuit of better information which necessarily meant postponed operational work -a kind of complete imersion in images of all kind seen very quickly being adressed without a deep analysis; b) necessity to compromise with a plan to the work to be developed....					
	s1	first we have to establish goals...		establish goals	FR								
	s2	how come, goals?, this is a project but it is not as our design studio project...it has much more components...	complexity of the exercise		FR								
	s1	yes but it has the same phases... Research information, study the context, sketches....	similar phases with previous design projects	establishing phases	FR								
	s3	until we have a concept...			FR								
	s1	and we should also do also a calendar?		to make a calendar	FR								
0:02:04	s3	so let us first see what is demanded... It is a lamp for an hotel or a representative building....		focus on brief	FR					company/client			
	s2	we have to do it in 4 sessions....	time available to the exercise		FR								
	s1	we should go and visit hotels...		explore context in loco	FR								
	s3	but we can do it no?... We can go for different types of hotels...no...	variety of possible places/contexts		FR								
	s1	yes they have different publics... We can go and visit some to have the feeling of the ambiance...		explore different hotel contexts (in situ)	FR								
0:03:17	s2	first we should go to the bars and restaurants because normaly we can have access freely to that....	other spaces/restaurants/bar		FR								
	s3	and if they see has staring at the hall and someone comes?			FR								
	s2	well we are looking no problem no?			FR								
	s1	it can be for what spaces... We have to define that... To specify it....			FR								
	s3	there is the possibility to work for other spaces, like ccb...	necessity to define context		FR								
	s1	let us list here the hypothesis of spaces...	museum context	enlarge the context study	FR								
	s2	there is that gorgeous hotel downtown....the design hotel... Kind of art nouveaux style...it is I think in Rua da Prata, in a corner, and it is in purple and rose... So nice...			FR					personal context reference	modern/design space adequacy		
0:04:37	s1	but we should choose other places so we have more freedom to create....	enlarge contexts of use		FR								
	s2	with ccb that was the idea... One space less luxurious, more related with modernity and innovation...	different context: diferent product attributes		FR						vs modern/innovative one		
	s1	modern hotel...in Belém there is one hotel that has instead of normal blinds, a system of pannels like walls, beautiful, ... It is near the area of restaurants...it is truly new... There are some parts not yet finished...			FR					personal context reference	modern/design space adequacy		
0:05:30	s2	near the marginal there is one... A kind of SPA hotel...which is a bit different...it has to induce relaxation....			FR					personal context reference	clean/relaxation space		
	s3	and what about to think of the muslim church of lisbon?	context of churchs/other cultures/ monumental spaces		FR						monumental/other culture space		
	s1	in that case people that go there are not going probably to rhink that much about lamps... Or on bying lamps...	impact that could have on climar sales		FR								
	s2	just to think of doing a lamp that it is not traditional, a kinfd of lamp we are not used to think of...	context of other cultures could be inspirational		FR								

Table 73| CLIMAR Experiment – Excerpt of Verbal Protocol Analysis of Group C2

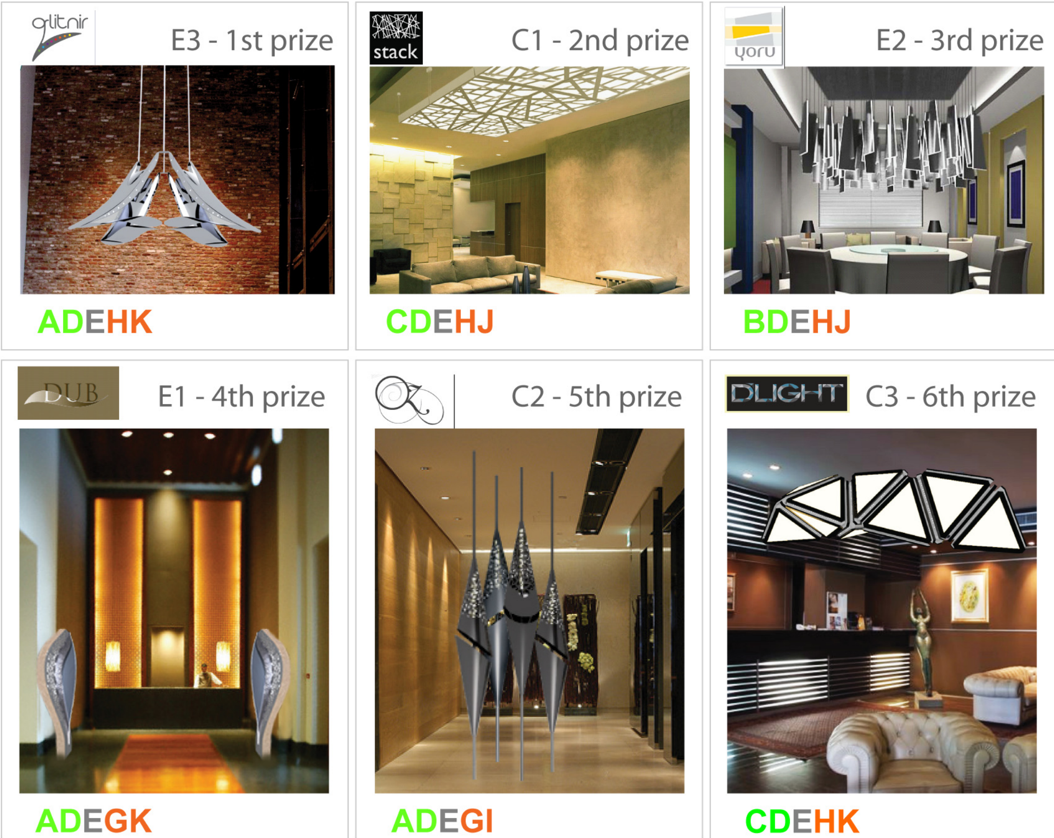


Fig.88 | The six Design Products resultant from the CLIMAR Experiment

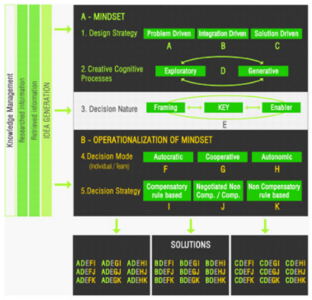
That analysis included also the critical assessment of all the videotapes, audiotapes, the DMTool records as well as the diaries and the screen record books. The amount of information was huge. First we tried to make the Verbal protocol Analysis of all the group sessions (see Table 73; Appendix AR). Because it was too time consuming to make the transcription and translation of all the dialogues we decided to make a synthesis based upon ‘critical incident analysis’ [51] of the process of each group in an excel file using as parameters the descriptors that integrate de Decision Making Model. (see Table 74; Appendix AS).

Furthermore it was made an attempt to translate in visual terms the ongoing work developed by each team. To do it there were several parameters analyzed such as: a) creativity (based upon the judgment made by the jury members and the analysis of the protocols); b) Knowledge management; decision making in a global overview resulting from the focused analysis of decision coherence, decision efficacy, decision timing; decision rational correctness and decision participation

51. A critical incident is often an event which made you stop and think, or one that raised questions for you (it has a parallel with the reflection in action defined by Schön. It may have made you question an aspect of your beliefs, values, attitude or behaviour. In the university setting, a critical incident might include as defended by Fook (2000) it can be : a) an aspect of a project or group work that went particularly well; b) an aspect of aproject or group work that proved difficult; c) a piece of work that was found particularly demanding; d) a piece of work which increased the awareness, or challenged our understanding; or e) an incident involving conflict, hostility, aggression or criticism.

E3

1st prize



ADEHK

- E3 group was *problem driven in terms of Design Strategy*
- engaged in a creative process where both *exploratory* and *generative* cognitive tasks were performed with a clear focus on exploratory ones;

- decisions with clear dominance of *framing* ones that gave origin to 3 *key decisions*, one of which gave origin to the final outcome;

- E3 group members had two distinct visions and approaches to the problem (the vision and *modus operandi* of the communication designers and the one of the product designers)
- Agreement was made among the conflicting members – development of the design was done with a high level of *autonomy* in terms of decisions; team leader keep track of major decisions
- Decision strategy was a *non compensatory rule based* one - intuition dominated; most of the information gathered was not used and no trade-offs were made among attributes being considered.

Fig.89 | E3 group Decision Making Model analysis

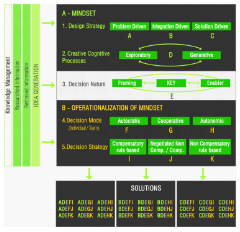
(in terms of the team elements). These parameters arise from literary critics (Mann, Harmoni and Power, 1989; Ross, 1981). To note that these parameters are not to be measured in quantitative terms but rather serve a comparative qualitative analysis based upon our interpretation of data.

When we use the Decision making Model (Figure 85) to assess each of the cases we find out that they correspond to six different types of outcomes that are the result of distinct combinations of the five areas of the model. The synthesis of the assessment resulted in the information presented in Figures 89 to 94.

> E3, the winner of the contest is a ADEHK type as it is possible to see in Figure 89.

C1

2nd prize



CDEHJ

- C1 was a *Solution driven* group;
- The creative cognitive process alternated from exploratory to *generative* tasks with a special focus on the last ones;

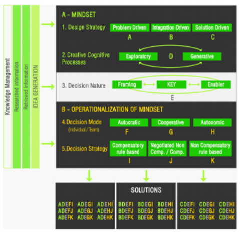
- All different natures of decisions with a particular emphasis on *enabler* ones having had two major *key* decisions.

- The cooperation was evident in establishing the plan; Due to the fact that all members had a deep knowledge of each other skills, *autonomy* prevailed;
- Decision strategy was globally *compensatory ruled based*.

Fig.90 | C1 group Decision Making Model analysis

E2

3rd prize



BDEHJ

- E2 group was an Integration *driven* group alternating from problem framing to solution enabling in a process of co-evolution between them;
- creative cognitive process that alternated from exploratory to *generative* tasks was intense and systematic;

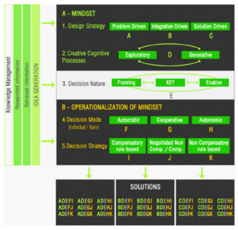
All different natures of decisions were taken; The group developed their first Key decision (2nd session) until the end with a high level of detail and having a very systematic and consistent process;

- The cooperation was evident in all the moments of the process; There was a clear leader that had an holistic view of the problem and an accurate vision of what would be the correct elements to better communicate their solution; That made possible the development of a very professional, complete and detailed final proposal to deliver to the Client.
- Decision strategy was globally *compensatory ruled based*.

Fig.91 | E2 group Decision Making Model analysis

E1

4th prize



ADEGK

E1 was a *problem oriented* group with a particular emphasis on the planning specially at the initial sessions;

exploratory and generative cognitive tasks were performed being the *exploratory* task predominant; the sketching was very intense in this group;

The greater number of decisions had a *framing nature*. The enabler decisions appeared in a final phase of the process and were not consensual;

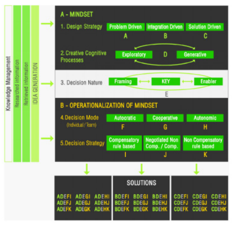
Cooperative way of decision (although most members got passive along the time) ; Leadership was much less efficacious and present at the last 2 sessions;

decision strategy was a *non compensatory rule based* one since they displayed a design fixation that inhibit them to reason upon knowledge available

Fig.92 | E1 group Decision Making Model analysis

C2

5th prize



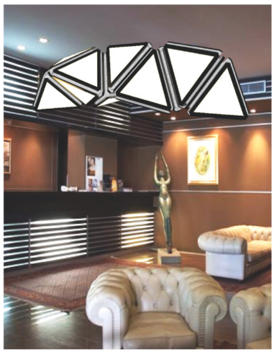
ADEGI

- C2 was a *problem oriented* team
- The creative process was ruled by *exploratory* cognitive tasks being the *generative* ones less succeeded. This was the group that has modeled and tested more their alternatives.

- 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.

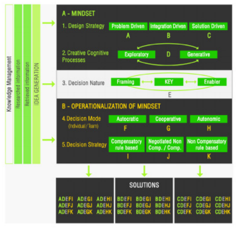
- Team members where very *cooperative* having enjoyed clearly the fact that they were working together.
- The dominant decision strategy was one *compensatory rule based* - huge amount of work regarding the gathered information, the evaluation of the attributes in a very rigorous and systematic way.

Fig.93 | C2 group Decision Making Model analysis



C3

6th prize



CDEHK

- C3 group was *product oriented* and had a design fixation since the beginning.
- 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.

- This was a problematic group having a leader that tried to exert an autocratic leadership without success. Soon autonomic *modus operandi* took place and the design was developed in a very chaotic manner.
- a *non compensatory rule based* strategy was used - complete ignorance on the part of the team members of the available information and the inability of evaluating and developing alternatives.

Fig.94 | C3 group Decision Making Model analysis

> C1, is a CDEHJ as it can be seen in Figure 90.

> E2 group assumed a BDEHJ profile as it can be seen in the synthesized analysis presented in Figure 91.

> E1 on the other hand is a ADGEK as show in Figure 92.

> C2 displayed an ADEGI profile that is briefly reported in Figure 93.

> C3 , as it can be seen in Figure 94 was a group with an CDEHK Profile according to the Decision Making Model.

A second analysis was also done that is synthesized in Figure 95. This second analysis is a visual translation of the ongoing work of the teams in terms of creativity (the criteria more important to the jury members), Knowledge management and decision making. Furthermore decision making (that was approached in the last graphic on the right side of the figure, as a whole integrating 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).

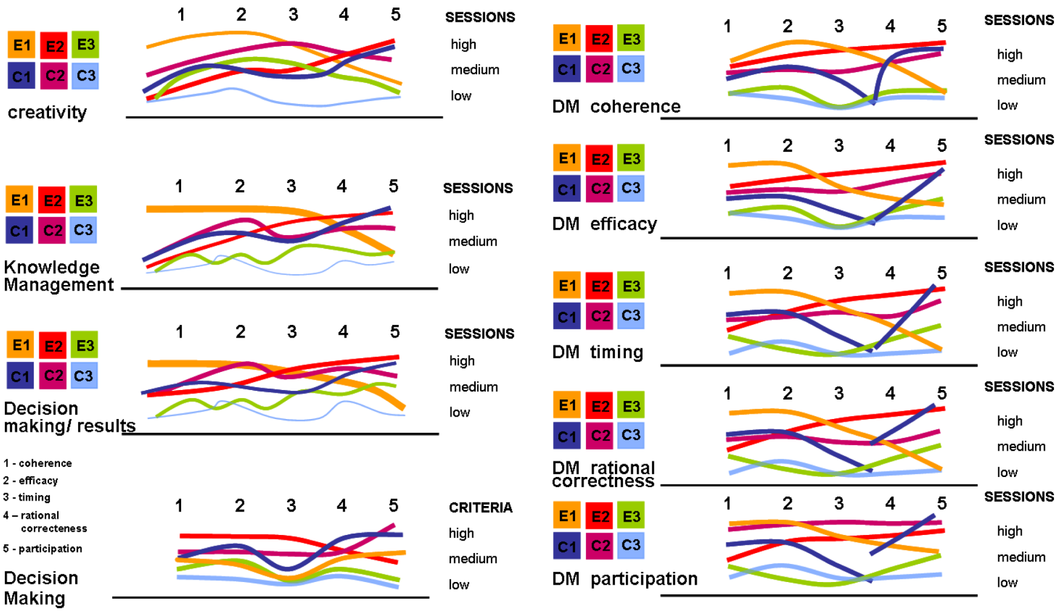


Fig.95 | Analysis of the overall behaviour of the design teams in terms of Creativity, knowledge management and Decision Making

A deeper analysis of the graphics presented in Figure 95 allows us to recognize for instance that apparently 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 lead 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

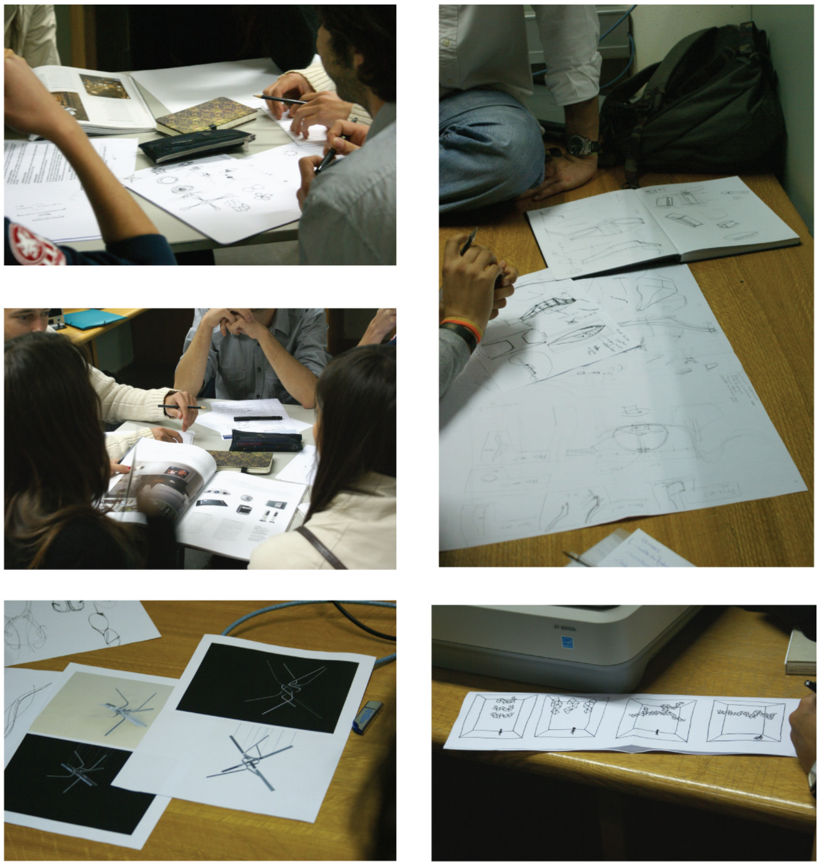


Fig.96 | Climar Experiment - Images of the sessions (source: the author)

session two 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 four and five 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.

Fig.97 | Climar Experiment - Images of the sessions (source: the author)

Fig.98 | Images of the CLIMAR Prize ceremony (source: CLIMAR)

SUMMARY OF THE CLIMAR EXPERIMENT - DESIGN STUDENTS GROUP EXERCISE

The CLIMAR experiment aimed to engage both design students (32 in groups of 5/6 elements) and a company in solving a Design problem. A brief was developed by the company which was presented by a team of the company that integrated the CEO, the marketing manager; the design manager and a designer during an one day visit to the firm's facilities and factory. The group of students developed their solutions during the Design Process's management course and along five sessions of two hours each. From the six groups two were videotaped, two audiotaped and 2 were followed by an assistant that made the register of th sessions using a tool developed by the researcher. That tool, named DMTool aimed to support 3 teams (Experimental) in their decision making process. Furthermore, a descriptive Decision making Model was created by the researcher and tested in the analysis of the experiment. Some findings are to be mentioned.

Regarding the DMTool

The use of a Decision making support tool was hard for the students 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 mode 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, it is important to mention 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 has 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, we must refer that the use of a descriptive model allows 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.

2.4 An experiment with Portuguese and Dutch Design students inside a company (CIMP)

After the CLIMAR experiment (where students in their class environment and during class period of time developed a brief presented by a company having the chance of accessing to its staff along the process) the challenge was to place design students working inside a company.

The central aim of this last experiment was to observe the students' performance while developing a design process in a real context.

Also the fact of having two distinct group of students with different design education backgrounds, eight Portuguese and eight Dutch (now in a team approach to design processes) was considered to be important since we wanted to see if changes in Education would result in different process approaches and different outcomes.

Fig.99 | Images of the CIMP Experiment – Group 3 Dutch Students (Source: the researcher)

2.4.1 The Method

The experiment was done with sixteen (16) final year Portuguese and Dutch students. The Portuguese students were from the 5th year of the Product Design Program (4 – 2 males and 2 females) and from the first year of the Product design Master course (4 – 3 males and one female). The Dutch students (5 males and 3 females) were from the three Delft Master Courses (Integration Product Design; Design for Interaction; Strategic product design).

The duration of the experiment was one week (from Monday to Friday) being the last day the moment of presentation of the proposal presentation and also of the Prize ceremony.

Four groups of four students were settled. The elements of the groups volunteered to participate in the experiment and organized themselves as teams according to their assessment of their own skills.

Videotaping took place for two groups (Group 3 – Dutch; Group 4 – Portuguese) while for the other two groups the more unobtrusive audiotaping was used (Group 1 – Dutch and Group 2 – Portuguese).

Each group had to make a diary of their activities to deliver at the end of the week. On that diary they had to describe briefly what they had done during the session and how they evaluate the team performance.

Although having the chance to contact freely every person on the firm a person was indicated by the company's CEO as being the responsible for the activity: The Design Director – Carla Portugal. She was responsible to enable the development of the exercise in what concerns to firm such as, information delivery, booking meetings with staff, authorizing production of models etcetera.

The author also had an assistant (a PhD candidate) that remained the entire week in the firm. Her task was to facilitate the contact of the students with the company and also to take care of technical support to the video and audio taping.

Both the researcher and the co-supervisor Prof. Henri Christiaans visited the firm and accompanied the experiment in a daily basis.

Each group had a specific work area integrated in the floor where the Creative/Design Department was installed. All the elements could circulate freely inside the company.

Groups received information about the company, its products, producing methods and tools, materials and costs. They also received plants of the interior areas to be reformulated (the reception), the portfolio of the company and the Manual of the Brand [Appendix AT]. The site of the firm was also a source to be used since it had videos of the firm, the products and production.

Groups also made a guided visit to the company (morning of the first day) and had opportunity to have an individual meeting with the CEO (on the third day of the experiment).

The group solutions were evaluated by a jury of four persons designated by the CEO of the company. [Appendix AU]

2.4.2 The Experiment

The experiment was planned to be developed during one week as it can be seen in Table 74.

Table 74 | Schedule of the CIMP experiment

	Monday 29 June	Tuesday 30 June	Wednesday 01 July	Thursday 02 July	Friday 03 July
Morning	> Visit to Firm > Installation of groups > Brief and information reception	> CEO meeting with groups > Working Session	Working Session	Working Session	> Presentation of the proposal to the firm > Jury evaluation
Afternoon	Working Session	Working Session	Working Session	Working Session	> Public presentation of the proposals > Prize Ceremony

2.4.2.1 The Company - CIMP

As it can be seen in Appendix AT, CIMP is a medium size company (70 employees) operating in the Promotion and Merchandising markets. It has two offices in international markets: Spain and Brazil.

The choice of this company complies with several factors important to the research:

> The company integrates an important work market for Portuguese designers;

> The size of the company and its level of Integration in terms of activities being internalized is adequate since it allows students to follow the entire process, from concept to production;

> The physical access to firm was easy;

> The firm accepted to receive a large number of students 16 and compromised with lodging them in separate spaces giving full support to them during the experiment;

> The Company's products/services allowed us to develop together with them a brief that would go beyond product design, i.e. a brief that aimed to make more visible the strategic adequacy of design.

2.4.2.2 The Brief

Appendix AV presents the complete brief delivered to the four groups of students (2 Portuguese with 4 elements each; 2 Dutch with 4 elements each).

The type of problem presented to the students was chosen by the researcher (and developed by the firm with the researcher full collaboration) and aimed to address some key issues. They are:

> The problem posed should allow us to see how students relate themselves with a Company Vision and its Business Strategy and how they, through design process, 'translate' it into products (graphic, interior design or product design).

> The assignment to be delivered should be adequate to a conceptual development of a Design that called for different specific skills: graphic, product and Interior Design;

> The assignment should correspond to a real problem developed in a real context and having a time to develop similar to the one firm gives to its employees.

> The level of information available for the students should be equal to the one firm gives to their designers in a real situation;

The brief proposes the reformulation of the Corporate Design that should be materialized in the following Items:

1. Communication Design elements: The Logo, the Brand Manual; Signage system

2. Interior Design Elements: Redesign of the reception area;

3. Product Design Elements: the counter of the reception; displays to place in the corridors and hall of each building floor.

The integration of all these elements should allow the company to transmit its DNA.

The work should be developed at the conceptual level.

2.4.2.3 The jury Evaluation

Jury members belonged to the Company and were chosen by its CEO. The criteria to judge the proposals were suggested by the researcher to the firm that accepted it [see Appendix AW]. The criteria were: Creativity, Quality of Communicative interaction; Strategic adequacy and overall quality. These concepts where defined as presented in the Glossary [Appendix A].

The evaluation was done in the last day of the experiment. Groups made a presentation to the firm. Each group had 15/20 minutes to present his proposal. After the presentations Jury members could question

	group 1 (D) Audio 0-20	group 2 (P) Audio 0-20	group 3 (D) Video 0-20	group 4 (P) Video 0-20
J1	11,4	17,8	11,6	14,3
J2	13	15,8	12,5	15
J3	15,2	17,5	16,3	14,2
J4	13,05	16,75	13,8	12,55
Total	52,65	67,85	54,2	56,05
Average (0-20):	*13,163*	*16,963*	*13,550*	*14,013*
Ranking Order	4º	1º	3º	2º

Table 75 | Synthesis of the Evaluation of CIMP Jury members

them about their work. After this presentation session the Jury evaluated each proposal using a scale from 0 to 20. The overall results of the evaluation are presented in Table 75.

After the session the researcher had the chance to talk with the Jury members in an informal conversation about their appreciation of the proposals. Their comments are consistent with what is observable in the individual scoring of each criterion for each group (see Appendix AU).

In fact it is observable that with the exception of one Jury member all weight 'creativity' and Strategic adequacy' with 30% while the remaining two criteria have 20% each. The one jury member that has a different weighting of criteria finds 'creativity' to weigh 20%, 'strategic adequacy' and the 'quality of the Communicative interaction' to weight 25% and the 'overall quality to weight 30%. Moreover, when looking more closely to evaluation we find out that two Jury members place the Dutch teams in second and third place classifying all criteria either higher of equally to the Portuguese group number 4 that in the end stayed in second place. However, due to the fact that the other two Jury members attributed very low scores to Dutch groups, at the end, the ranking order was the two Portuguese groups followed by the two Dutch groups.

2.4.2.4 Experiment Data Treatment and Analysis

The Data was collected as previously said both in videotape and audiotape. In addition, the sketches done along the process and the written documents as well as the presentations that were prepared by all the groups were also delivered to the researcher at the end of the experiment.

Tapes were analysed using the method of Critical Incident Analysis. The entire process of each group was described in a Table making use of broaden descriptors: Time; Data (the information being used at the moment) Process (issues related with process development; methods, tools); Problem (partial; Whole) and Solution (partial; whole). Figure 100 presents an excerpt of one of the tables that are fully accessible in [Appendix AX].

This analysis was translated in graphics (see Figures 101-106) where besides the information about groups being dedicated to problem, to solution or process activities it was made a synthesis of the Decision making supported by the framework created in this thesis (Figure 86).In the next pages we will only present the graphics of one of the Dutch groups . Nevertheless in terms of results all the four groups will be analysed.

The graphics also present a brief assessment of the parameters that integrate the Decision making framework as well as some reflection about Idea Generation and Knowledge management.

Similarly to what was done in the CLIMAR experiment (Figure 95) several graphics comparing all the groups in terms of Creativity, knowledge management and Decision Making were also made (see Figure 107).

Figure 102 presents the design process of groups 3 and 4 during the first day of their performance. It is visible that they developed a quite different approach to design problem. Group 3 of Dutch students engaged in a process of reflection about the firm and its strategy having generated an exhaustive amount of lists of their analysis of the firm characteristics, of questions to ask to the company representatives etcetera. They generated

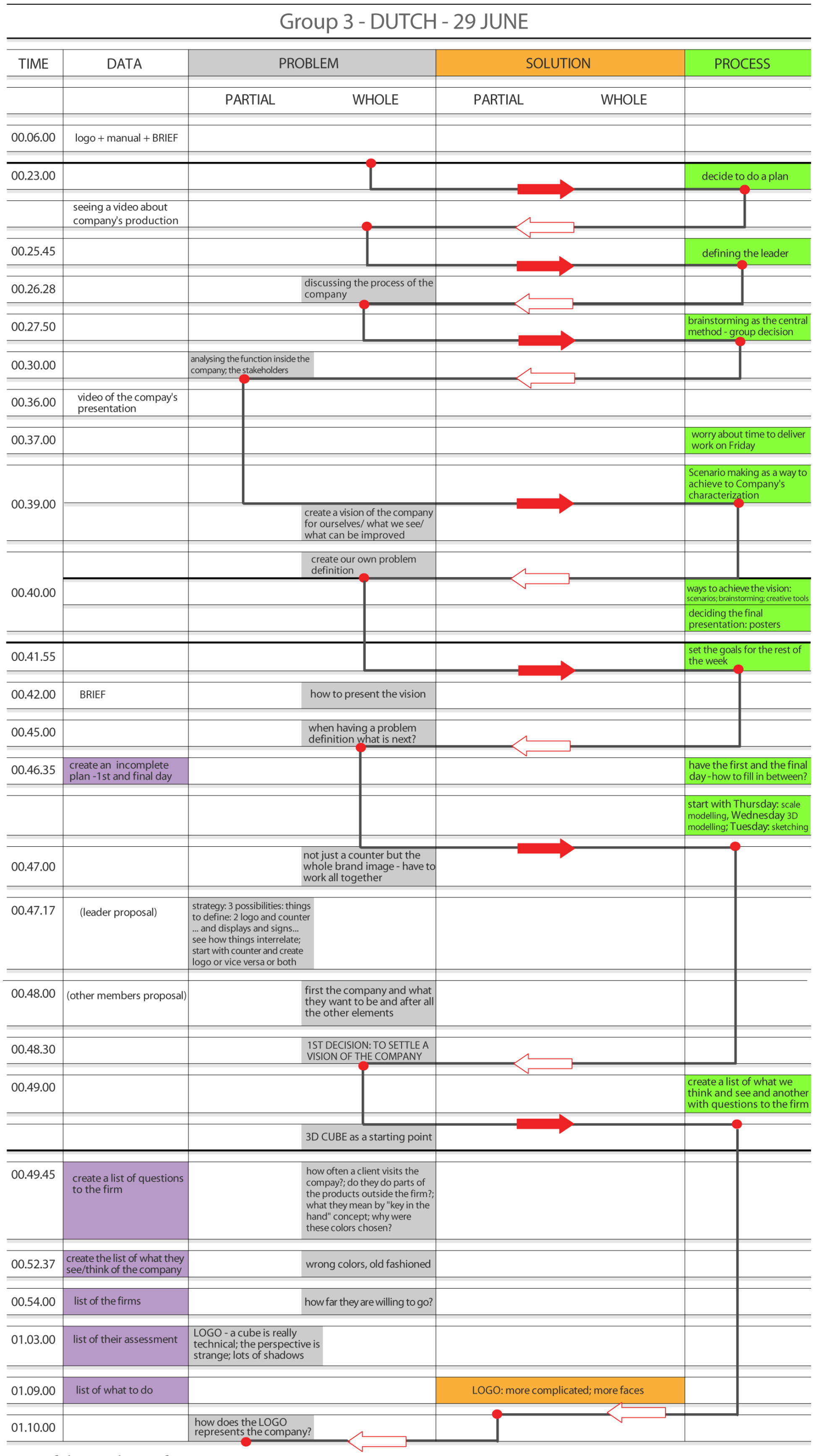


Fig.100 | Excerpt of the analysis of Group 3 (Dutch) Design Process

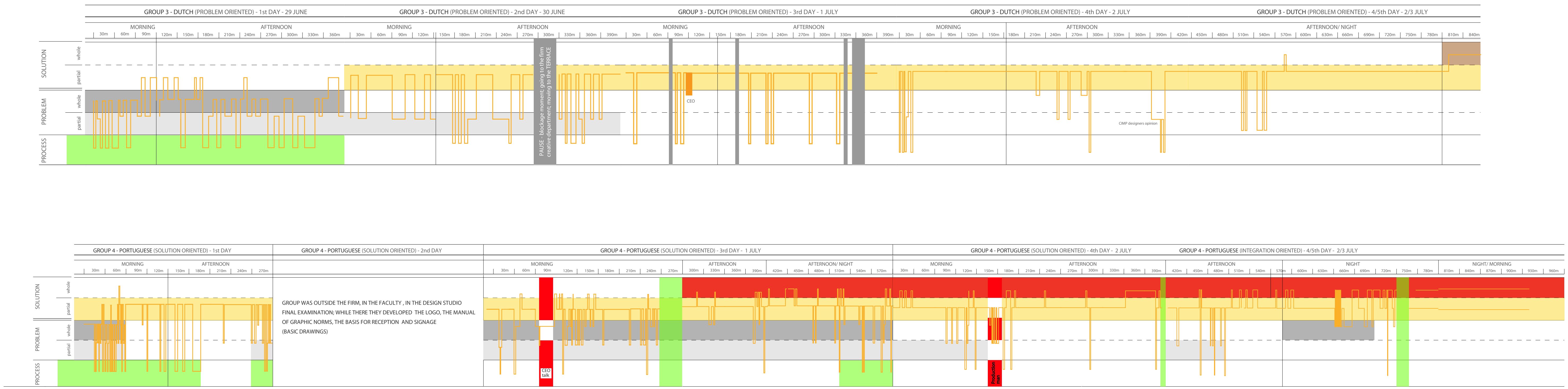
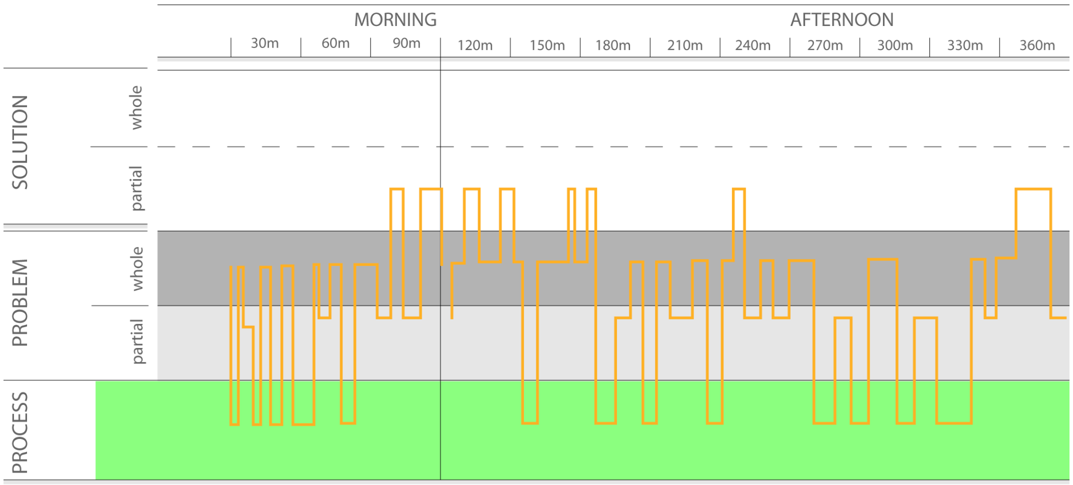


Fig.101 | Analysis of the Design Process of Groups 3 and 4 (5 days), see details in Figs 102-106 a large amount of information that had found hard to synthesize and that they exposed to be consulted during the process. Since the beginning they assumed that they would departure from the Vision of the firm to the development of solutions starting with the LOGO. Curiously they did not sketch that much in this first day but the LOGO presented as a final solution was designed during this first session.

On the other hand and regarding group 4, a Portuguese team, time dedicated to problem interpretation was shorter. The process was more in control of the leader that during the first day tried to stimulate the other elements as well as to make a close control of the generated ideas presenting a synthesis of the achievements from time to time. The group defined early that the generated solution was dependent on the LOGO design that works as a symbol of the whole company. Team assumed that LOGO definition should be done in this first day having defined a draft of the work plan for the entire week. Sketching of LOGO dominated the session being 2 the concepts that were developed by all in multiple variations. At a certain point of the process (when LOGO was near its final definition) tasks were divided and one element started to insert the plant of RECEPTION in the modelling software and another element also started working the LOGO in computer. The MANUAL of Graphic norms also started to be worked on at the end of the session.

The analysis of this first day according to the Decision Making framework presents us two distinct behaviors. Concerning Design strategy, group 3 was clearly problem driven and group 4 was solution driven. The Dutch group engaged in a creative process where exploratory activities dominated while in the Portuguese group the creative process alternated intensely between exploratory and generative activities. In respect to the decision nature in group 3 framing decisions were more frequent, a key decision regarding the LOGO occurred and few enabler decisions were undertaken. Group 4 had a different profile as to decision nature. The enabler decisions were prevalent and the key decision of LOGO design appeared in this session.

GROUP 3 - DUTCH (PROBLEM ORIENTED) - 1st DAY - 29 JUNE



Decision Nature: dominance of FRAMING DECISIONS

Creative Process: dominance of EXPLORATORY mode

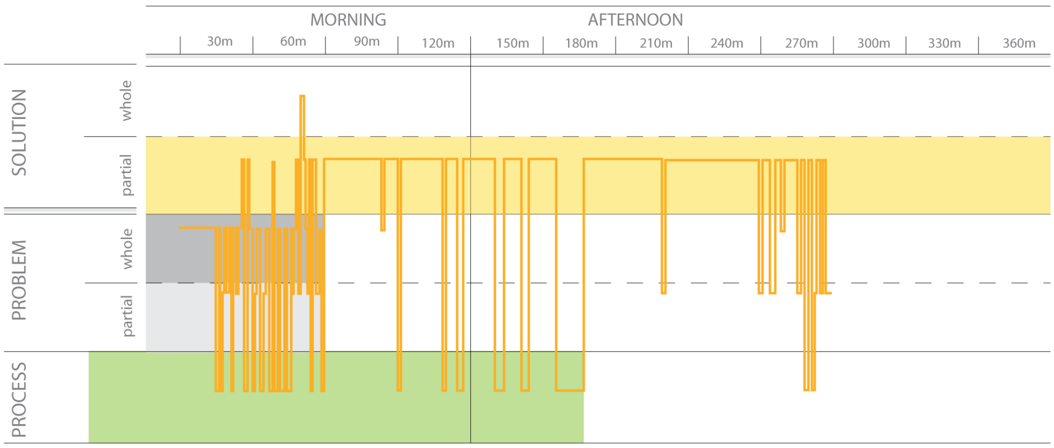
Decision Strategy: dominance of NEGOTIATED COMPENSATORY/NON COMPENSATORY

Decision Mode: COOPERATIVE, although leader tries to impose a path

Information Management: huge amount of generated Information; difficulties in its synthesis

Idea Generation: focused on a partial solution: LOGO. generation of 10 ideas; the idea for the final LOGO was generated at the beginning of the afternoon session

GROUP 4 - PORTUGUESE (SOLUTION ORIENTED) - 1st DAY - 29 JUNE



Decision Nature: dominance of ENABLER DECISIONS

Creative Process: EXPLORATORY/ generative loop

Decision Strategy: dominance of NEGOTIATED COMPENSATORY/ NON COMPENSATORY

Decision Mode: COOPERATIVE, leader pushes the group and tries to make synthesis and coordination

Information Management: previous gathered Information; special use of visual information

Idea Generation: focused on LOGO as the enabler of other elements ; generation of 2 main concepts; the idea for working the basis of reception and Manual almost at the same time (coordination)

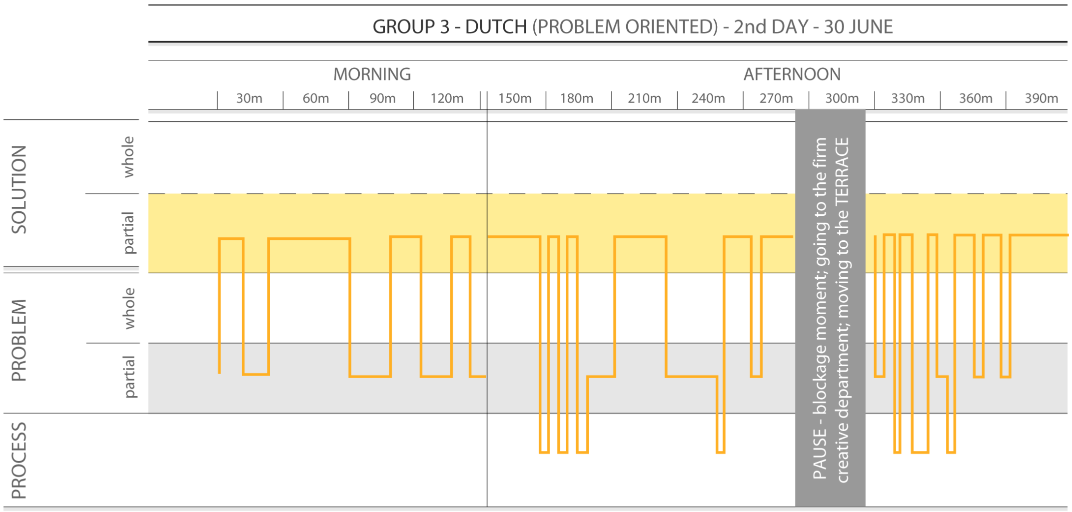
Fig.102 | Analysis of the Design Process of Groups 3 and 4 – 1ST Day

The mode of Decision was in both groups a cooperative one but due to the differences of leadership that cooperation occurred in different ways. In group 3 the leader had a frenetic activity of reflecting aloud about everything and pushed other elements to intervene. He produced extended written documents with ideas and at a certain point in the process some of the elements got a bit worried about the time being spent in this task. Somehow the other elements adopted silence as a way to stop that process of endless discussion of an issue in order to find time and space to make what they found to be more logical or needed. The leadership on group 4 was a calmer one. Several moments occurred of making point of situations; the leader stimulated all the members to present their ideas and at the end tried to synthesize what was said. He also had prepared information to support the process and was in control of the information to still be asked or created. Finally, about the decision strategy both groups display the use of a negotiated non compensatory/ compensatory rule based one. That is to say that when having a compensatory strategy some poor evaluations they made of one attribute was compensated by a positive one on another attribute (for example they can sacrifice usability issues in some objects designed for an increase in the visual shape attributes of them. On the other hand the non compensatory rules were trade-offs among attributes are not allowed were suitable when commensurability was absent (e.g. absence of the representation of the three core business areas is Logo is an impossible choice).

Similarly to what happens in other experiments (Hong and Chan, 2004) in this case both groups preferred the non compensatory rules in situations of overload of information (group 3 is a clear example of that) or when the value of a certain aspect in the overall solution was not clear for them (sometimes it was observable in both groups the absence of a clear difficulties to rank the choices among them and to utilise choice rules).

The second day in company is presented in Figure 103.

This second day was a peculiar one since elements from both of the Portuguese teams had to go to Faculty to present their design studio final project. Therefore the



Decision Nature: dominance of ENABLER DECISION, blockage is evident

Creative Process: EXPLORATORY/ GENERATIVE without direction

Decision Strategy: dominance of NEGOTIATED COMPENSATORY/NON COMPENSATORY

Decision Mode: COOPERATIVE, although leader tries to impose a path; other members lack motivation

Information Management: no use of generated Info; difficulties in selecting Idea for a partial solution

Idea Generation: focused on a partial solution: LOGO. generation of 16 partial ideas based on the ones previously made; going circular and not really transforming or innovating; last hour unblocked and created solutions for RECEPTION and DISPLAY

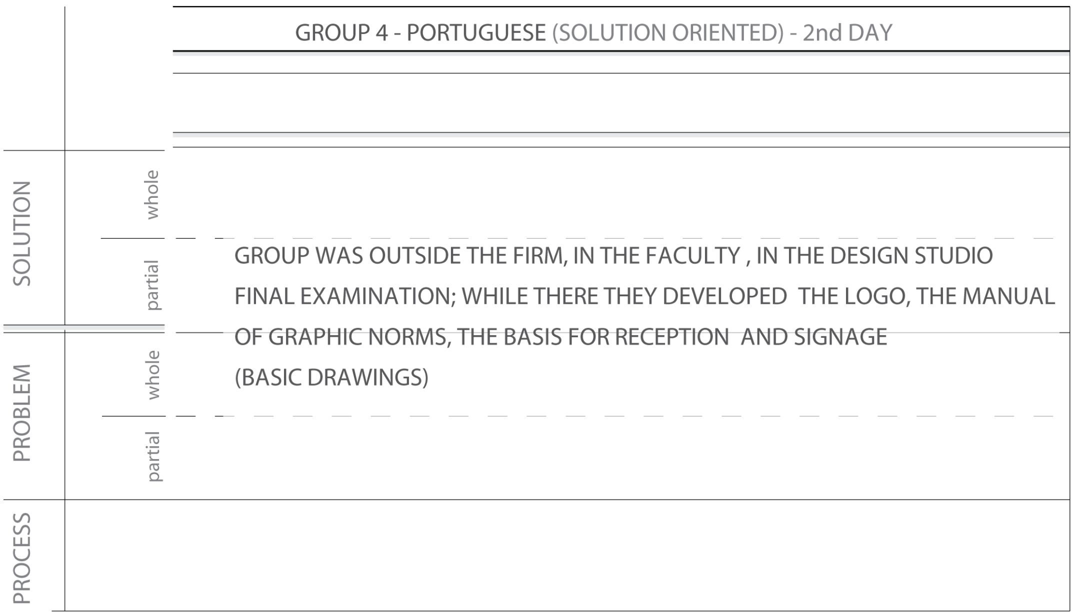


Fig.103 | Analysis of the Design Process of Groups 3 and 4 – 2ND Day

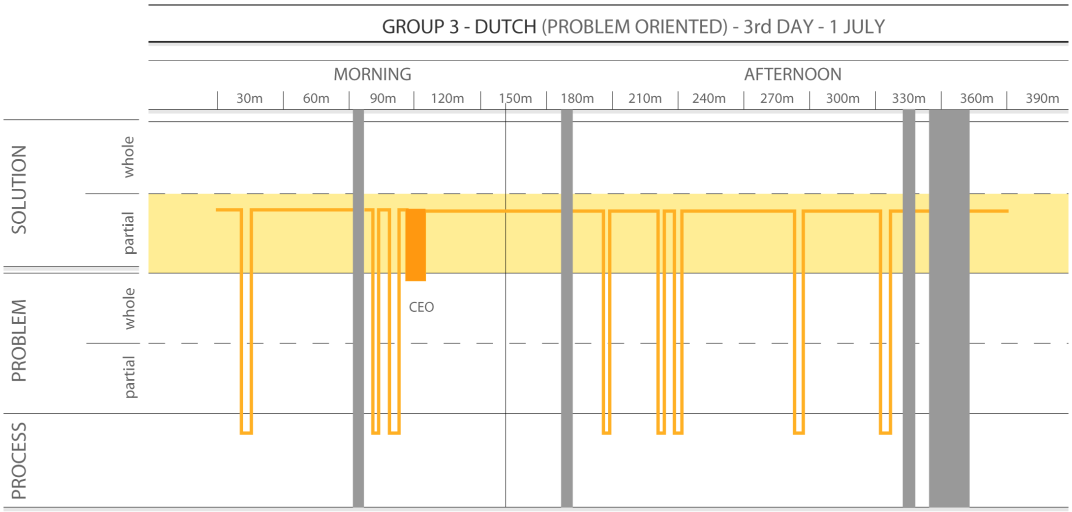
Portuguese teams were out of the company being their work being accessed not by video or audio but taking into account their reports and the work they brought to company on the third day.

Nevertheless it is possible to characterize the Dutch second day that as the Portuguese one was dedicated to enable solutions. In the case of the Dutch group they were concentrated on LOGO and experienced a blockage moment that tried to solve by changing the place of work from the office to the terrace of the company. Finally at the end of the day they could make a choice of the LOGO to develop and some sub solutions regarding RECEPTION and DISPLAY started to appear.

In terms of group dynamics this was a critical day where team members displayed a lack of motivation and difficulties overcoming it. They also displayed behaviour of a certain resistance to leader's ideas and way of ruling the process.

In what concerns the Portuguese achievements and the way they saw the process of this particular day again they had a balanced dynamic of group and they made it possible to define entirely the LOGO and the MANUAL having also worked in the basic drawings (technical) to support the construction of 3D modelling of the RECEPTION and DISPLAY.

The third day in company for both teams revealed two distinct team beahviors and design development. Group 3 was clearly solution driven trying to overcome the blockage they had in the previous day. They dedicate themselves especially to LOGO and the RECEPTION although they started to think in the DISPLAY. At this moment the LOGO was not yet stabilized and the RECEPTION alternatives were done in sketches that evolved in a slow rhythm. Furthermore the lack of cohesion in the group and the lack of motivation contributed for the surprising reaction they had when CEO come to answer their questions. First they were not ready, after they made the option to go and watch the interview CEO was having with the other Dutch team. This means that the huge amount of lists and analysis done in the first day regarding the company and the



Decision Nature: dominance of ENABLER DECISION, LOGO and RECEPTION; low conviction

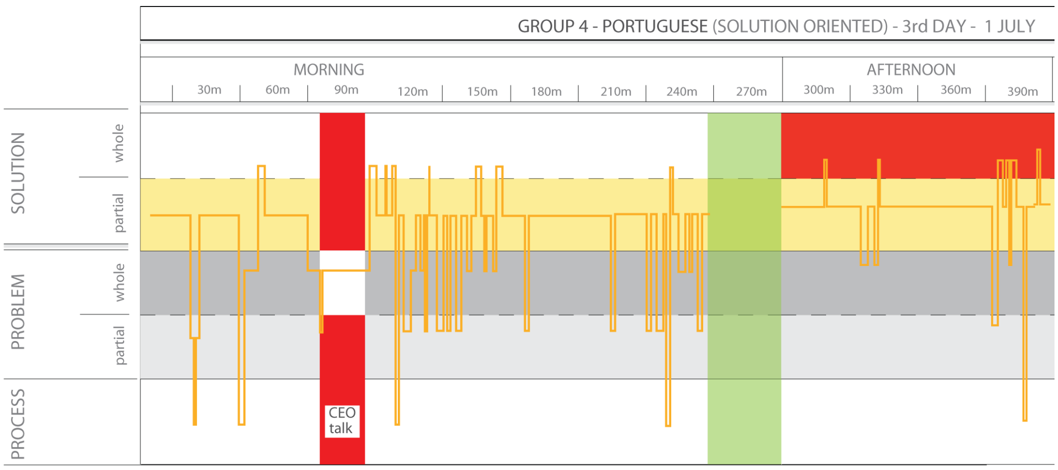
Creative Process: EXPLORATORY/ GENERATIVE

Decision Strategy: dominance of NON COMPENSATORY

Decision Mode: AUTONOMY, leader is a bit isolated; other members use silence as a NO

Information Management: low efficacy in using information; no iteration or revision of generated info

Idea Generation: focused on a partial solution: LOGO. generation of 16 partial ideas based on the ones previously made; going circular and not really transforming or innovating; last hour unblocked and created solutions for RECEPTION and DISPLAY



Decision Nature: alternation FRAMING and ENABLER DECISIONS

Creative Process: EXPLORATORY/ GENERATIVE loop - real intense process

Decision Strategy: dominance of NEGOTIATED COMPENSATORY/ NON COMPENSATORY

Decision Mode: AUTONOMY, with leader coordinating closely the schedules and activities developed

Information Management: tried to match the information obtained with CEO with the one they created

Idea Generation: thinking of the whole and partial solutions in an integrated way; thinking the way to improve it in order to better match CEO aims 30% immediate application; 20% transition ideas; 70% pure innovation; several ideas for RECEPTION and DISPLAY as well as for the FINAL PRESENTATION; LOGO and MANUAL almost finished; display completely defined (aft) - going to production

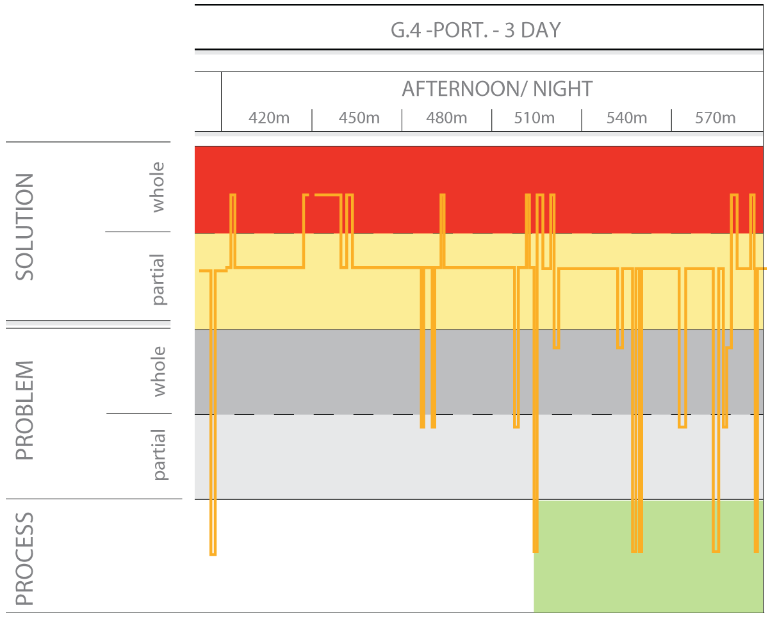
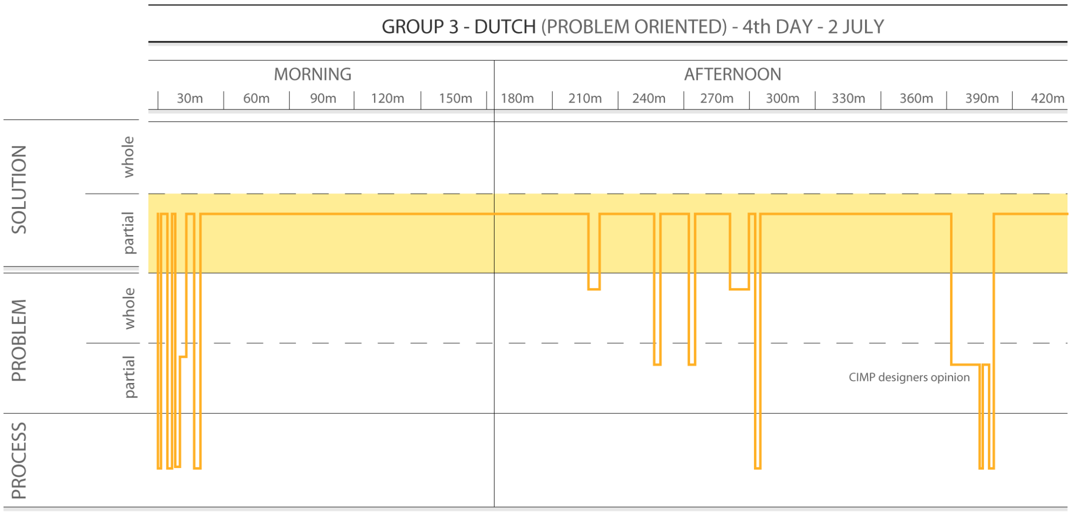


Fig.104 | Analysis of the Design Process of Groups 3 and 4 – 3RD Day

questions to ask to their representatives were set apart. Group 4 approach this third day with all members highly motivated and feeling confident. Their design strategy along this period was integration driven meaning that they alternated between problem and solution in a very interactive process that helped them to structure the entire solution and its parts. The group profited immensely of the meeting with the CEO. They had a structured and profitable talk with the CEO and at the end of the conversation they made a point of situation evaluating their path against the perceived solution they built based on the CEO speech. The LOGO and The MANUAL were fully defined, the RECEPTION was being worked and was assumed as being the design piece that would synthesize the entire design proposal of Rebranding and the DISPLAY, after the talk with the CEO was definitely defined as the object that would be prototypized. Moreover the team approved the leader suggestion of having a proposal phased in time. For the short term the change would have protagonists the DISPLAY and the SIGNAGE system; in the Medium term LOGO would be the main actor and in the long term the execution of the RECEPTION.



Decision Nature: E.DECISION, LOGO/ MANUAL/ RECEPTION/ COUNTER; energic; decisions while designing in computer

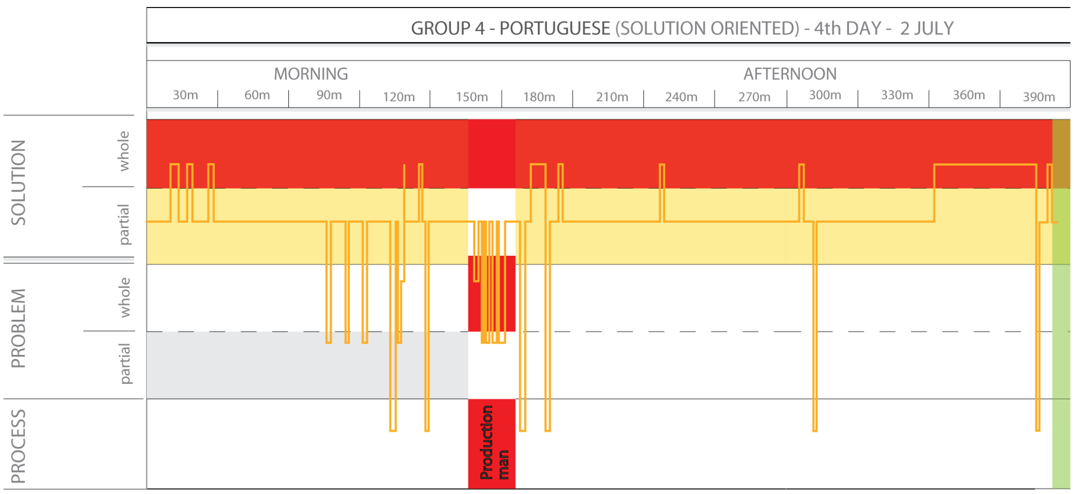
Creative Process: dominance: GENERATIVE - literal association made by shape, colors

Decision Strategy: dominance of NON COMPENSATORY

Decision Mode: COOPERATIVE, 2 teams and all together; 'no time to lose'

Information Management: geting more operational information; low iteration/revision of generated info

Idea Generation: still focused on a partial solutions: LOGO refinement in computer; RECEPTION - being changed while draw in computer; MANUAL - low investment; DISPLAY (direct link with LOGO). The Whole solution is made by the element 'leaf' and by the colors.



Decision Nature: ENABLER DECISION, RECEPTION/ DISPLAY FOCUS ; intense enabling with checkpoints periods

Creative Process: dominance: GENERATIVE - intense association with other situations /ideas

Decision Strategy: dominance of NEGOTIATED NON COMPENSATORY/ COMPENSATORY

Decision Mode: COOPERATIVE - ENTHOUSIASM OF TEAM MEMBERS, LEADER COORDINATING ALWAYS

Information Management: specialized information directly with production (late); focused selection of info

Idea Generation: still inumerous partial solutions to each of the designs to be made; the coherence of all elements is a concern; several ideas are put aside since they are rather innovative and difficult to implement quickly; idea generation is heavily supporting in designing

Fig.105 | Analysis of the Design Process of Group 3 – 4TH Day

Regarding the Creative Process both groups engaged in the loop exploratory/generative activities although group 4 showed a more accelerated rhythm and a dynamic that was absent from group3.

In terms of the nature of decision undertaken group 3 had a clear dominance of Enabler decisions while group 4 displayed and intense 'ping-pong' from framing to enabler decisions.

The Mode of Decision was autonomic for both groups but leadership performed differently in the two teams and the dynamics of the groups were deeply diverse. Leadership of group 3 was tense and experiencing long silence moments on the part of team members that isolate themselves in their own tasks. In group 4 the opposite occurred, there were long periods of exchange of ideas and an intense dialogue about details and the whole solution. The 'pattern' was discussion of the situation in hands with contribution of all, intense working on the situation, discussion of the new alternatives and achievements. Leader articulated the work developed by each member and incentivised them to pursue their work.

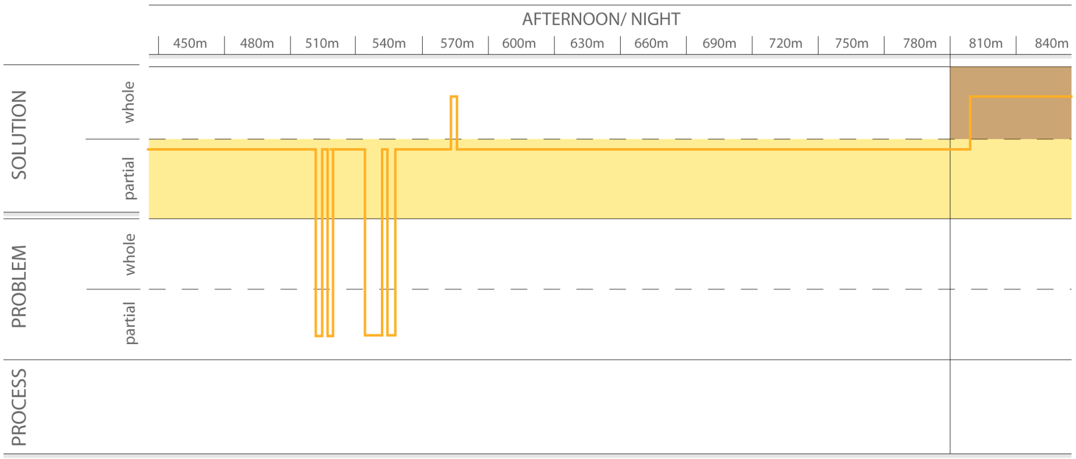
Finally the decision strategies also differed in the two groups. Group 3 displayed a non compensatory rule based strategy and group 4 a negotiated one equating the different attributes of the Brand reformulation having into account the vision of the CEO.

The fourth day (and the final one in terms of work sessions) was a day of intense enabling for both groups. The sessions for the Portuguese and Dutch team were product oriented but the team attitude was dissimilar. Dutch were concentrated in recovering the 'time lost' and to materialize final drawings and Portuguese being highly motivated were trying to improve the already defined designs and to explore its multiple virtues through a good communication strategy.

Being so the creative process for both groups was dominated by generative activities and the mode of decision was cooperative.

The Portuguese team was highly committed to have a good proposal and decided to invest part of their time

GROUP 3 - DUTCH (PROBLEM ORIENTED) - 4/5th DAY - 2/3 JULY



Decision Nature: ENABLER DECISION, LOGO/ MANUAL/ RECEPTION/ COUNTER/ DISPLAY/ PRESENTATION

Creative Process: dominance: GENERATIVE - puting elements together in obvious ways

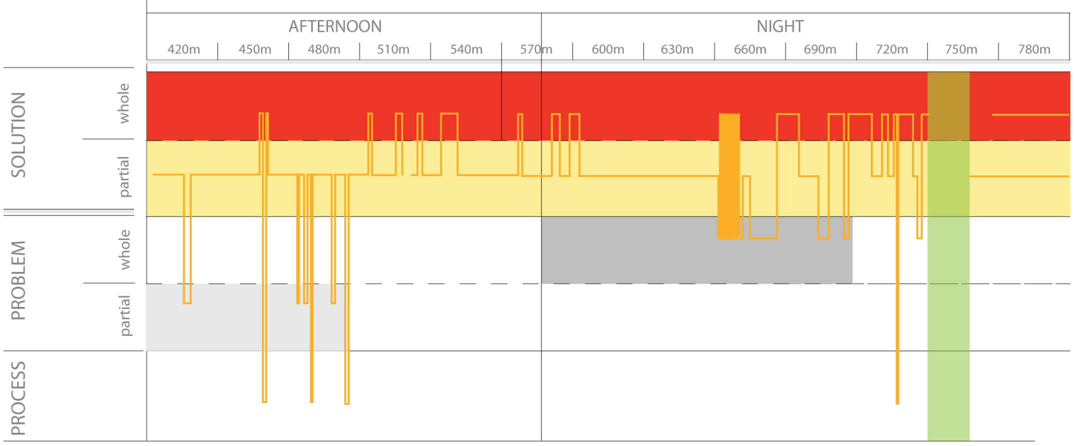
Decision Strategy: dominance of NON COMPENSATORY

Decision Mode: COOPERATIVE, 2 teams and all together; 'no time to lose' - reinforcement of team spirit

Information Management: speech - glue a synthesis of the VISION, KEYWORDS to design

Idea Generation: ideas for different elements where put together in the presentation in a tradicional way; speech fills the gaps and unbalance of the design; the option of pannels A3 as a presentation media diminished the impact of the proposal

GROUP 4 - PORTUGUESE (INTEGRATION ORIENTED) - 4/5th DAY - 2/3 JULY



Decision Nature: ENABLER DECISION - trying to match it with FRAMING decision taken in the first day

Creative Process: more GENERATIVE one - all objects defined and almost finished; presentation focus

Decision Strategy: dominance of NON COMPENSATORY

Decision Mode: COOPERATIVE - leader role remains determinant in synthesizing as defining strategies

Information Management: generated impressive info that do not make visible at all

Idea Generation: all objects developed; the general presentation's idea was complex and resulted confused and not as valuable as the designs produced.

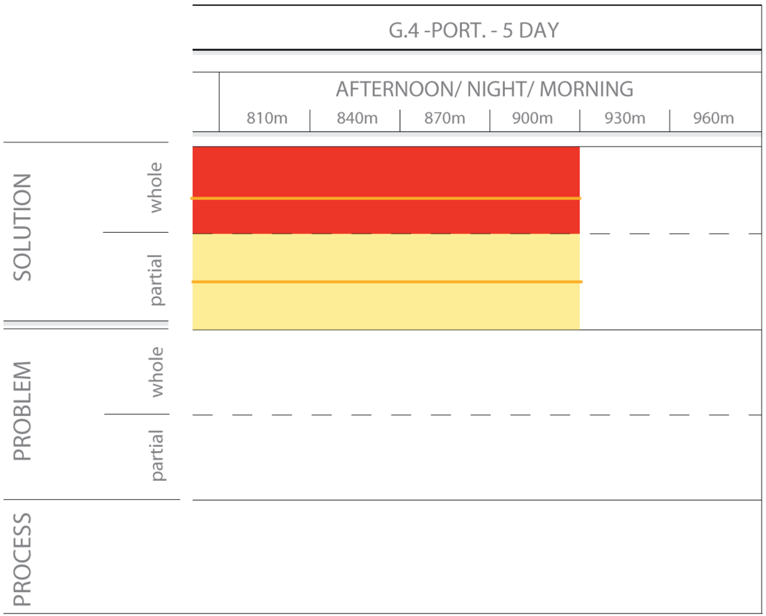


Fig.106 | Analysis of the Design Process of Group 3 – 5TH Day

in the prototype. To do so they had a meeting with the responsible of the firm's production.

Concerning the decision strategy the two groups diverge. Group 3 maintained his non compensatory rule based behaviour and group 4 a negotiated strategy.
Since it was the last work session day of the experiment both teams stayed longer in the firm. Dutch team stayed until the middle of the night and the Portuguese one until early morning. Figure 106 shows both teams' process.

This period of late afternoon and night was for both groups one to be dedicated to finish the proposal.

The Dutch group was working with two computers making the final renders of RECEPTION and of DISPLAY; at the same time two elements were dedicated to the execution of a scale model of the counter. In the morning they had the model ready and also the A3 posters to support the presentation. It was evident for all the team members that they had manage deficiently the time dedicated to the tasks and the overall process. They also had conscience that they had a bad performance managing information, especially the one they created and the one to be gathered with the company members.

The Portuguese group had 4 computers to work since the beginning that they used in an alternate mode with intense periods of sketching. During this period they worked in finishing the SIGNAGE system, making renders and photo simulations of the different spaces and of the RECEPTION, printing the LOGO elements and the MANUAL and designing the PowerPoint presentation template and the sequence of the elements in it.

The team attitude was a confident one since they felt that had managed the overall process's time well.

2.4.2.5 Results

The results of this experiment are analysed taking into account the jury evaluation as well as the critical incident analysis made of each group's performance. It is important to refer that the audiotapes of both group 1 and 2 did not allow us to have such rich information than the one collected with the videotapes.

Nevertheless it was possible to make a global analysis of the four group's design processes. The analysis done is

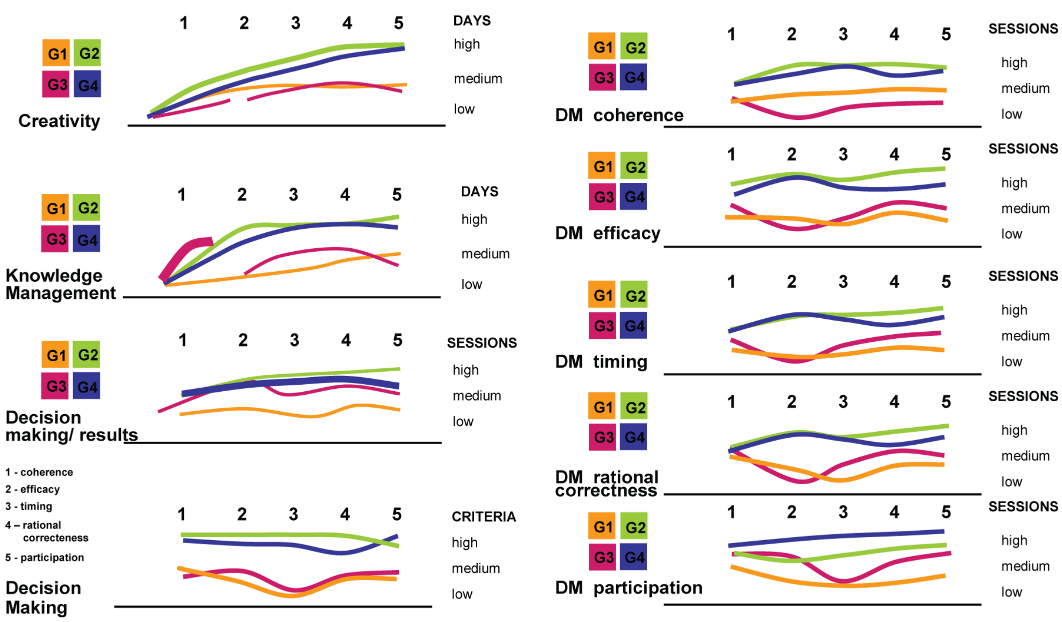
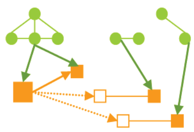
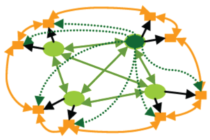
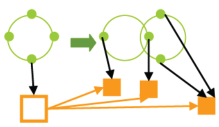
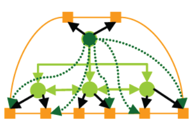


Fig.107 | Analysis of the overall behaviour of the design teams in terms of Creativity, knowledge management and Decision Making similar to the one made in the Climar experiment. Figure 107 synthesizes the main aspects analyzed: creativity process; knowledge management and the decision making process as a whole and also in detailed way.

In addition to the assessment shown in Figure 107 it was also made a table where further information on the design processes of the four groups is presented in a

Fig.108 | Synthesis of Groups performance in CIMP Experiment

Group ID	Jury Class.	Design Strategy	Group Dynamics	Overview of the Process	Outcomes
Group 1 Dutch AUDIO AD	14/20 3rd Prize	PROBLEM DRIVEN	Cooperative but with focus of conflict; lack of a plan; autonomous development at the end 	Intense research phase; use of moodboards; lack of communication design specific skills and knowledge; lack of an holistic view in the final solution	LOGO INTERIOR DESIGN - social areas DISPLAY MODEL
Group 2 Portuguese AUDIO	17/20 1st Prize	INTEGRATION DRIVEN	Networking; cooperative; leadership delegates and keeps control of the parts in the whole 	Net development; wining attitude; excellent dominance of time management; clear capture of the DNA of the firm and of its needs; effective use of resources; holistic approach and richness of elements to communicate the solution - marketing oriented presentation	LOGO + MANUAL BRAND + SAMPLES INTERIOR DESIGN - social areas + employess space DISPLAY MODEL
Group 3 Dutch VIDEO	13/20 4th Prize	PROBLEM DRIVEN SOLUTION DRIVEN (they started with a strategy and changed it in the 2nd day, at the end tried to match the two)	Cooperative but resistence to leadership; division of tasks; each element isolated - chain 	Very conceptual approach; intense use of brainstorming and of sketching; search for foundational elements to rebuilt the company's image; lack of an holistic view of the solution to deliver; lack of specific knowledge in communicational design	LOGO INTERIOR DESIGN - social areas COUNTER MODEL
Group 4 Portuguese VIDEO	14/20 2nd Prize	SOLUTION DRIVEN/ INTEGRATION DRIVEN/ PROBLEM DRIVEN	Strong leadership; division of tasks according to a plan ruled by the concept and by the leader 	Ambitious in terms of the proposed solution; the solution was not explicit in its strategy to present a new company image to the markets; unbalanced performance among all the areas to be covered;	LOGO INTERIOR DESIGN - social areas DISPLAY MODEL

way that it is possible to quickly identify some structural differences among them. The elements focused on that table are the classification of each team, its design strategy along the process, the overall group's dynamics a short overview of the process and the list of the produced outcomes.

The more relevant aspects to underline in the analysis of the four groups design processes are the ones related with the decision making framework's parameters. However, it is important to state that in this particular exercise the knowledge of specific domain skills in the area of communication design clearly determined the outcomes. Dutch students of both groups lack that specific knowledge and got unstructured in their approach since they got stucked in several aspects of the graphic design field of action. That make them spend too much time with the more graphical elements that made them not to explore their capabilities in the industrial design, interaction design and strategic product fields.

This aspect is directly linked with the curricula of the two faculties since although the Portuguese students formation was in product design the curricula of this program includes communication design as well as design management.

Another central issue that contributed to the results was the use groups made of methods and the resources they made available to the process. The Dutch groups made use of several methods both for information management and creativity stimulation while Portuguese were more modest in these aspects. On the other end Dutch groups only used two computers and the Portuguese ones had four computers available to work. This aspect was important along the process since Dutch groups discovered late that more computers would be a precious resource to reach a more efficacious presentation of their proposals. Inclusively, one of the groups (group 1) used computers from the company to overcome that situation. It is relevant to say that the use of computers did not signify in terms of the Portuguese groups that sketching was put aside. In fact the designing activity by hand was intense especially in group 4.

Concerning Information and knowledge management Portuguese groups were the ones that had made a more accurate and 'in control' management of it. They had prepared information to bring to the firm and while there they made synthesis of what they received, asked for what they found needed, gathered in internet and other sources complementary information and make intense use of retrieved information from previous design situations. On the other hand the Dutch groups appeared to be more 'lost' in the information and knowledge management. Either they entered in an endless exploitation of information both received or created through the interpretation they made of the company or they simply ignored information available (at demand) and assumed it dedicating themselves to other activities.

Crucial was also the moments of contact with firm's representatives and the way groups managed their interaction and integration with and in the company.

Dutch groups had an intense contact with the elements of the Creative/ design Department. This interaction was made along the five days where teams asked for the opinion on their designs to different elements of the department. Teams also had the opportunity to see the work CIMP' creative people was developing and at all time they were available to answers to their doubts and inclusively to help them with materials and equipment. The same occurred with the production department of the company. On the other hand when CEO visit the groups to answer their questions only one of the Dutch groups was prepared to do it and even though they did it in a not organized and structured way.

The Portuguese teams also had a good integration process in the firm but contrary to the Dutch ones they did not share the work they were doing to the different company persons. The exception was the production team since they had to have access to what was to be produced. The meeting with the CEO was in both cases an incentive to their work and a moment that clearly interfered with the decision making process and with the final proposals.

Fig.109 | Images of the Proposal of Dutch Group 1 – CIMP Experiment

Fig.110 | Images of the Proposal of Dutch Group 3 – CIMP Experiment

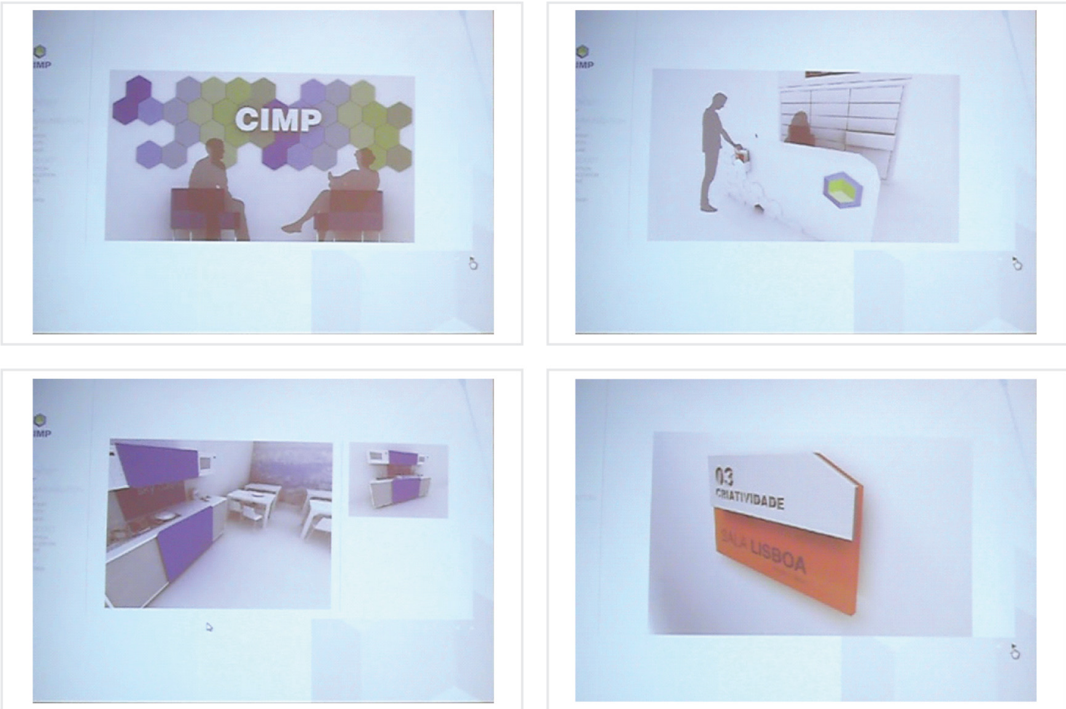


Fig.111 | Images of the Proposal of Portuguese Group 2 – CIMP Experiment

Fig.112 | Images of the Proposal of Portuguese Group 4 – CIMP Experiment

Fig.113 | Images of the Public Presentation and Prize Ceremony (Source: researcher)

Finally it was determinant to the overall process and to the final outcomes the group dynamics and the way team members interacted with each other as well as the motivation and attitude they had towards this challenge.

It was visible that Portuguese teams were more solid as groups, all team members were highly motivated and had a very positive and competitive attitude. Cooperation and responsibility were dominant in group dynamics that had a clear concern with organization, collaboration and convergence of singular contributions to a common goal. Individual competitive behaviors never arise in these two groups.

In Dutch groups the interaction among members was more difficult. Leadership had tense moments and conflict arised in some situations. The individual design approaches of some of the team members seemed to prevail over the group integrated approach. This fact had influence in the process development that had moments of clear blockage, of difficulties in decision making regarding the choice of alternatives, the enabling of technical and constructive details, the defense of ideas and its presentation.

SUMMARY OF THE CIMP EXPERIMENT - DESIGN STUDENTS GROUP EXERCISE INSIDE A COMPANY

The CIMP experiment aimed to made possible to study the design process of teams of students integrated in a company. Four teams of 4 students each, two Portuguese and two Dutch developed a brief proposed by the company during 1 week. The brief was developed by the company with the participation of the researcher and was not a simulated situation but instead a real one compatible with the firm's aptitudes and skills. It was a broaden assignement that called for different design skills ranging from industrial/product design, to communication Design and Interior Design. From the four groups two were videotaped and two audiotaped. The teams had an individual workspace and free access to all the departments inside the firm. A contact person was assigned by the CEO to facilitate their moves inside the company. Moreover the researcher had an assistant (a PhD candidate) that was there all the time to facilitate the communication and access to information and resources to all teams involved.

We could observe with clearness that the Dutch teams experienced difficulties addressing the communication design tasks involved in the design problem. On the other hand the more generalist education Product Design program of the Portuguese students allowed them to think the whole problem in its multiple factes in a more holistic and integrated way.

The winning design was consensual among the jury members (all from the firm) being considered the best in all the criteria aspects. Being the firm CIMP one that operates in the communication, brand activation, marketing and promotion areas the presentation of proposals was a key issue. On that respect Portuguese teams prepared more consistent, complete and appealing presentations.

Furthermore it is noticeable that Portuguese teams dedicated much more time (about 40% more) to the work. They also made a more diverse use of computer drawing softwares according to the specificity of the type of design work to present (some softwares were used specifically to graphic design, other to technical and constructive details of industrial and interior design, others to the modeling to industrial design and other to the presentation of the proposal. On the other hand Dutch teams made use of a more diverse group of methods and tools to enable creativity and idea generation (brainstorming, sketchstorming, scenarios, simulations/drama acting; moodboards).

In terms of group dynamics the Portuguese teams showed to be more integrated and organized being the role of the leaders one of coordination and incentivation. In the Dutch groups interaction happen to be in several moments conflictuous or even absent and that meant that sometimes designers of the teams were developing tasks on their own.

The integration of both the Portuguese and Dutch groups in the firm was easily done and groups had the opportunity to have direct contact with the creative department and the production one. They also could talk with the CEO and with staff members of the areas they found necessary to accomplish their work.

The opinions of the practitioners from creative department were asked by the Dutch groups in several moments and influenced their decisions in key moments of the process. The Portuguese teams do not asked the opinion of creative CIMP team but questioned them about several aspects of their work and procedures.

The CEO conversation with teams was determinant for all the groups but more effective to the Portuguese ones since these have made more structured interviews with the CEO and obtained more rich information about the vision and strategy of the company. That was particularly visible in group 4 that after the talk with the CEO decided to a more strategic approach to the problem that included a plan to the correct implementation of the Brand redesign.

BIBLIOGRAPHIC REFERENCES OF CHAPTER IV

CHRISTIAANS, H. 1992. *Creativity in Design: The role of domain knowledge in designing*, Utrecht, Lemma.

CHRISTIAANS, H., RESTREPO, J. 2004. Problem structuring and information access in design. *Journal of Design Research*, 4 (2).

CROSS, N. 2006. *Designerly ways of knowing*, London, Springer.

Design Council. 2007. Lessons from Europe - Visit to The Netherlands, Denmark and Finland, pp. 1-16.

DORST, C., CROSS, N. 2001. Creativity in the design process: co-evolution of problem-solution. *Design Studies*, 22 (5), pp.425-437.

DORST, K. 1997. *Describing Design: A Comparison of Paradigms*, Delft, The Netherlands, Delft University of Technology.

GOLDSCHMIDT, G. 1996. The Designer as a team of one. *In*: CROSS, N., CHRISTIAANS, H., DORST, C. (ed.) *Analysing Design Activity*. New York: Wiley.

GUNTER, J., FRANKENBERGER, E.; AUER, P. 1996. Investigation of Individual and team design processes. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity.* New York: John Wiley & Sons.

HOFSTEDE, G. 2001. *Culture's Consequences: comparing values, behaviors, institutions, and organizations across nations* (2nd ed.), Thousand Oaks, CA, SAGE Publications.

HONG, J-l, CHANG, N-K. 2004. Analysis of Korean High School Student's Decision-making processes in solving a problem involving biological knowledge, *Research in Science Education*, 34, pp97-111

HUITT, W. 1992. Problem solving and decision making: Consideration of individual differences using the Myers-Briggs Type Indicator. *Journal of Psychological Type*, 24, pp. 33-44.

HYTÖNEN, J. 2003. Quality and Content of International Design Education. DESIGNIUM, University of Art and Design Helsinki,. Available:http://www.uiah.fi/designium. [Accessed 12-10-2007].

MASSIRONI, M. 1982. *Ver pelo Desenho, aspectos técnicos, cognitivos, comunicativos*., Lisboa, Edições 70.

MOULTRIE, J., LIVESEY, F. 2009. International Design Scoreboard: Initial indicators of international design capabilities. University of Cambridge, Design Council. Available:http://www.ifm.eng.cam.ac.uk/dmg/documents/090406int_design_scoreboard.pdf.

NEWELL, A., SIMON, A. 1972. *Human Problem Solving*, New York, Prentice-Hall.

NIEMINEN, T., LAUTAMAKI, S., SALIMAKI, M. 2005. Modelling the Strategic Impacts of Design in Businesses. UIAH/ Designium.

REHMAN, F., YAN, X. 2007. Supporting early design decision-making using design context knowledge. *Journal of Design Research*, 6 (1-2), pp.169-189.

RESTREPO, J. 2004. *Information Processing in Conceptual Design. Design Science Planning*, Delft, The Netherlands, Delft University Press.

ROTHROCK, L., YIN, J. 2008. Integrating Compensatory and Noncompensatory Decision-Making Strategies in Dynamic Task Environments. In: KUGLER, T., SMITH, J., CONNOLY, T., SON, Y-J. (eds.) *Decision Modeling and Behavior in Complex and Uncertain Environments*. New York: Springer, Part II, pp. 125-141.

CHAPTER V - DISCUSSION – CROSS FINDINGS OF ALL THE ACTIONS TAKEN

In the foregoing research we have made a distinction between the inner and the outside assessment. The inner assessment had to do with the perceptions both students and companies have about their own design processes. The outside assessment regarded the observations the researcher/author made of those design processes. In this chapter the results of both assessments will consecutively be discussed. Next, both assessments will be compared in order to draw conclusions.

To make a discussion of the way all the information gathered through the use of different methods converges or not to some conclusions we first made the discussion of the information gathered in the Inner assessment; after the information gathered in the outside assessment and finally we cross both assessments.

1. About the Inner Assessment – the perception of both students and companies about their own design processes

The results obtained with the survey made among students and the ones obtained with the design process exercise are complementary in creating a description of how design students perceive their own processes. In the two sets of results it was visible that information gathering and knowledge management lead to difficulties in time management, both being crucial elements to the success of the process outcomes. The reference of time management as being a central issue is present in the results of both activities. However, when making a deep analysis we find time management to be pointed out as a reason that somehow 'covers' other critical aspects of the design process such as information management, the absence of a methodology, and deficiencies in decision making.

In addition, the survey and the design process exercise allowed us to confirm the existence of three different design strategies: problem, solution and integration driven strategies. The last category was added to the ones found out by Christiaans and Restrepo (2004) and describes a behavior of alternating between problem and solution in what Cross and Dorst (2001) called the co-evolution problem solution. These strategies are not put forward by students in a conscious way.

Regarding the methods used by students in addressing design problems, it was clear that the survey alone could not capture the same richness of information regarding students' perception of their own processes that as was attainable through the design process exercise. Nevertheless, it was also hard for students to describe their own process even using a visual description (diagrams) of such process. This lack of practice in monitoring and reflecting upon their own processes is also related with the absence of a consistent use of a methodology or even methods to structure the design process.

According to the students' perception, decision making appears to be a key issue of the design process. The ability or inability of making decisions is mostly linked by students to personality characteristics, to the quality of information gathered, and to the existence of domain or specific knowledge.

Concerning the impact of each phase of the design process, the conceptual phase was the one identified in the survey as the most important in terms of time spent perceived by the students, having the highest average in this regard among all the phases. The main reasons students mentioned for spending more time in this phase were: a) decisions made in this phase concern creativity which are hard to be made (20%); b) this phase determines the whole process (20%); c) having an innovative idea is crucial and difficult to generate (20%). In the design exercise the conceptual phase was the one that deserved special attention on the behalf of students. It is the phase that students identified as the in which they worked on more activities –- either related with information treatment, creativity, selection of alternatives, and decision making in general.

On the topic of the companies' perception of design processes the assessment made was a general one. It gave us insight into the way business evaluates the role of design and designers. In that way it helped us to better understand what 'strategic adequacy' means to firms giving also some clues about the firm's perception of 'design quality' and the way it can be measured.

2. About the Outside Assessment – the observation of Design Processes

The outside assessment was made through the observation of several activities that are synthesized in Table 76.

experiment	time	context	nº subjects
Individual exercise	2 hours 2,5 hours	Portuguese Design Education (FA.UTL) Dutch Design Education (TU.Delft)	13 subjects 10 subjects
Group Exercise CLIMAR	5 sessions of 2 hours each	Portuguese Students (FA.UTL) - collaboration at distance with the Firm	32 subjects groups of 5/6
Group Exercise CIMP	1 week 4 days + 1 presentation	Company integrated both Portuguese and Dutch design students from FA and TU Delft	16 subjects groups of 4

Table 76 | Experiments - Design Processes with individual and teams of students

The Verbal Protocol analysis of the Individual experiment made us turn the focus of our research from information and knowledge management to decision making in design processes. The fact was that the findings concerning information access and use were consistent with studies made by other researchers (Restrepo and Christiaans, 2004; Cross, 2001, 2006); and decision making being a constant along the design process was found to be not as well documented in existing Design field studies.

2.1 – Knowledge Management and Decision Making in individual and Team actions

When comparing the decision making process in an individual exercise with that in teams we tend to disagree both with the vision defended by Goldschmidt where the 'designer alone behaves like a team of one' (1996, pp. 65-91) and the one by Lewis et al (1975) and

Erev et al (1993) who respectively found out that: 1) group problem solving processes are not necessarily superior to individual ones, and 2) the motivation of team members tend to decrease as much as 30% when there is no personal penalty for slacking or no reward for successful performance. In our case, on the contrary, we observed that the performance of teams had a higher quality of outcomes. The fact that compensation (award winning competition) was present in both group cases might have influenced the performance of the teams and their outcomes.

Furthermore, our observations show that team dynamics have different impacts on decision making behavior that are not visible in individual performance. Sometimes the team interaction called for more conscious decision making since the scrutiny of decisions is made by several individuals that have their own view of the problem; sometimes the decision making process got diffused by the velocity and continuous interpellation of team members instead of gaining a structured coherent path.

On the basis of our analysis we can state that decision making in teams is more complex than in individual designing. This complexity can either enrich the decision making outcomes (example: E3 group in Climar experiment) or constrain the whole design process and compromise the results (example: the Dutch group 1 in Cimp experiment).

2.2 – Knowledge Management and Decision Making for Portuguese and Dutch Design Students

Regarding knowledge management we observed in all experiments that Portuguese and Dutch students showed similar behaviors. Some students and groups tend to collect an enormous amount of information while making use of only a small part of it (that was the cases of, for example, group 3 in the CIMP experiment and Portuguese subject 1 in the individual experiment). The structuring of the gathered information was critical for both the Portuguese and Dutch students (this was especially observed in the individual experiment and in the CLIMAR one). Dutch students make use of a wider number of techniques and tools to treat, assess and evaluate information than Portuguese ones.

The lack of domain knowledge in the area of communication design negatively affected the results of Dutch students in CIMP experiment. However, in the individual experiment where the brief asked essentially for product design skills, the overall results of the Dutch students were higher.

Portuguese students, because of their more broad design education showed better performance when they were facing a more holistic design problem calling for skills in specific design areas that integrated their curricula.

In the Individual experiment with the design of a garbage system in the train, the piece of information regarding the type of the garbage (that stated different types of possible garbage to be found in train bins and the percentages of it) gave origin to 8 in 12 proposals that considered the recycling/separation of garbage. Such ecological concerns were absent from the Dutch protocols but that might have to do with the fact that 15 years separate the execution of both experiments. It also might have to do with the fact that the ecological green approach to design is an important issue in the design agenda of FA.UTL.

Similarly to what happened with the information and knowledge management approach in terms of creative process management there was an obvious difference between Portuguese and Dutch students behavior. Portuguese students make poor use of tools and methods to enable or enhance creative processes in their design process. On the contrary, Dutch students make an intense use of different tools and methods to boost their creative process and to make easier choice among design alternatives. This was particularly visible in the CIMP experiment.

Looking at the decision making process both Portuguese and Dutch students made use of different decision making approaches according to our decision making framework.

3. Crossing the Inner and the outside assessments

It is important to determine if the perceptions of both the students and the companies regarding design processes in general and decision making in particular coincide or diverge.

Starting with the analogous visions, the difficulties students have with information and knowledge management are also mentioned by the firms when they state they hardly have specific information about the markets and the competitors. The way information and knowledge management occurs along the design process is similar for outside and the inner assessment made by students and firms. In fact it becomes evident that there are innumerous problems that arise along the design process that interfere with the final outcomes: they are connected with the inefficiency of the information and knowledge management.

Moreover, students also mentioned decision making as being a critical issue in the design process. The experiments conducted by the researcher also detected that decision making is closely related with design moves that clearly influences the results of the design process. The decision making process is rarely assumed by students as being a conscious process and most of the key decisions taken along the process are not reflected by the decision maker (not even at an a posteriori moment).

The group dynamics are not referred to by the students since their reflection was made upon their own design process. However, the experiments make clear the importance of the role of the leader for decision making and also of the decision system that arises from the articulation of the different elements of a team.

The dominant decision strategies were the non-compensatory rule based and the negotiated non-compensatory/compensatory rule based ones. The compensatory rule based strategy occurred less and was mostly limited to the initial phase of the group's approach to a design problem.

With respect to the quality of the outcomes the two assessments show that:

> The quality of design (for firms that had answered the De.:SID questionnaire) is best guaranteed by a good customer relationship management. In addition, the 'quality of the concept' (as defined by Stoll, 1999) which refers to the performance, product features, aesthetics and ergonomic issues, is also highly valued by firms. This result is important in the context of this research since the concept is by excellence a territory where design intervention is natural and very intense. However, the survey also shows that only 51% of the firms use design in the conceptual phase.

> When considering the way students define the quality of design in the survey the definitions with the higher averages were: a) the one "that presents sustainable and ethically responsible solutions as an outcome"[52] and b) the one that associates quality of the design with the optimization of the human, material and financial resources.

In short, it seems that quality assessment in the two fields is centered on different issues. Students associate quality of the outcomes with design principles ruled by sustainable concerns as well as with a firm's strategic use of resources, while firms see the quality of outcomes clearly linked to the perception customers have of it and the way it is possible to build a consistent relationship between firm and customer.

Moreover the quality is also a criterion that integrates all the evaluations of the different experiments. In fact there were two criteria addressing quality in the evaluations: 'quality of the communicative interaction' and 'overall quality'.

52. It is important to notice that this concern with sustainability and ethics in design practice were also relevant and verifiable in the experiments done within this research.

Part Four: Conclusions and recommendations

CHAPTER VI – CONCLUSIONS

Design processes are complex and dynamic processes and their outcomes depend upon multiple variables.

When accessing the way students perceive their own processes time management and Knowledge/ information management are a unanimously conscious problem.

It was also clear in all the experiments that information and knowledge management are central in Design processes. There was also evidence that a relevant amount of information was lost, ignored along the process and this was true for both for Portuguese and Dutch students.

Moreover, the student's evaluation of design process made it clear the importance of the conceptual phase in particular. This is consistent with what we found in the literature review.

In terms of outside assessment the creation of a Decision making framework resulted from the analysis of the designer's behavior in Design Process while doing the individual experiment. It was then created a descriptive model aiming to create awareness both in the Education and the Business fields.

From that model we believe to be possible to build in the future some tools that might help the design process development. DMTool was an attempt to create such a supporting tool (see Chapter IV, 2.3.2). However, it was apparent that those tools should not be prescriptive ones but rather used as a reflection tool that would help the divergence/convergence process, the analysis/ synthesis moments without being too intrusive in terms of operational process flow.

The Decision making framework made also possible for us to observe several dimensions in Design Processes: the Design Strategy; the creative cognitive processes involved; the Nature of the Decisions; and the group dynamics, i.e. the decision mode and the decision strategy.

Regarding Design Strategy, that can be either Problem or Solution driven or even Integration Driven, in all experiments all the three strategies were observed but they were not conclusive regarding whether any of these strategies is more likely to conduce to a more strategic process leading to higher quality outcomes. However, in all the experiments the groups that presented an Integration driven design strategy had always consolidated, coherent decision making processes and well ranked results on the behalf of the juries involved in the experiments.

In terms of the creative cognitive process it was observable that idea generation may occur along the entire design process and in many different ways. It can be a partial or a whole idea and it can derive from the association or synthesis of information or even occur following an information retrieval moment. Consistent with the literature survey we could observe that the generation of a great amount of ideas does not necessarily result in a better solution. Still, the processes in the experiments that obtained the best results were those that had generated several ideas.

In terms of group dynamics and the mode of Decision it was observable that leadership influences the Design process. It can be a facilitator of the development of a solution of high quality. When leadership was not consistent it was possible to observe two different types of behavior: either the whole team loses dynamics and stimuli and the process gets very unstructured and, as a result, the outcomes display less quality or, some of the team members react and try to work autonomously. In this case, they react in individual terms to the 'failure' in performance of the group.

Concerning decision strategy, although in some cases the groups and individuals display a compensatory rule based strategy, the fact is that the more common strategies are the non-compensatory rule or the negotiated ones. On the other hand, it is noticeable that the compensatory strategy, when used, occurs in most cases in the early phases of the design process to support framing activities.

The dominance of the non compensatory and negotiated decision strategies appears to be directly related with the role that intuition assumes in the development of the Design processes. Also of importance is to consider the findings of Kuhn (2001) referred to by Hong and Chang (2004, 108) that indicate:

"that exercise of strategies at the performance level feeds back and enhances the metalevel understanding which will guide subsequent strategy selection and hence, performance. This can be considered in decision-making problems. That is, teaching strategies encouraging meta-decision making are needed. Specially, criteria for selection are important components to solve decision-making problems. Since the ability to resolve conflicts between choices during decision-making is limited by individual information-load, if the degree of conflict is high because too many things are obscure or must be considered, then the decision-making is performed by intuition. In each of the phases, students did not solve the conflictive context effectively because they were confused in selecting criteria and not familiar with needed skills. At this time, value clarification skill enables students to adopt which selective criterion among many alternative criteria for choice. The selected criteria will function as clues to resolve the conflictive contexts by reducing individual information-load. It is important that students accept the scientific values such as objectiveness of scientific method, accuracy, reliability and validity of data in their value systems, and utilise them to solve problems".

GAP BETWEEN THE INNER ASSESSMENT AND THE OUTSIDE ASSESSMENT?

This work showed that Design students ignore the structure and detailed nature of their difficulties along design processes and when asked about it cannot propose clear ways to overcome those problems.

Group versus individual perceptions of own design process are similar. The possibility of sharing responsibilities was seen as being either occasion of good performance or, on the contrary a barrier to the achievement of good outcomes.

In general terms, all the actions developed in the Education field and while putting together Education and companies reinforced our awareness of the inadequacy of the existing methodologies. In fact, the general methodologies used in Design Education are mainly based on a logical kind of reasoning that differs from the abductive one in the way Peirce, referred to by Hartshorne and Weiss, (1958) defined it a century ago. This type of reasoning supports an activity similar to 'reverse engineering' i.e. 'working backwards' as proposed by Polya (1957) that is defended by Peirce as being the only logical operation that introduces new ideas.

In reality both in the student's perceptions assessment and in the outside assessment made through the experiments it is visible that methodologies could help designers to deal, in a more conscious or even controlled way, with knowledge management and decision making during the Design processes.

Education and Industry

Education and Industry are and always will be two distinct worlds of design practice. That has to do with the fact that although both pursue the goal of having the best practitioners, they do it in different contexts, and with different methods and resources. The rhythm of learning in the education area is vaster and its environment is a controlled one, in the sense it does not have consequences in markets. On the other hand, in the 'real world' the practice of Design has direct implications in business results and the time to act is more reduced since velocity to markets in a key issue to the competitiveness of firms. However, it is a reality that both fields are intimately related since one prepares the practitioners that the other will employ. Therefore it is crucial that both fields are aligned in respect to what they consider to be the discipline of Design, its limits and potential of intervention. Nowadays, in the Portuguese context the gap between the two fields still exists (see Chapter I). The possibility of reducing it relies on several factors at different levels of intervention.

In firms, it depends heavily on the consolidation of design as a strategic resource in business; that consolidation will confirm design has a valuable resource of the firms being the designers and their work a crucial element in the business strategy.

It is also important to promote the openness of firms to Academia in general; the development of a cooperative attitude is something that needs to be implemented in consistent and continuous ways. That will enable both parts to work in more efficient and effective manners.

Strategic Adequacy

The criterion of 'strategic adequacy' (see Glossary-Appendix A) was used in all the experiments and the concept was also present in the surveys. In the student's questionnaire, it appears in question 21 related with the definition of 'design quality' and in the questionnaire to firms there are several questions that try to establish the level of strategic adequacy of design in terms of firm's usage.

The strategic adequacy of the processes depends upon the clear communication of the firm's strategy to Designers that will try to make the Vision of the company operative. The Brief, as the document that explains to the designer the problem, its context and the expected results, is a piece of information that assumes the most relevant role in the design process in general and in the communication of the strategic adequacy concept in particular. In addition, there are all the other sources of information about the firm that, being consistent in its 'speech' allowed designers to understand what the firm is, how it is positioned in the market, and where it wants to be in the future.

When analyzing the way the different jury of the three experiments evaluated the 'strategic adequacy' of the proposed design solutions, we conclude that jury members of the individual experiment and of the Climar one diverge in the evaluation of the outcomes and also in the weight they attribute to this operational concept in the overall evaluation, although using the same definition of the concept. In the Cimp experiment 'strategic adequacy is positively related with other criteria and it has the same weight for the majority of the jury members.

It also is noteworthy to mention that the strategic adequacy of the outcomes from design process is expected to be better guaranteed when the relationship between Education and Industry gets more consistent and a more dialoguing one.

Quality

Concerning the quality in the way we defined it in Chapter III, Section 4 it was observable that all the winning Design proposals resulting from the group experiments had the ability to communicate clearly and in a harmonic way all the facets of the project. There was a balance between the graphic and product design that was reinforced by the written information that complemented it in a pertinent way. The technical and constructive elements were presented with proficiency.

Assuming the model proposed in Chapter III, Section 4, it is possible to say that there were common traits among all the design proposals that were chosen as the best one, especially in the ones of in CLIMAR and CIMP's experiments. These traits were the following:

> They revealed high level of communicative interaction; meaning that had the ability to trigger interaction with the persons involved in the design process and in those evaluating it. This ability was expressed by the existence of a dialogue on each of the presented drawings and design pieces.

> They displayed quality of communication that has to do with the coherence of the whole and the parts that integrate it. The proposals balanced well the six communicative functions proposed by Jakobson and

referred by Clive Ashwin (1989, pp. 203-209): 1) the referential objective one; 2) the emotive that tries to trigger emotional responses; 3) the conative that is a persuasive type of communication that impels the receiver to act or respond in a specific way;4) the poetic that communicates in a way that is self justifying 5) the phatic that allows the starting maintenance and conclusion of the communication process and the 5) the meta linguistic that creates the possibility of explaining all the signs that are presented along the design proposals.

> They exposed operational quality in the sense that it was easy and clear to verbally and visually dismantle the design. This type of quality also characterizes the ability of transforming complex and entropic information in simpler one through the use of multiples ways of presenting information, its links and importance.

In what concerns the quality of the process of design it is possible to say that in terms of the external component of quality the proposals revealed:

1. Ample quality of communication that, similarly to the one in the design as a final product, refers to the designer's communication capacity in verbal and visual terms but that in here it also has to do with the mechanisms that are developed so that the information and knowledge is managed between the different agents effectively and throughout the process.

2. Adequate strategic quality meaning that they revealed a balanced management of the different knowledge areas involved in the design process bearing in mind the company's planning, formulation and strategic implementation.

As said in the Discussion chapter (V) the criteria 'overall quality' and 'quality of communicative interaction' integrated all the evaluations of the different experiments.

Both criteria were positively related with the final score of the different design outcomes of the experiments.

CHAPTER VII – RECOMMENDATIONS

New Methodologies' framework

This research was initiated with the belief that new design methodologies wee required and so one of its goals was to develop such a methodology. As the research unfolded such an aim was abandoned due to several factors but at the end of the study it is still our conviction that new design methodologies are needed.

New methodologies to be developed should ensure that designers will be able to engage in design processes having a real improved time, strategic adequacy and total quality management of it.

Design in the context of the construction of such methodologies must be seen as a process that develops a synthesis pattern in which solutions are actively constructed by designers who can make use of different strategies while designing.

It is also important to be conscious that, as Rittel and Webber (1984:135-144) observed, the design problems are usually 'wicked problems' meaning that they are not problems for which all the necessary information is available being, therefore, not susceptible to an exhaustive analysis. Thus we have no guarantee that the 'correct' solutions may be found. In this context a strategy focused on the solution could seem preferable to a problem-focused one. It is always possible to analyze the 'problem' but the designer's task is to produce 'a solution'. Being so, it is only in terms of a conjectured solution that the problem can be contained within 'manageable bounds' as advanced by Hillier & Lieman (1974:4-11). What designers tend to do is search or impose what Darke (1979:36-44) named as a 'primary generator' that both defines the limits of the problem and points out to its possible solution.

Another aspect to take into account in the construction of a new methodology derives from Foucault's (1971) idea that of our knowledge is nothing more than the result of a process including a) the experience (conscious or unconscious) of stimuli in a 'specific sequence up to the given moment' through our senses and, concurrently, b) the continual processing of these stimuli 'in the same specific sequence' within the 'dynamic' framework of memory (conscious or unconscious). Two important issues elapse from this. First of all, because knowledge is depending on senses and memory, it cannot exist without a body. Secondly, because knowledge is dynamic and inter-processed it may take different forms depending on the 'sequence of stimuli', e.g. if stimuli X comes before stimuli Y (and Y is processed with the experience of X) knowledge may be different than if stimuli Y comes before stimuli X (and X is processed with the experience of Y). This implies that what we know is highly dependent on where we have been, meaning not only physical places, but also 'place' as a position where physical aspects, institutions, discourses, languages and so on come together. For us to successfully communicate what we know is also highly dependent on where we have been and where the person we are communicating with has been.

It is also structural for the construction of a new methodology the recognition of Dorst and Cross (2001) findings that 'design problem' and 'design solution' have a co-evolution and cannot be seen as separate moments. Especially in what concerns 'ill-defined' or 'wicked' problems it is a matter of developing and refining both the formulation of the problem and ideas for a solution, in a constant iteration that includes analysis, synthesis, evaluation and decision processes.

Taking into account the issues listed above, it is recommended to explore, as way of framing time, strategic adequacy and quality management in the design processes, the use of two general structuring aspects: a) 'case-based design' (based upon experience/ memory that is used to facilitate retrieval and use) and b) 'constraints and decisions posting' (a method of formulating and propagating values, constraints decisions and structure).

In terms of time management, which was persistently pointed at by students as being a key issue in their own design processes, similar principles to those contained and structured in the Critical Chain Project Management Method (CCPM) should be researched and tested. As Zultner (2003: 10-18) defines it CCPM (a method developed by Eliyahu M. Goldratt in 1997) as a method of planning and managing projects that considers all tasks in a project as a system and puts more emphasis on the resources required to execute project tasks, especially time. It also puts accent on the identification and minimization of the impact of constraints, a subject that is strongly connected with the structure of the new methodology.

Decision Making Process

In future work it should be taken into account that designers conceive their activity as a problem-solving one which inhibits them to consciously think of it in terms of a decision-making one. This standpoint, in our opinion, would bridge in a meaningful way design education and design practice in organizations. In fact, during most of the time in the experiments, subjects were not aware that they were taking decisions. If they would realize that the competing objectives, when formulated in a conscious manner, would probably steer the decision-making process towards the development of a balanced and effective solution.

We should never forget that we are evaluating risks and making decisions all the time. It should be possible to make this process more conscious. That is also valid in design processed where the amount of decision making is high and its velocity is significant.

Therefore, it would be important to understand the nature and structure of decision making process in a better and deeper way.

To do so, it would be essential to monitor decision making in freshman design students and in experienced designers to see if the corresponding processes are different, how different they are, where they diverge, and so on.

Also relevant would be the introduction of Decision making as a topic in the Design program. It should be addressed in a transversal way – making it an explicit and formalized topic, at least, in design studio courses, design management courses, and product engineering course. That could be done, departing from the framework created,(the decision making model) by organizing design exercises to work each of the components that integrate the decision-making process. This work should be done integrating both Education and Business.

In addition, the role of Decision making as the result of group dynamics should be better assessed. It has to do with the development of Design Program contents such as negotiation, communication, and team management in general.

Moreover, the research of how idea generation in the design process relates with decision making is another topic that deserver further commitment on the part of researchers. Similarly, the role of intuition in Decision making and in Design Process in general remains to be inspected.

Finally, the study of the impact of cultural differences in design Process and Decision making was not addressed in this thesis but the possibility of working with both Portuguese and Dutch students made us aware that this issue might be significant in the design process's development and outcome.

Design Process in general

A few recommendations regarding design process in general seem justifiable. For instance, the study of how design Cognition should be explored by education in order to promote a more effective relationship among research-education and industry is a topic that emerged from the present work as being essential.

In operational terms and in what concerns design practice in school there should be the possibility of working not only with diverse design problems but also with distinct approaches to design problems. The structuring of the approach to the problem can be stimulated in a way that designers can get stronger in group dynamics management, idea generation, information management, and decision making.

Finally, it is crucial to make a consistent and systematic use of the knowledge created, disseminating it and establishing a net where the exchange of information will allow a consistent enlargement of Design Thinking.

BIBLIOGRAPHIC REFERENCES

AHMED, S., BRACEWELL, R. KIM, S. 2005. Engineering Knowledge Management. *A Symposium in Honour of Ken Wallace.* Cambridge, UK.

ALEXANDER, E. 1982. Design in the decision-making process. *Policy Sciences*, 14.

ALMENDRA, R. 2008. Reflection on the quality of design: from the product to the project. *Journal of Design Principles and Practices: an international Journal.*, 2 (1).

AMABILE, T. 1983. The social psychology of creativity: a componential conceptualization. *Journal of Personality and Social Psychology*, 45(2).

ARCHER, B. 1979. The three R's. *Design Studies*.

ASHWIN, C. 1989. Drawing Design Semiotics. *In*: MARGOLIN, V. (ed.) *Design Discourse*. Chicago: The University of Chicago Press.

BEHESHTI, R. 1993. Design decisions and uncertainty. *Design Studies*, 14(1).

BILDA, Z., GERO, J., PURCELL, T. 2006. To sketch or not to sketch? That is the question. *Design Studies,* 27(5).

BORJA DE MOZOTA, B. 1985. *Essai sur la fonction du design et son rôle dans la stratégie marketing de l'entreprise*, Université de Paris I Panthéon Sorbonne.

BORJA DE MOZOTA, B. 2003. *Design Management. Using Design to Build Brand Value and Corporate Innovation*, New York, Allworth Press.

BRERETON M., C., D., MABOGUNJE, A., LEIFER, L. 1996. Collaboration in design teams: how social interaction shapes the product. In: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity*. New York: John Wiley & Sons.

CE 2004. Manufuture: a Vision for 2020. Assuring the future of manufacturing in Europe. Report of the High Level Group. Luxembourg: Office for Official Publications of the European Communities.

Centro Português de Design. 2003. Cadernos de Design. Anuário. Ano Seis, 17/18.

CHOI, Y., RASMUSSEN, E. 2002. Users' relevance criteria in image retrieval in American history. *Information Processing and Management*, 38.

CHRISTENSEN, B., SCHUNN, C. 2009. Putting Blinkers on a Blind Man. Providing Cognitive Support for Creative Processes with Environmental Cues. In: MARKMAN, A. (ed.) *Tools for Innovation*. Oxford University Press.

CHRISTIAANS, H. 1992. *Creativity in Design: The role of domain knowledge in designing*, Utrecht, Lemma.

CHRISTIAANS, H., RESTREPO, J. 2001. Information Processing in Design: a theoretical and empirical perspective. In: ACHTEN, H., DE VRIES, B., HENNESSEY, J. (ed.) *Design Research in the Netherlands 2000*. Eindhoven: Eindhoven University of Technology.

CHRISTIAANS, H., RESTREPO, J. 2004. Problem structuring and information access in design. *Journal of Design Research,* 4(2).

CHUA, R., IYENGAR, S. 2008. Effects of experience, instruction, and choice on creativity. *Journal of Creative Behavior*, 42(3).

COX, V. Year. An Application of Cognitive Science to Understand Problem Solving Activity for Well Structure Problems: Cognition, Algorithms, Metacognition and Heuristics. In: Proceedings of Frontiers in Educational Annual Conference, 1987.

COYNE, R. 1995. *Designing information technology in the postmodern age*, Cambridge MA, The MIT Press.

COYNE, R., SNODGRASS, A. 1991. Is designing mysterious? Challenging the dual knowledge thesis. *Design Studies*, 12(3).

CROSS, N. 2006. *Designerly ways of knowing*, London, Springer.

CROSS, N., CHRISTIAANS, H., DORST, C. (EDS) 1996. *Analysing Design Activity*, Chichester, Wiley.

CROSS, N., CROSS, A. 1996. Observations of teamwork and social processes in design. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity*. New York: John Wiley & Sons.

DARKE, J. 1979. The primary generator and the design process. *Design Studies*, 1(1).

DELBECQ, A., VAN DE VEN, A., GUSTAFSON, D. (ed.) 1975. *Group Techniques for Program Planning: a Guide to Nominal Group and Delphi Processes*, Glenview, Illinois.: Scott Foresman.

DEMING, W. 1986. *Out of the Crisis*, MIT Press.

DEMING, W. 1993. *The New Economics for Industry, Government, Education*., Cambridge, MA, MIT Centre for Advanced Engineering Study.

Design Council. 2004. The impact of Design on Stock Market Performance: An Analysis of UK Quoted Companies 1994-2003. [Accessed 19 April 2007].

Design Council. 2005. The Business of Design: Design Industry Research 2005. Available:http://www.designcouncil.org.uk/Design-Council/3/Publications/?PageNum=2 [Accessed 19 April 2007].

Design Council. 2007. Lessons from Europe - Visit to The Netherlands, Denmark and Finland.

DO, E., GROSS, M., NEIMAN, B., ZIMRING, C. 2000. Intentions in and relations among design drawings. *Design Studies*, 21(5).

DORST, C. 2003. *Understanding Design*, Amsterdam, BIS Publishers.

DORST, C., CROSS, N. 2001. Creativity in the design process: co-evolution of problem-solution. *Design Studies*, 22(5).

DORST, K. 1997. *Describing Design: A Comparison of Paradigms*, Delft, The Netherlands, Delft University of Technology.

DORST, K. 2004. On the problem of design problems - problem solving and design expertise. *Journal of Design Research,* 4(2).

DOUGHERTY, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organization Science*, 3(2).

DOWNING, F. 2000. *Remembrance and the Design of Place*, College Station, Texas, A&M University Press

DUBBERLY, H. (ed.) 2004. *How do You Design?*, San Francisco: Dubberly Design Office.

DUMAINE, B. 1990. Who needs a boss? *Fortune*. Time Inc's Fortune/Money Group.

DUMAS, A., WHITEFIELD, A. 1989b. Why design is difficult to manage: A survey of attitudes and practices in British industry *European Management Journal*, 7(1).

EASTMAN, C. 2001. New Directions in Design Cognition: Studies on Representation and Recall. *In*: C.M. EASTMAN, W. M., MC CRACKEN, W.C. NEWSTETTER (EDS) (ed.) *Design Knowing and Learning: Cognition in Design Education*. Amsterdam: Elsevier.

ENDSLEY, M., HOFFMAN, R., KABER, D., ROTH, E. 2007. Cognitive engineering and decision making: an overview and future course. *Journal of Cognitive Engineering and Decision Making*, 1(1).

ERICSSON, K. 2005. Recent advances in expertise research: a commentary on the contributions to the special issue. *Applied Cognitive Psychology*, 19.

ERICSSON, K., LEHMANN, A. 1996. Experts and exceptional performance: evidence on maximal adaptations on task constraints. *Annual Review of Psychology*, 47.

ERICSSON, K., SIMON,H. 1984. *Protocol Analysis. Verbal Reports as Data*, Cambridge, MIT Press.

European Community. 2006. MEMO/06/190. http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/190&format=HTML&aged=0&language=EN&guiLanguage=fr (Accessed in May 2007).

Faculdade de Arquitectura da Universidade Técnica de Lisboa. Relatório de Avaliação Interna. 2005.

FAUST, W. 2000. Building and fostering long-term client relationships. *Design Management Review*, 11(2).

FIDEL, R., GREEN, M. 2004. The many faces of accessibility. *Journal of Information Processing and Management*, 40(3).

FINKE, R., WARD, T., SMITH, S. 1992. *Creative Cognition: Theory, Research and Applications*., Cambridge, MIT Press.

GADAMER, H.-G. 1975. *Truth and Method*, London, Sheed and Ward.

GADAMER, H.-G. 1986. *The relevance of the beautiful and other essays*, Cambridge, Cambridge University Press.

GERO, J. S., KANNENGIESSER, U. 2006. A Function-Behaviour-Structure ontology of processes. *In*: GERO, J. (ed.) *A Function-Behaviour-Structure ontology of processes.* New York: Springer.

GREENE, J., CARACELLI, V., GRAHAM, W. 1989. Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis,* 11(3).

GOLDSCHMIDT, G. 1991. The dialects of sketching. *Creativity Research Journal*, 4(2).

GOLDSCHMIDT, G. 1996. The Designer as a team of one. *In*: CROSS, N., CHRISTIAANS, H., DORST, C. (ed.) *Analysing Design Activity*. New York: Wiley.

GOLDSCHMIDT, G. 2005. How good are good ideas? Correlates of design creativity. *Design Studies*, 26.

GOLDSCHMIDT, G., SMOLKOV, M. 2006. Variances in the impact of visual stimuli on design problem solving performance. *Design Studies*, 27.

GORB, P. 1990. *Design Management*, London, Architecture Design and Technology Press.

GORB, P., DUMAS, A. 1987. Silent Design. 8(3).

GORDON, W. 1961. *Synectics: the Development of Creative Capacity.*, New York, Harper and Row.

GUINDON, R. 1990. Designing the design process: exploiting opportunistic thoughts. *Human Computer Interaction*, 5(2).

GUNTER, J., FRANKENBERGER, E.; AUER, P. 1996. Investigation of Individual and team design processes. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity.* New York: John Wiley & Sons.

HAMMOND, J., KEENEY, J., RAIFFA, H. 1999. *Smart Choices: A Practical Guide to Making Better Decisions*, Boston, MA, Harvard Business School Press.

HAQUE, B., BELECHEANU, R., BARSON, R., PAWAR, K. 2000. Towards the application of case based reasoning to decision-making in concurrent product development (concurrent engineering). *Knowledge-Based Systems*, 13(2/3).

HERRMANN, J. 2004. Decomposition in Product Development - Technical Report 2004-6. College Park: Institute for Systems Research, University of Maryland.

HERRMANN, J., SCHMIDT, L. 2002. Viewing product development as a decision production system. *In*: Proceedings of DETC 2002, ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September, 29 - October, 2, Montreal, Canada.

HERTENSTEIN, J., PLATT, M., BROWN, D. 2001. Valuing Design: enhancing corporate performance through design effectiveness. *Design Management Journal*, 12(3).

HOWARD, T., CULLEY, S., DEKONINCK, E. 2008. Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, 29.

HUITT, W. 1992. Problem solving and decision making: Consideration of individual differences using the Myers-Briggs Type Indicator. *Journal of Psychological Type*, 24.

HYTÖNEN, J. 2003. Quality and Content of International Design Education. DESIGNIUM, University of Art and Design Helsinki,.Available:http://www.uiah.fi/designium. [Accessed 12-10-2007].

ISHIKAWA, K. 1982. *Introduction to Quality Control*, Tokyo, JUSE Press Ltd.

ISHIKAWA, K. 1985. *What is Total Quality Control? The Japanese Way.,* Englewood Cliffs, NJ, Prentice-Hall.

JEVNAKER, B. 2000. Championing design: perspectives on design capabilities. *Design Management Journal; Academic Review*,1.

JEVNAKER, B. 2000b. How design becomes strategic. *Design Management Journal*, 11(1).

JIN, Y., CHUSILP, P. 2005. Study of mental iteration in different design situations. *Design Studies*, 27(1).

JOHNSON, R., ONWUEGBUZIE, A. 2004. Mixed methods research: a research paradigm whose time has come. *Educational Researcher*, 33(7).

JOHNSON, R., TURNER, L. 2003. Data collection strategies in mixed methods research. *In*: TASHAKKORI, A., TEDDLIE, C. (ed.) *Handbook of mixed methods in social and behavioral research* Thousand Oaks, CA: Sage.

JONES, J. 1992 *Design Methods*, New York, John Wiley & Sons Inc.

JONSON, B. 2005. Design Ideation: the conceptual sketch in the digital age. *Design Studies*, 26(6).

JURAN, J. 1951. *Quality Control Handbook*, New York, McGraw Hill.

KIM, M., KIM, Y. 2007. Perceived Creativity and Design Team interaction. *IASDR07*. The Hong Kong Polytechnic University.

KATZENBACH, J., SMITH, D. 1993. *The Wisdom of Teams: Creating the High-Performance Organization*, Boston, Harvard Business School Press.

KLEIN, G. 1989. Recognition-primed decisions. *In*: ROUSE, W. (ed.) *Advances in man-machine systems research*. Greenwich: JAI Press.

KLEIN, G. 1993. A recognition-primed decision (RPD) model of rapid decision making. *In*: KLEIN, G., ORASANU, J., CALDERWOOD, R., ZSAMBOK, C. (ed.) *Decision making in action: Models and methods* Norwood, NJ: Ablex, pp.138-147.

KLEIN, G., CALDERWOOD, R., CLINTON-CIROCCO, A. Year. Rapid decision making on the fire ground. *In*: Proceedings of the Human Factors Society, 1986 CA. Human Factors and Ergonomics Society.

KLEIN, G., ROSS, K., MOON, B., KLEIN, D., HOLLNAGEL, E. 2003. Macrocognition. I*EEE Intelligent Systems*, 18(3).

KLEINSMANN, M., VALKENBURG, R. 2008. Barriers and enablers for creating shared understanding in co-design projects. *Design Studies*, 29, pp.369-386.

KOTLER, P., RATH, G. 1984. Design: a powerful but neglected strategic tool. *Journal of Business Strategy*, 5(2).

KRABUANRAT, K., PHELPS, R. 1998. Heuristics and rationality in strategic decision making: an exploratory study. *Journal of Business Research*, 41, pp.83-93.

KREITNER, R., KINICKI, A. 2004. *Organizational Behavior*, New York, McGraw-Hill.

KRISTENSEN, T. 1998. The Contribution of Design to Business: A competence-based perspective. *In*: BRUCE, M., JEVNAKER, B. (EDS) (ed.) *Management of Design Alliance. Sustaining Competitive Advantage*. Chichester: Wiley

KUUSELA, H., PAUL, P. 2002. A comparison of concurrent and retrospective verbal protocol analysis. *The American Journal of Psychology, University of Illinois Press*, 113(3).

LAWSON, B. 1979. Cognitive strategies in architectural design. *Ergonomics*, 22(1).

LAWSON, B. 1990. *How designers think: the design process demystified* London, Butterworth.

LAWSON, B. 1994. *Design in mind,* Oxford, Architectural Press.

LLOYD, P., SCOTT, P. 1994. Discovering the design problem. *Design Studies*, 15(2).

LONGUEVILLE, B., LE CARDINAL, J., BOCQUET, J., DANEAU, P. 2003. Towards a project memory for innovative product design: a decision-making process model. *International Conference on Engineering Design (ICED03)*. Stockholm.

LOVE, T. 2005. A unified basis for design research and theory. *International Design Congress - IASDR 2005: New Design Paradigms.* Douliou, Taiwan: International Association of Societies of Design Research, Taiwan.

MACKEY, A., GASS,S. 2005. *Second Language Research: Methodology and Design*, New Jersey, Lawrence Erlbaum Associates, Inc.

MALAGA, R. 2000. The effect of stimulus modes and associative distance in individual creativity support systems *Design Support Systems*, 29.

MASSIRONI, M. 1989. *Ver pelo Desenho, aspectos técnicos, cognitivos, comunicativos*., Lisboa, Edições 70.

MICHEL, L. 2007. Understanding decision making in organizations to focus its practices where it matters. *Measuring Business Excellence,* 11(1).

MOODY, S. 1984. The Role of Industrial Design in the Development of New Science based Products. *In*: LANGDON, R. (ed.) *Design and Industry*. London: The Design Council

MORROW, D., MILLER, L., RIDOLFO,. H., KELLY, R., FISHER, U., STINE-MORROW, E. 2003. The influence of pilot expertise on comprehension and decision making. *12th International Symposium on Aviation Psychology*. Dayton.

MOULTRIE, J., LIVESEY, F. 2009. International Design Scoreboard: Initial indicators of international design capabilities. University of Cambridge, Design Council. Available:http://www.ifm.eng.cam.ac.uk/dmg/documents/090406int_design_scoreboard.pdf.

NEVADO, P., BARATA, J., ALMENDRA, R., ROMÃO, L. 2008. The "Igloo Model": A proposal for an analysis of the contribution of design to the competitiveness of companies. *ICAM - 15th Annual International Conference on Advances in Management*. Hyatt Harborside Hotel,Boston.

NEWELL, A., SIMON, A. 1972. *Human Problem Solving*, New York, Prentice-Hall.

NICHOLLS, K. 1990. Engineering changes under control. *Journal of Engineering Design*, 1(1).

NIEMINEN, T., LAUTAMAKI, S., SALIMAKI, M. 2005. Modelling the Strategic Impacts of Design in Businesses. UIAH/ Designium.

ONWUEGBUZIE, A., LEECH, N. 2004. Enhancing the interpretation of significant findings: The role of mixed methods research. *Annual meeting of the Eastern Educational Research Association*. Clearwater.

ONWUEGBUZIE, A., TEDDLIE, C. 2003. A Framework for Analysing Data in Mixed Methods Research. *In*: (EDS), C. T. (ed.) *Handbook of Mixed Methods in Social and Behavioral Research*. Thousand Oaks, CA: Sage.

OWENS, D. 2000. Structure and status in design teams: implications for design management. *Design Management Journal, Academic Review,* 1(1).

PAHL, G., BEITZ, W. 1984. *Engineering Design*, London, The Design Council.

POLANYI, M. 1983 (1st ed. 1966). *The Tacit Dimension,* Gloucester Peter Smith, Mass.

POTTER, S., ROY, R., CAPON, C., BRUCE, M., WALSH, V., LEWIS, J. 1991. The Benefits and Costs of Investment in design: using professional design expertise in product, engineering and graphics projects. Design Innovation Group, Milton Keynes: The Open University and UMIST.

PRESS, M., COOPER, R. 2003. *The Design Experience – the Role of Design and Designers in the Twenty-first Century,* UK, Ashgate.

QIU, Y.-F., CHUI, Y-P., HELANDER, M. 2007. A cognitive approach to understanding knowledge-based virtual team decision making in product design. *International Journal of Intelligent Enterprise*, 1(1).

REHMAN, F., YAN, X. 2007. Supporting early design decision-making using design context knowledge. *Journal of Design Research*, 6(1-2).

RESTREPO, J. 2004. *Information Processing in Conceptual Design. Design Science Planning*, Delft, The Netherlands, Delft University Press.

RESTREPO, J., CHRISTIAANS, H. 2003a. Design Requirements: Conditioners or Conditioned? *ICED03 - International Conference on Engineering Design*. Stockholm.

RESTREPO, J., CHRISTIAANS, H. 2003b. Problem Structuring and Information Access in Design. *Paper accepted for the Design Thinking Research Symposium 6: 'Expertise in design'.* Australia.

RHEA, D. 1992. A new perspective on design: focusing on customer experience. *Design Management Journal*, 9(4), pp.10-16.

RICKARDS, T. 1987. "Closing Down": a classification of creative decision making aids. *Journal of Managerial Psychology,* 2(3).

RIEDEL, J., ROY, R., POTTER, S. 1996. Market Demands that Reward Investment in Design. *8th International Forum on Design Management Research and Education*. Barcelona.

RITCHEY, T. 2007. Wicked Problems: Structuring Social Messes with Morphological Analysis. *Swedish Morphological Society* [Online].
Available:http://www.swemorph.com/wp.html [Accessed 24 November 2007].

RITTEL, H., WEBBER, M. 1973. Dilemmas in a general theory of planning. *Policy Science*, 4.

ROOZENBURG, N., CROSS, N. Year. Models of the design process - integrating across the disciplines. *In*: HUBKA, V., ed. Proceedings of ICED 91, 1991 Zürich. Heurista.

ROOZENBURG, N., EEKELS, J. 1995. *Product Design: Fundamentals and Methods*, Chichester, John Wiley & Sons, Inc.

ROY, R., POTTER, S. 1993. The commercial impact of investment in design. *Design Studies*, 14(2), pp.171-193.

ROY, R., RIEDEL, J., POTTER, S. 1998. Market Demands that Reward Investment in Design (MADRID): Final Report submitted to the Design Council. Design Innovation Group, Milton Keynes: The Open University.

ROY, R., SALAMAN, G., WALSH, V. 1986. Research Grant Final Report, Design-based Innovation in manufacturing Industry. Principles and Practices for Successful Design and Production. Milton Keynes: Design Innovation Group, Open University.

SARMA, V. 1994. Decision Making in Complex Systems. *Systems Practice*, 7(4).

SCHÖN, D. 1983. *The Reflective Practitioner: How Professionals Think in Action*, New York, Basic Books.

SCHÖN, D. 1987. *Educating the Reflective Practitioner,* San Francisco, Jossey-Bass – A Wiley Imprint.

SENTENCE, A., CLARKE, J. 1997. The Contribution of Design to the UK Economy. *In*: COUNCIL, D. (ed.). London: Centre for Economic Forecasting, London Business School.

SIMON, H. 1973. The ill structure of ill-structured problems. *Artificial Intelligence*, 4, pp.181-204.

SIMON, H. 1996. *Sciences of the Artificial*, Cambridge, The MIT Press.

SIMON, H., DANTZIG, G., HOGARTH, R., PIOTT,C., RAIFFA, H., SCHELLING, T., SHEPSLE, K., THAIER, R., TVERSKY, A., WINTER, S. 1986. Report on the Research Briefing Panel on Decision Making and Problem Solving. Washington DC: National Academy of Sciences.

SNODGRASS, A., COYNE, R. 1997. Is Designing hermeneutical? *Architectural Theory Review, Journal of the Department of Architecture,* 2(1).

SOLOVYOVA, I. 2003. Conjecture and Emotion: An Investigation of the Relationship Between Design Thinking and Emotional Content. *DTRS6 - Design Thinking Research Symposium 6 , Creativity and Cognition Studios*. Sidney, Australia: University of Technology.

SONG, S., DONG, E., AGOGINO, A. 2002. Modeling information needs in engineering databases using tacit knowledge. *Journal of Computing and Information Science in Engineering*, 2.

STOLL, H. 1999. *Product Design Methods and Practices*, New York, Marcel Dekker, Inc.

SVENGREN, L. Year. Industrial Design as a Strategic Resource. *In*: The European Academy of Design, 11-13 April 1995 University of Salford.

SUWA, M., GERO, J., PURCELL, T. 2000. Unexpected discoveries and S-invention of design requirements: important vehicles for a design process. *Design Studies*, 21(6).

SUWA, M., TVERSKY, B. 1997. What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4).

TEIXEIRA, J. 2007. Applying Design Knowledge to Create Innovative Business Opportunities. Available: trex.id.iit.edu/papers/design_knowledge.pdf [Accessed February 2009].

THOMAS, J., CARROLL, J. 1979. The psychological study of design. *Design Studies*, 1(1).

TOVEY, M., PORTER, S., NEWMAN, R. 2003. Sketching, concept development and automotive design *Design Studies*, 24(2).

TURNER, R., TOPALIAN, A. 2002. Core Responsabilities of Design Leaders in Commercially Demanding Environments. *Design Leadership Forum* (Inaugural session). London: Alto Design Management.

ULLMAN, D., DIETTRICH, T., STAUFFER, L. 1988. A model of the mechanical engineering process based on empirical data. *AI EDAM,* 2(1).

VAN DER LUGT, R. 2001. Sketching in design idea generation meetings. TU Delft, Faculty of Industrial Design Engineering.

VARELA, F., THOMPSON, E., ROSCH, E. 1991. *The Embodied Mind*, Cambridge MA, The MIT Press.

VINCENTI, W. 1990. *What Engineers Know and How They Know It?,* Baltimore, John Hopkins University Press.

VISSER, W. 2009. Design: one, but in different forms. *Design Studies,* 30(3), pp.187-223.

WALSH, V. 1995. The evaluation of design. *International Journal of Technology Management*, 10(4/5/6).

WALSH, V. 2000. Design, Innovation and the Boundaries of the Firm. *Design Management Journal*, Academic Review.

WALTON, M. 2003. Building a case for added value though design. *Report to Industry New Zealand*. Wellington: NZ Institute of Economic Research (Inc.).

WANG, K. R., L., TONG, S., EYNARD, B., MATTA, N. 2008. Design Knowledge for Decision-Making Process in a DFX Product Design Approach. *In*: YAN, X., ION, W., EYNARD, B. (ed.) *Global Design to Gain Competitive Edge: an Holistic and Collaborative Approach Based on Computational Tools*. London: Springer.

YATES, J., VEINOTT, E., PATALAN, A. 2002. Hard Decisions, Bad Decisions: on Decision Quality and Decision Aiding. *In*: SCHNEIDER, S., SHANTEAU, J. (EDS.) (ed.) *Emerging Perspectives on Judgment and Decision Research*. Boston, MA: Cambridge University Press.

YIN, R. 1994. *Case Study Research: Design and Methods. Applied Social Research Methods*, SAGE Inc.

ZHANG, Y. 1998. *Computer-Based Modelling and Management for Current Working Knowledge Evolution Support*. PhD Thesis, Strathclyde University.

BIBLIOGRAPHY

Guide to the Preparation of Specifications. 1998. London: British Standards Institution.

ADAMS, R., TURNS, J., ATMAN, C. 2003. Educating effective engineering designers: the role of reflective practice. *Design Studies*, 24(3), pp. 175-294.

AKIN, Ö. 1979. Exploration of the Design Process, *Design Methods and Theories*, 13(3), pp. 115-119.

AKIN, Ö., LIN, C. 1996. Design Protocol data and novel design decisions. *In*: CROSS, N. CHRISTIAANS, H.; DORST, K. (eds.) *Analysing Design Activity*. Chichester: John Wiley & Sons, pp. 36-62.

ALBERT, D., STEINER, C. 2005. Representing Domain Knowledge by Concept Maps: How to Validate Them? *In*: OKAMOTO, T., ALBERT, D., HONDA, T.,HESSE, F. (eds.) The 2nd Joint Workshop of Cognition and Learning through Media-Communication for Advanced e-Learning, 28-30 September 2005, Tokyo. Sophia University, pp. 169-174.

ALEXANDER, C. 1964. *Notes on the synthesis of form*, Cambridge MA, Harvard University Press.

ALMENDRA, R. 2007. 2º Relatório de Progresso da Dissertação de Doutoramento, Área Científica de Design. Lisboa: FA.UTL.

ALMENDRA, R. 2007. The enhancement of the time, quality and strategic adequacy dimensions of product design processes: a doctoral study in its first stage. *In*: Conference of Defsa International Design Education,3-5 October 2007, Cape Town.

ALMENDRA, R. 2008. Reflection on the quality of design: from the product to the project. *Journal of Design Principles and Practices: an international Journal*. 2 (1), pp. 1-6.

ALMENDRA, R., CHRISTIAANS, H. 2009. Decision-making in Design: a comparative study. *In*: CHAKRABARTI, A. (ed.) *Research into Design: Supporting multiple facets of product development*. Singapore: Research Publishing, pp. 508-519.

ALMENDRA, R., CHRISTIAANS, H. 2009. Decision-making in the conceptual design phases: a comparative study. *Journal of Design Research*, 8(1), pp. 1-20.

AMABILE, T. 1983. The social psychology of creativity: a componential conceptualization. *Journal of Personality and Social Psychology*, 45(2), pp. 357-376.

AMABILE, T. 1990. Within you, without you. The social psychology of creativity and beyond. In: RUNCO, M., ALBERT, R. (ed.) *Theories of Creativit*y. Newbury Park, CA.: Sage

ANON. 2004. Manufuture: a Vision for 2020. Assuring the future of manufacturing in Europe. Report of the High Level Group. Luxembourg: Office for Official Publications of the European Communities.

ARCHER, B. 1979. The three R's. *Design Studies,* 1, pp. 17-20.

ARCHER, L. 1969. The Structure of the Design Process. *In*: BROADBENT, G. W. A. (ed.) *Design Methods of Architecture*. New York Witteborn

ASHWIN, C. 1989. Drawing Design Semiotics. In: MARGOLIN, V. (ed.) *Design Discourse*. Chicago: The University of Chicago Press.

ATMAN, C., CHIMKA, J., BURSIC, K., NACHTMANN, H. 1999. A Comparison of freshman and senior engineering design processes. *Design Studies*, 20(2), pp. 131-152.

BADKE-SCHAUB, P. 2007. Decision making processes and leadership in product development. *In*: MOSIER, K., FISCHER, U. (eds.) Proceedings of the 8th International NDM Conference, 2007 s.l., pp. 1-5.

BAJOR, P., HORVÁTH, A. 2008. The role of decision-making parameters in constructing and re-engineering of distribution networks. *In*: KÓCZY, L. Á. (ed.), FIKUSZ 2008 Business Sciences - Symposium for Young Researchers., 2008 Budapest Tech, Keleti Faculty of Economics, pp. 55-63.

BANHAM, R. 1974. *The Aspen Papers: Twenty Years of Design Theory from The Design Conference in Aspen*, New York, Praeger.

BARDIN, L. 1979. *Análise de Conteúdo*, Lisboa, Edições 70.

BAUDRILLARD, J. 1973. *O Sistema dos Objectos*, São Paulo, Editora Perspectiva.

BAXTER, M. 1995. *Product Design*, London Chapman and Hall.

BEITZ, W. 1994. Design science – the need for a scientific basis for engineering design methodology. *Journal of Engineering Design*, 5(2), pp. 129-133.

BEYER, H., HOLTZBLATT, K 1998. Contextual Design: Defining Customer-Centered Systems. *In*: CARD, S., GRUDIN, J., LINTON, M., NIELSEN, J., SKELLY, T. (ed.). San Francisco: Morgan Kaufmann

BEZERRA, C., OWEN, C. L. 1999. Managing Complexity in Design: the role of computer-supported methods. *In*: Proceedings of The 15th International Conference on Computer-Aided Production Engineering, University of Durham, UK, pp. 3-8.

BILDA, Z., GERO, J., PURCELL, T. 2006. To sketch or not to sketch? That is the question. *Design Studies*, 27(5), pp. 587-613.

BODEN, M. A. 1990. The Creative mind: *Myths and Mechanisms,* London, George Weidenfeld and Nicolson.

BONOLLO, E., LEWIS, B. 1996. The industrial design profession and models of the design process. *Design and Education*, 6(2).

BONSIEPE, G. 1992 (1st ed. Ital. 1975). T*eoria e Prática do Design Industrial. Elementos para um Manual Crítico,* Lisboa, Centro Português de Design.

BORG, J., YAN, X. Year. Design decision consequences: key to 'design for multi-X' support'. *In*: 2nd International Symposium Tools and Methods for Concurrent Engineering, 1988 Manchester, UK, pp. 169-184.

BORJA DE MOZOTA, B. 1985. *Essai sur la fonction du design et son rôle dans la stratégie marketing de l'entreprise*., Université de Paris I Panthéon Sorbonne.

BRERETON M., C., D., MABOGUNJE, A., LEIFER, L. 1996. Collaboration in design teams: how social interaction shapes the product. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (ed.) *Analysing Design Activity*. New York: John Wiley & Sons, pp. 319-340.

BUCHANAN, R., MARGOLIN, V. 1995. D*iscovering Design – Explorations in Design Studies,* Chicago, The University Chicago Press.

BÜRDEK, B. E. 1992 (1st ed. 1991). *Design, Storia, Teoria e Prassi del Disegno Industriale,* Milano, Arnoldo Mondadori Editore.

CAI, Y. 2001. Design strategies for global products. *Design Management Journal*, 12(4), pp. 59-64.

CAGAN, J., VOGEL, C. 2002. *Creating Breakthrough products - innovation from product planning to program approval,* FT Press.

CAREY, H., VOGEL, C., CAGAN, J., WEINGART, L. 2002. Integrating Design Thinking into the strategic planning phase of product development. *In*: IDSA (ed.) *National Education Conference*. San Jose, California: IDSA: Dulles.

CASAKIN, H., KREITLER, S. 2006. Evaluating creativity in design problem solving. *Design Research International Conference*. IADE, Lisbon: Wonderground, Lisbon.

CHOI, Y., RASMUSSEN, E. 2002. Users' relevance criteria in image retrieval in American history. *Information Processing and Management*, 38695-726.

CHRISTENSEN, T., YASAR, S. 2007. Paradigms and Protocols in the Study of Creative Collaboration: Implications for Research of Design Team Process and Product. *IASDR07 Emerging Trends in Design Research*. Hong Kong: The Hong Kong Polytechnic University: Hong Kong.

CHRISTIAANS, H. 1992. *Creativity in Design: The role of domain knowledge in designing*, Utrecht, Lemma.

CHRISTIAANS, H., VAN ANDEL, J. 1993. The effects of examples on the use of knowledge in a student design activity: The case of the 'Flying Dutchman'. *Design Studies*, 14(1), pp. 58-74.

CHRISTIAANS, H., VAN ANDEL, J. 1998. Information Processing and Storage during the Design Process: the use of a flexible information system. *In*: FRANKENBERGER, E., BADKE-SCHAUB, P., BIRKHOFER, H. (ed.) *Designers: The key to successful product development*. UK: Springer Verlag, pp. 12-28.

CHRISTIAANS, H., RESTREPO, J. 2001. Information Processing in Design: a theoretical and empirical perspective. In: ACHTEN, H., DE VRIES, B., HENNESSEY, J. (eds.) *Design Research in the Netherlands* 2000. Eindhoven: Eindhoven University of Technology, pp. 63-73.

CHRISTIAANS, H. 2002. Creativity as a design criterion. *Creativity Research Journal,* 14(1), pp. 41-54.

CHRISTIAANS, H., RESTREPO, J. 2004. Problem structuring and information access in design. *Journal of Design Research,* 4(2).

CHRISTIAANS, H., ALMENDRA, R. 2008. Problem structuring and information access in a design problem: a comparative study between Dutch and Portuguese students. *P&D Design 2008 - 8º Congresso Brasileiro de Pesquisa e Desenvolvimento em Design*. São Paulo, Brasil: Centro Universitário Senac, São Paulo.

CHUA, R., IYENGAR, S. 2008. Effects of experience, instruction, and choice on creativity. *Journal of Creative Behavior*, 42(3), pp. 164-180.

CLARK, K., WHEELWRIGHT, S. (eds.) 1994. *The Product Development Challenge: Competing through Speed*, Boston, Quality and Creativity.

COREY, E. 1975. Key options in market selection and product planning. *Harvard Business Review*, (75502).

COSTA, D. 1992. *Design e Mal-Estar*, Lisboa-Porto, Porto Editora - Centro Português de Design.

DESIGN COUNCIL. 2004. The impact of Design on Stock Market Performance: An Analysis of UK Quoted Companies 1994-2003. [Accessed 19 April 2007].

DESIGN COUNCIL. 2005. The Business of Design: Design Industry Research 2005. Available: http://www.designcouncil.org.uk/Design-Council/3/Publications/?PageNum=2 [Accessed 19 April 2007].

COURT, A. 1997. The relationship between information and personal knowledge in new product development. *International Journal of Information Management*, 17(2), pp. 123-138.

COYNE, R., SNODGRASS, A. 1991. Is designing mysterious? Challenging the dual knowledge thesis. *Design Studies,* 12(3), pp. 124-131.

COYNE, R. 1995. *Designing information technology in the postmodern age,* Cambridge MA, The MIT Press.

CROSS, N. 1982. Designerly ways of knowing. *Design Studies,* 3(4), pp. 221-227.

CROSS, N., (ed) 1984. *Developments in Design Methodology,* Chichester, John Wiley & Sons.

CROSS, N. 1989. *Engineering Design Methods*, Chichester, Wiley.

CROSS, N., ROOZENBURG, N. 1992. Modelling the design process in engineering and in architecture. *Journal of Engineering Design*, 3(4), pp. 325-337.

CROSS, N., CHRISTIAANS, H., DORST, C. 1994. Design expertise among student designers. *Journal of Art and Design Education,* 13(1), pp. 39-56.

CROSS, N., CHRISTIAANS, H., DORST, C. (eds) 1996. *Analysing Design Activity*, Chichester, Wiley.

CROSS, N., CROSS, A. 1996. Observations of teamwork and social processes in design. *In*: CROSS, N., CHRISTIAANS, H.,DORST, K. (eds.) *Analysing Design Activity*. New York: John Wiley & Sons, pp. 291-317.

CROSS, N. 2001. Design Cognition: Results of Protocol and Other Empirical Studies of Design Activity. In: EASTMAN, C., MCCRACKEN, W., NEWSTETTER, W. (eds.) *Design Knowing and Learning: Cognition in Design Education*. Amsterdam: Elsevier, pp. 79-103.

CROSS, N. 2006. *Designerly ways of knowing.* London, Springer.

CSIKSZENTMIHALYI, M., ROCHENBERG-HALTON, E. 1981. *The Meaning of Things: Domestic symbols and the Self,* Cambridge, Cambridge University Press.

DAMÁSIO, A. 1995. *O Erro de Descartes, Emoção, Razão e Cérebro Humano*, Mem Martins, Publicações Europa América.

DAMÁSIO, A. 2000. *O Sentimento de Si – o Corpo, a Emoção e a Neurobiologia da Consciência*, Mem Martins, Publicações Europa América.

DARKE, J. 1979. The primary generator and the design process. *Design Studies*, 1(1), pp. 36-44.

DASGUPTA, S. 1991. *Design Theory and Computer Science: Processes and Methodology of Computer Systems Design*, Cambridge, Cambridge University Press.

DAVIES, S. 1991. Characterizing the program design activity: neither strictly top-down nor globally opportunistic. *Behavioral Information Technologies* 10(3), pp. 173-190.

DERRIDA, J. 1976. *Of Grammatology*, USA, G.C. Spivak Johns Hopkins University Press.

DEWEY, J. 1934. *Art as Experience,* New York, Minton Balch.

DEWEY, J. 1948 (1st ed. 1920). *Reconstruction in philosophy*, Boston MA, Beacon Press.

DO, E., GROSS, M., NEIMAN, B., ZIMRING, C. 2000. Intentions in and relations among design drawings. *Design Studies*, 21(5), pp. 483-503.

DORMER, P. 1995 (1st ed. London, 1990). *Os significados do Design Moderno – a caminho do séc. XXI,* Lisboa, Centro Português de Design.

DORST, C., CROSS, N. 2001. Creativity in the design process: co-evolution of problem-solution. *Design Studies*, 22(5), pp. 425-437.

DORST, C. 2003. *Understanding Design*, Amsterdam, BIS Publishers.

DORST, C. 1995. Comparing the paradigms of design methodoldogy. *In*: HUBKA, V., (ed.) Proceedings of ICED 95, 1995, Zürich, Heurista.

DORST, K. 1997. *Describing Design: A Comparison of Paradigms,* Delft, The Netherlands, Delft University of Technology.

DORST, K., CROSS, N. 2001. Creativity in design process: Co-evolution of problem-solution. *Design Issues*, 22(5), pp. 425-437.

DORST, K. 2004. On the problem of design problems - problem solving and design expertise. *Journal of Design Research,* 4(2).

DOUGHERTY, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organization Science,* 3(2), pp. 179-202.

DOUGLAS, M., ISHERWOOD, B. 1979. *The World of Goods,* London, Allen Lane.

DOWNING, F. 2000. *Remembrance and the Design of Place*, College Station, Texas, A&M University Press.

DREYFUS, H. 1992. *What Computers still can't do,* Cambridge MA, MIT Press.

DREYFUS, H. 2003. Unpublished Notes from the Spinoza Lectures. University of Amsterdam.

DUMAINE, B. 1990. Who needs a boss? *Fortune*. Time Inc's Fortune/Money Group.

DUMAS, A., MINTZENBERG, H. 1989a. Managing design/ design management. *Design Management Journal*, 1(1), pp. 37-43.

DUMAS, A., WHITEFIELD, A. 1989b. Why design is difficult to manage: A survey of attitudes and practices in British industry *European Management Journal,* 7(1), pp. 50-56.

EASTMAN, C., MCCRACKEN, W. (EDS) 2002. Design knowing and learning: cognition in design education - Newsletter. *Design Studies*, 23(4), July 2002.

EASTMAN, C. M. 1970. On the analysis of intuitive design processes. *In:* MOORE, G. (ed.) *Emerging Methods in Environmental Design and Planning.* Cambridge MA, USA: MIT Press

EDER, W. 1998. Design modelling, a design science approach (and why does industry not use it?). *Journal of Engineering Design*, 9(4), pp. 355-371.

EREV, I., BORNSTEIN, G., GALILI, R. 1993. Constructive intergroup competition as a solution to the free rider problem: a field experiment. *Journal of Experimental Social Psychology,* 29, pp. 463-478.

ENDSLEY, M., HOFFMAN, R., KABER, D., ROTH, E. 2007. Cognitive engineering and decision making: an overview and future course. *Journal of Cognitive Engineering and Decision Making*, 1(1), pp. 1-21.

ENSICI, A., BAYAZIT, N., BADKE-SCHAUB, P., LAUCHE, K. 2008. Decision making in design teams: analysis of used and rejected decisions. *In:* MARJANOVIC, D., STORGA, M., PAVKOVIC, N., BOJCETIC, N. (eds.) Proceedings of the 10th International Design Conference 2008, Glasgow. Design Society, pp. 1121-1128.

ERICSSON, K., LEHMANN, A. 1996. Experts and exceptional performance: evidence on maximal adaptations on task constraints. *Annual Review of Psychology*, 47, pp. 273-305.

ERICSSON, K. 2005. Recent advances in expertise research: a commentary on the contributions to the special issue. *Applied Cognitive Psychology,* 19, pp. 233-241.

European Community. 2006. MEMO/06/190. http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/190&format=HTML&aged=0&language=EN&guiLanguage=fr (Accessed in May 2007).

FAUST, W. 2000. Building and fostering long-term client relationships. *Design Management Review,* 11(2), pp. 33-42.

FIDEL, R., GREEN, M. 2004. The many faces of accessibility. *Journal of Information Processing and Management*, 40(3), pp. 563-581.

FOOKS, J., RYAN, M., HAWKINS, L. 2000. *Professional Expertise: Practice, Theory and Education for Working in Uncertainty,* London, Whiting and Birch.

FORTY, A. 1986. *Objects of Desire. Design and Society Since 1750*, London, Thames and Hudson.

FRANKENBERGER, E., BADKE-SCHAUB, P. 1996. Modelling design processes in industry – empirical investigations of design work in practice. *In*: AKIN, Ö., SAGLAMER, G. (eds.) Proceedings of DMD'96, 1996, Istambul.

FREIRE, A. 1994. *Casos de Inovação de Sucesso*, Lisboa, Abril ControlJornal Editora.

FREIRE, A. 1997. *Estratégia – Sucesso em Portugal,* Lisboa, Editorial Verbo.

FRENCH, M. 1985. *Conceptual Design for Engineers,* London, UK, Design Council.

FROST, R. 1999. Why does industry ignore design science? *Journal of Engineering Design*, 10(4), pp. 301-304.

GABRIELSEN, G., GRØNHAUG, K., KAHL, L., KRISTENSEN, T., PLENBORG, T., WILKE, R. 2007. Is good design good business? Available: www.nhh.no/Admin/Public/DWSDownload.aspx?File...pdf.

GADAMER, H.-G. 1975. *Truth and Method*, London, Sheed and Ward.

GADAMER, H.-G. 1986. *The relevance of the beautiful and other essays*, Cambridge, Cambridge University Press.

GERO, J. S., KANNENGIESSER, U. 2006. A Function-Behaviour-Structure ontology of processes. *In*: GERO, J. (ed.) *A Function-Behaviour-Structure ontology of processes*. New York: Springer, pp. 407-422.

GIEDION, S. 1948. *Mechanization Takes Command,* New York Oxford University Press.

GIERKE, M., HANSEN, J., TURNER, R. 2002. Wise Counsil: a trinity of perspectives on the business value of design. *Design Management Journal,* 13(1), pp. 10-17.

GOEL, V., PIROLLI, P. 1992. The structure of design problem spaces. *Cognitive Science*, 16(3), pp. 395-429.

GOLDSCHMIDT, G. 1991. The dialects of sketching. *Creativity Research Journal*, 4(2), pp. 123-143.

GOLDSCHMIDT, G. 1996. The Designer as a team of one. *In:* CROSS, N., CHRISTIAANS, H., DORST, C. (eds.) *Analysing Design Activity*. New York: Wiley, pp. 65-92.

GOLDSCHMIDT, G. 2005. How good are good ideas? Correlates of design creativity. *Design Studies*, 26, pp. 593-611.

GOLDSCHMIDT, G., SMOLKOV, M. 2006. Variances in the impact of visual stimuli on design problem solving performance. *Design Studies*, 27, pp. 549-569.

GOLEMAN, D. 1996 (1st ed. 1970). *Emotional Intelligence,* London, Bloomsbury.

GOODMAN, N. 1984. *Of Mind and Other Matters,* Cambridge and London, Harvard University Press.

GOODMAN, N. n.d. *Ways of Worldmaking,* Indiana, Hackett Publishing Company.

GORB, P., DUMAS, A. 1987. Silent Design. 8(3), pp. 150-156.

GORB, P. 1990. *Design Management*, London, Architecture Design and Technology Press.

GREENBERG, E. 1992. Creativity, autonomy and evaluation of creative work: artistic workers in organizations. *Journal of Creative Behavior,* 26(2), pp. 75-80.

GREENE, J., CARACELLI, V., GRAHAM, W. 1989. Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis*, 11(3), pp. 255-274.

GREGORY, S. 1966. *The Design Method,* London, Butterworths.

GUINDON, R. 1990. Designing the design process: exploiting opportunistic thoughts. *Human Computer Interaction*, 5(2), pp. 305-344.

GUNTER, J., FRANKENBERGER, E., AUER, P. 1996. Investigation of Individual and team design processes. **In**: CROSS, N., CHRISTIAANS, H.,DORST, K. (eds.) *Analysing Design Activity*. New York: John Wiley & Sons, pp. 117-131.

GUNTHER, J., FRANKERBERGER, F., AUER, P. 1996. Investigation of individual and team design processes. *In:* CROSS, N. CHRISTIAANS, H., DORST, C. (eds.) *Analysing Design Activity.* New York: Wiley, pp. 117-132.

HAMMOND, J., KEENEY, J., RAIFFA, H. 1999. *Smart Choices: A Practical Guide to Making Better Decisions,* Boston, MA, Harvard Business School Press.

HAQUE, B., BELECHEANU, R., BARSON, R., PAWAR, K. 2000. Towards the application of case based reasoning to decision-making in concurrent product development (concurrent engineering). *Knowledge-Based Systems,* 13(2/3), pp. 101-112.

HARTSHORNE, C., WEISS, P. (eds.) 1958. *Collected papers of Charles Sanders Peirce*, Boston, Harvard University Press.

HAWKINS, D., BEST, R., CONEY, K. 1998. *Consumer Behavior – Building Marketing Strategy,* Boston, McGraw Hill.

HEIDEGGER, M. 1962. *Being and Time*, London, Basil Blackwell.

HEIN, L. 1994. Design methodology in practice. *Journal of Engineering Design*, 5(2), pp. 145-163.

HERRMAN, J. 2004. Decomposition in Product Development - Technical Report 2004-6. College Park: Institute for Systems Research, University of Maryland.

HERRMAN, J. W., SCHMIDT, L. C. 2002. Viewing product development as a decision production system. *In*: Proceedings of DETC 2002, ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September, 29 - October, 2, 2002, Montreal, Canada.

HERTENSTEIN, J., PLATT, M. 2000. Profiles of strategic alignment: the role of cost information in new product development. *Design Management Journal, Academic Review,* 1(1), pp. 8-24.

HERTENSTEIN, J., PLATT, M., BROWN, D. 2001. Valuing Design: enhancing corporate performance through design effectiveness. *Design Management Journal,* 12(3), pp. 10-19.

HERTZUM, M., PEJTERSEN, A. 2000. The information-seeking practices of engineers: searching for documents as well as for people. *Information Processing and Management*, 36(5), pp. 761-778.

HESKETT, J. 1993. I*ndustrial Design*, London, Thames and Hudson.

HILLIER, B., LEAMAN, A. 1974. How is design possible? . *Journal of Architecture and Planning Research*, 3(1), pp. 4-11.

HINRICHS, T. 1992. *Problem Solving in Open Worlds: a case study in Design* New Jersey, Lawrence Eribaum Associates, Inc. Publishers.

HONG, J-I, CHANG, N-K. 2004. Analysis of Korean High School Student's Decision-making processes in solving a problem involving biological knowledge, *Research in Science Education*, 34, pp97-111

HOFSTEDE, G. 2001. *Culture's Consequences: comparing values, behaviors, institutions, and organizations across nations* (2nd ed.), Thousand Oaks, CA, SAGE Publications.

HONGO, K., AMIRFAZLI, A. 1994. Design philosophy. *Journal of Engineering Design*, 5(2), pp.93-102.

HOWARD, T., CULLEY, S., DEKONINCK, E. 2008. Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, 29, pp. 160-180.

HUANG, G., MAK, K. 1999. Web-based collaborative design. *Journal of Engineering Design*, 10(2),pp.183-194.

HUITT, W. 1992. Problem solving and decision making: Consideration of individual differences using the Myers-Briggs Type Indicator. *Journal of Psychological Type*, 24, pp. 33-44.

JAMES, W. 1995 (1st ed. 1907). *Pragmatism*, New York, Dover.

JAY-HAK, C. 2008. National Design Competitivness Report 2008. Korean Institute of Design Promotion.

JEVNAKER, B. 2000. Championing design: perspectives on design capabilities. *Design Management Journal;* Academic Review, 1, pp. 25-39.

JEVNAKER, B. 2000b. How design becomes strategic. *Design Management Journal,* 11(1), pp. 41-47.

JIN, Y., CHUSILP, P. 2005. Study of mental iteration in different design situations. *Design Studies,* 27(1), pp. 25-55.

JOHNSON, D. 1992. *Approaches to Research in Second Language Learning*, New York, Longman.

JOHNSON, R., TURNER, L. 2003. Data collection strategies in mixed methods research. *In*: TASHAKKORI, A., TEDDLIE, C. (eds.) *Handbook of mixed methods in social and behavioral research Thousand Oaks*, CA: Sage, pp. 297-319.

JOHNSON, R., ONWUEGBUZIE, A. 2004. Mixed methods research: a research paradigm whose time has come. *Educational Researcher*, 33(7), pp. 14-26.

JONES, J. 1992 *Design Methods*, New York, John Wiley & Sons Inc.

JONSON, B. 2005. Design Ideation: the conceptual sketch in the digital age. *Design Studies,* 26(6), pp. 613-624.

JOSEPH, S. 1996. Design Systems and Paradigms. *Design Studies*, 17(3), pp. 227-239.

KATZENBACH, J., SMITH, D. 1993. *The Wisdom of Teams:Creating the High-Performance Organization*, Boston, Harvard Business School Press.

KELLER, K. 1998. *Strategic Brand Management,* Hemel Hempstead, Prentice-Hall.

KEPNER, C., TREGOE, B. 1965. *The Rational manager: a systematic approach to problem solving and decision making,* New York, McGraw-Hill.

KESTER, L., HULTINK, H., BADKE-SCHAUB, P., LAUCHE, K. 2007. Complex decision making in portfolio management: an exploratory study. *In*: MOSIER, K., FISCHER, U. (eds.) Proceedings of the 8th International Conference on Naturalistic Decision Making, NDM 8, San Francisco. San Francisco State University, pp. 1-7.

KESTER, L., HULTINK, H., LAUCHE, K., BADKE-SCHAUB, P. 2008. An exploratory study of the practices and challenges of portfolio decision making genres. *In:* KOLLER, H., HERSTATT, C., TEICHERT, T. (eds.) Proceedings of the 15th International Product Development Management Conference 2008, Brussels. EIASM, pp. 1-18.

KIM, M., KIM, Y. 2007. Perceived Creativity and Design Team interaction. *IASDR07*. The Hong Kong Polytechnic University. 12-15 November 2007.

KLEIN, G., CALDERWOOD, R., CLINTON-CIROCCO, A. 1986. Rapid decision making on the fire ground. *In:* Proceedings of the Human Factors Society, CA. Human Factors and Ergonomics Society, pp. 576-580.

KLEIN, G. 1989. Recognition-primed decisions. *In:* ROUSE, W. (ed.) *Advances in man-machine systems research*. Greenwich: JAI Press, pp. 47-92.

KLEIN, G. 1993. A recognition-primed decision (RPD) model of rapid decision making. *In*: KLEIN, G., ORASANU, J., CALDERWOOD, R., ZSAMBOK, C. (eds.) *Decision making in action: Models and methods Norwood*, NJ: Ablex, pp. 138-147.

KLEIN, G., ROSS, K., MOON, B., KLEIN, D., HOLLNAGEL, E. 2003. Macrocognition. IEEE *Intelligent Systems*, 18(3), pp. 81-85.

KLEIN, N. 2002. *No Logo,* Lisboa, Relógio d'Água Editores.

KLEINSMANN, M., VALKENBURG, R. 2008. Barriers and enablers for creating shared understanding in co-design projects. *Design Studies*, 29, pp. 369-386.

KOLODNER, J., WILLS, L. 1996. Powers of Observation in Creative Design. *Design Studies,* 17(4), pp. 385-416.

KOPEIKINA, L. 2005. *The Right Decision Every Time: How To Reach Perfect Clarity on Though Decisions*, Upper Saddle River, NJ, Prentice-Hall.

KOTLER, P., RATH, G. 1984. Design: a powerful but neglected strategic tool. *Journal of Business Strategy,* 5(2), pp. 16-21.

KOTLER, P. 2000. *Marketing Management - The Millenium Edition*, s.l., Prentice Hall.

KOTONYA, G., SUMMERVILLE, I. 1998. *Requirements Engineering Processes and Techniques,* Chichester, Wiley.

KREITNER, R., KINICKI, A. 2004. *Organizational Behavior,* New York, McGraw-Hill.

KRISTENSEN, T. 1998. The Contribution of Design to Business: A competence-based perspective. *In*: BRUCE, M., JEVNAKER, B. (eds.) *Management of Design Alliance. Sustaining Competitive Advantage*. Chichester: Wiley

KROES, P. 2002. Design Methodology and the Nature of Technical Artifacts. *Design Studies*, 23(3), pp. 287-302.

KUBLER, G. 1990. *A Forma do Tempo*, Lisboa, Vega.

KUHN, D. 2001. How do people Know? *Psychological Science*, 12 (1), pp. 1-8.

KUUSELA, H., PAUL, P. 2002. A comparison of concurrent and retrospective verbal protocol analysis. *The American Journal of Psychology, University of Illinois Press*, 113(3), pp. 387-404.

LAKOFF, G., JOHNSON, M. 1980. *Metaphors We Live,* Chicago, USA, University of Chicago Press.

LAUCHE, K., CARDOSO, C., BADKE-SCHAUB, P., ROOZENBURG, N. 2008. Ways to encourage reflection on design methodology and professional practice. *In*: CLARKE, A., EVATT, M., HOGARTH, P., LLOVERAS, J., PONS, L. (eds.) *New perspectives in design education* Courtleigh: IED, pp. 535-540.

LAUREL, B. 2003. *Design research, Methods & Perspectives*, Cambridge, The MIT Press.

LAWSON, B. 1979. Cognitive strategies in architectural design. *Ergonomics*, 22(1), pp. 59-68.

LAWSON, B. 1990. *How designers think: the design process demystified*. London, Butterworth.

LAWSON, B. 1994. *Design in mind*. Oxford, Architectural Press.

LELE, M., KARMAKAR, U. 1983. Good product support is smart marketing. *Harvard Business Review*, (83611).

LEVIN, P. 1966. *Decision Making in Urban Design - Building Research, Station Note EN51/66 Building Research Station*, Herts, UK, Garston.

LEWIS, A., SADOSKY, T., CONNOLY, T. 1975. *IEEE Transactions on Engineering Management,* pp.119-124.

LLOYD, P., SCOTT, P. 1994. Discovering the design problem. *Design Studies,* 15(2), pp. 125-140.

LOCOPOULOS, P., KARAKOSTAS, V. 1995. *System Requirements Engineering*, New York, McGraw-Hill.

LONGUEVILLE, B., LE CARDINAL, J., BOCQUET, J., DANEAU, P. 2003. Towards a project memory for innovative product design: a decision-making process model. *International Conference on Engineering Design* (ICED03). Stockholm.

LONGUEVILLE, B., LE CARDINAL, J., BOCQUET, J. 2007. La gestion des connaissances pour les projects de conception de produits innovants. *Journal of Design Research*, 6(1-2), pp. 169-189.

LOVE, T. 2005. A unified basis for design research and theory. International *Design Congress - IASDR 2005: New Design Paradigms*. Douliou, Taiwan: International Association of Societies of Design Research, Taiwan.

MAFFIN, D. 1998. Engineering design models: context, theory and practice. *Journal of Engineering Design*, 9(4), pp. 315-327.

MAIDEN, N., GIZIKIS, A. 2001. Where do requirements come from? *IEEE Software*, 16(5), pp. 10-12.

MAIDEN, N., GIZIKIS, A. 2004. Requirements and design are creative processes: Is it not time we understand creativity? *In*: HALE, A., KERWAN, B., KJELLEN, U. (eds.). Forthcoming.

MALAGA, R. 2000. The effect of stimulus modes and associative distance in individual creativity support systems *Design Support Systems,* 29, pp. 125-141.

MALDONADO, T. 1991 (1st ed. 1976). *Disegno Industriale:un riesame,* Milano, Feltrinelli.

MALLICK, D. 2000. The Design Strategy Framework. *Design Management Journal,* 11(3), pp. 66-73.

MANN, L., HARMONI, R., POWER, C. 1989. Adolescent Decision Making : The development of competence. *Journal of Adolescence*, 12 (3), pp. 265-278.

MARCH, L. 1976. The Logic of Design and the Question of Value. In: MARCH, L. (ed.) *The Architecture of Form.* Cambridge, UK: Cambridge University Press

MARGOLIN, V. 1989. *Design Discourse – History, Theory and Criticism*, Chicago, The University Press.

MARGOLIN, V., BUCHANAN, R. (eds.) 1995. *The Idea of Design*, Cambridge and London, The MIT Press.

MARGOLIN, V. 2002. *The Politics of the Artificial*, Chicago and London, The University of Chicago Press.

MARI, E. 2001. *Progetto e Passione,* Torino, Bollati Boringhieri.

MARPLES, D. 1960. *The Decisions of Engineering Design,* London, Institute of Engineering Designers.

MARSH, J., 1997. The Capture and Utilisation of Experience in Engineering Design, PhD Thesis, Cambridge University.

MASON, P. 1982. Recent trends in design education. *Design Studies*, 3(4), pp. 169-191.

MASSIRONI, M. 1982. *Ver pelo Desenho, aspectos técnicos, cognitivos, comunicativos*., Lisboa, Edições 70.

MAYER, R. 1992. *Thinking, Problem Solving and Cognition* New York, W.H. Freeman and Company.

MEIJERS, A. 2000. The relational ontology of technical artifacts. *In*: KROES, P., MEIJERS, A. (eds.) *The Empirical Turn in the Philosophy of Technology*. Oxford: Elsevier Science

MERLEAU-PONTY, M. 1992. *Phenomonology of Perception*, London, Routledge.

MICHEL, L. 2007. Understanding decision making in organizations to focus its practices where it matters. *Measuring Business Excellence*, 11(1), pp. 33-45.

MITCHELL, T. 1996. *New Thinking in Design – Conversations on Theory and Practice*, New York, Van Nostrand Reinhold.

MOLES, A. 1972. *Semiologia dos Objectos,* Petrópolis, Editora Vozes.

MOODY, S. 1984. The Role of Industrial Design in the Development of New Science based Products. *In*: LANGDON, R. (ed.) *Design and Industry*. London: The Design Council

MORROW, D., MILLER, L., RIDOLFO,. H., KELLY, R., FISHER, U., STINE-MORROW, E. 2003. The influence of pilot expertise on comprehension and decision making. *12th International Symposium on Aviation Psycology*. Dayton,pp. 1-4.

MURTY, P., PURCELL, T. 2007. Designerly, reflective and insightful ways of designing. *IASDR07 Emerging Trends in Design Research*. Hong Kong: The Hong Kong Polytechnic University.

NELSON, B., YEN, J., ROSEN, D. 2009. Refined metrics for measuring ideation effectiveness. *Design Studies,* 30(6), pp. 737-743.

NEVADO, P., BARATA, J., ALMENDRA, R., ROMÃO, L. 2008. The "Igloo Model": A proposal for an analysis of the contribution of design to the competitiveness of companies. *ICAM - 15th Annual International Conference on Advances in Management*. Hyatt Harborside Hotel,Boston. July 16-19, 2008, pp.1-12.

NEWELL, A., SIMON, A. 1972. *Human Problem Solving,* New York, Prentice-Hall.

NGUYEN, L., SWATMAN, P. 2003. Managing the requirements engineering process. *Requirements Engineering*, 8(1), pp. 55-68.

NICHOLLS, K. 1990. Engineering changes under control. *Journal of Engineering Design*, 1(1), pp. 5-15.

NIEMINEN, T., LAUTAMAKI, S., SALIMAKI, M. 2005. Modelling the Strategic Impacts of Design in Businesses. Helsinki: UIAH/Designium.

NUTTGENS, P. 1977. *Learning to Some Purpose,* London, SIAD.

OAKLEY, M. 1990. *Design Management – a Handbook of Issues and Methods*, Oxford/Cambridge, Blackwell Reference.

OLSON, E. 1997. Design equity: a corporate perspective. *Design Management Journal*, 8(2), pp. 78-83

OLSON, E. 2000. Managing design for competitive advantage: a process approach. *Design Management Journal,* 11(4), pp. 10-17.

ONWUEGBUZIE, A., LEECH, N. 2004. Enhancing the interpretation of significant findings: The role of mixed methods research. *Annual meeting of the Eastern Educational Research Association*. Clearwater.

OWENS, D. 2000. Structure and status in design teams: implications for design management. *Design Management Journal, Academic Review*, 1(1), pp. 55-64.

OXMAN, R. 1999. Educating the Designerly Thinker. *Design Studies*, 20(2), pp. 105-122.

OXMAN, R. 2004. Think-maps: teaching design thinking in design education. *Design Studies,* 25(1), pp. 63-91.

PAHL, G., BEITZ, W. 1984. *Engineering Design,* London, The Design Council.

PATEL, V, AROCHA, J., 2001. The nature of constraints on collaborative decision-making in health care settings. In SALAS, E., KLEIN G. (Eds.), *Linking expertise and naturalistic decision making.* Mahwah, NJ, Erlbaum.

PAUL, J. 2000. Performance Metrics to Measure the Value of Design. *Design Management Journal*, 11(4), pp. 71-75.

PERKINS, D. 1986. *Knowledge as Design,* Hillsdale, NJ, Erbaum.

PETERS, T. 2000. Design as Advantage Nº I: The Design + Identity 50. *Design Management Journal*, 11(1), pp. 10-17.

POHL, K. 1994. Three dimensions of Requirements Engineering: Framework and its applications. *Information Systems*, 19(3), pp. 243-258.

POLANYI, M. 1983 (1st ed. 1966). *The Tacit Dimension,* Gloucester Peter Smith, Mass.

POLYA, G. 1957. *How to solve it: a new aspect of mathematical method*, Princeton NJ, Princeton University Press.

POPOVIC, V. 1996. Design activities structural categories. *In*: CROSS, N., CHRISTIAANS, H., DORST, K. (eds.) *Analysing Design Activity*. New York: John Wiley & Sons, pp. 211-220.

POPPER, K. 1994. *Knowledge and The Body-Mind Problem: In Defense of Interaction,* London and New York, Routledge.

POPPER, K. 1994. *The Myth Of The Framework: In Defense of Science and Rationality,* London and New York, Routledge.

POTTER, S., ROY, R., CAPON, C., BRUCE, M., WALSH, V., LEWIS, J. 1991. The Benefits and Costs of Investment in design: using professional design expertise in product, engineering and graphics projects. Design Innovation Group, Milton Keynes: The Open University and UMIST.

PRATS, M., LIM, S., JOWERS, I., GAMER, S., CHASE, S. 2009. Transforming shape in design: observations from studies of sketching. *Design Studies*, 30(5), pp. 503-520.

PRESS, M., COOPER, R. 2003. *The Design Experience – the Role of Design and Designers in the Twenty-first Century,* UK, Ashgate.

PUGH, S. 1991. *Total Design: Integrated Methods for Successful product Engineering*, Wokingham, Addission-Wesley.

PYE, D. 1978. *The nature and Aesthetics of Design,* London, Barry and Jenkins.

QIU, Y.-F., CHUI, Y-P., HELANDER, M. 2007. A cognitive approach to understanding knowledge-based virtual team decision making in product design. *International Journal of Intelligent Enterprise*, 1(1), pp. 45-64.

REHMAN, F., YAN, X. 2007. Supporting early design decision-making using design context knowledge. *Journal of Design Research,* 6(1-2), pp. 169-189.

REINERTSEN, D. 1997. *Managing the Design Factory: A Product Developer's Toolkit*, New York, Free Press.

REITMAN, W. 1964. Heuristic decision procedures, open constraints and the structure of ill-defined problems. *In*: SHELLY, M., BRYAN, G. (eds.) *Human Judgments and Optimality*. New York: Wiley

RESTREPO, J., GREEN, W., CHRISTIAANS, H. Structuring design problems: strategies, hindrances and consequences to design education. *International Journal of Technology and Design Education*.

RESTREPO, J., RODRÍGUEZ, A., CHRISTIAANS, H. 2000. The Finality Argument on Design Methods: A Theoretical Approach From the Social Sciences *In*: PIZZOCARO et al (eds.) *Design Plus Research* Milano: Politecnico di Milano, pp. 109-115.

RESTREPO, J., CHRISTIAANS, H. 2003. Design Requirements: Conditioners or Conditioned? *ICED03 - International Conference on Engineering Design*. Stockholm.

RESTREPO, J., CHRISTIAANS, H. 2003. Problem Structuring and Information Access in Design. *Paper accepted for the Design Thinking Research Symposium 6: 'Expertise in design'.* Australia.

RESTREPO, J. 2004. *Information Processing in Conceptual Design. Design Science Planning*, Delft, The Netherlands, Delft University Press.

RHEA, D. 1992. A new perspective on design: focusing on customer experience. *Design Management Journal,* 9(4), pp. 10-16.

RIEDEL, J., ROY, R., POTTER, S. 1996. Market Demands that Reward Investment in Design. 8*th International Forum on Design Management Research and Education*. Barcelona.

RITCHEY, T. 2007. Wicked Problems: Structuring Social Messes with Morphological Analysis. *Swedish Morphological Society* [Online]. Available: http://www.swemorph.com/wp.html [Accessed 24 November 2007].

RITTEL, H., WEBBER, M. 1973. Dilemmas in a general theory of planning. *Policy Science*, 4, pp. 155-169.

RITTEL, H., WEBBER, M. 1973. Dilemmas in a General Theory of Planning. *In*: CROSS, N. (ed.) *Developments in Design Methodology.* Chichester: J. Wiley & Sons, pp. 135-144.

ROBERTSON, S., ROBERTSON, J. 1999. *Mastering the Requirements Engineering Process,* London, Addison-Wesley.

RODGERS, P., GREEN, G., MCGOWN, A. 2001. Using concept sketches to track design progress. *Design Studies*, 21(5), pp. 451-464.

ROMÃO, L., ALMENDRA, R., DIAS, E.; BARATA, J., NEVADO, P., URBANO, P., MARCELINO, J., DIAS, J., GOMES, F. 2007. An online survey's design to capture Portuguese companies' perspective of Design. *In*: Proceedings of the 2007 Conference of Defsa International Design Education, Cape Town.

ROOZENBURG, N., CROSS, N. 1991. Models of the design process - integrating across the disciplines. *In*: HUBKA, V. (ed.) Proceedings of ICED 91, 1991 Zürich. Heurista.

ROOZENBURG, N. 1993. On the pattern of reasoning in innovative design. *Design Studies*, 14(1), pp. 4-18.

ROOZENBURG, N., EEKELS, J. 1995. *Product Design: Fundamentals and Methods,* Chichester, John Wiley & Sons, Inc.

ROSS, J. 1981. Improving adolescent decision making skills. *Curriculum Inquiry*, 11, pp. 279-295.

ROTHROCK, L., YIN, J. 2008. Integrating Compensatory and Noncompensatory Decision-Making Strategies in Dynamic Task Environments. *In*: KUGLER, T., SMITH, J., CONNOLLY, T., SON, Y-J. (eds.) *Decision Modeling and Behavior in Complex and Uncertain Environments*. New York: Springer,Part II, pp. 125-141.

ROWE, P. 1998. *Design Thinking*, Cambridge and London, The MIT Press.

ROY, R., SALAMAN, G., WALSH, V. 1986. Research Grant Final Report, Design-based Innovation in manufacturing Industry. Principles and Practices for Successful Design and Production. Milton Keynes: Design Innovation Group, Open University.

ROY, R., POTTER, S. 1993. The commercial impact of investment in design. *Design Studies*, 14(2), pp. 171-193.

ROY, R., RIEDEL, J., POTTER, S. 1998. Market Demands that Reward Investment in Design (MADRID): Final Report submitted to the Design Council. Design Innovation Group, Milton Keynes: The Open University.

SARMA, V. 1994. Decision Making in Complex Systems. *Systems Practice*, 7(4), pp. 399-407.

SCHÖN, D. 1983. *The Reflective Practitioner: How Professionals Think in Action*, New York, Basic Books.

SCHÖN, D. 1987. *Educating the Reflective Practitioner,* San Francisco, Jossey-Bass – A Wiley Imprint.

SELLE, G. 1975. *Ideologia e Utopia del Diseño*, Barcelona, Gustavo Gili.

SENTENCE, A., CLARKE, J. 1997. The Contribution of Design to the UK Economy. *In*: Design Council (ed.). London: Centre for Economic Forecasting, London Business School.

SHAH, J., VARGAS-HERNANDEZ, N., SUMMERS, N., KULKARNI, S. 2001. Collaborative sketching as an idea generation technique for engineering design. *Journal of Creative Behavior,* 35, pp. 169-198.

SIMON, H. 1973. The ill structure of ill-structured problems. *Artificial Intelligence*, 4, pp. 181-204.

SIMON, H. 1996. *Sciences of the Artificial*, Cambridge, The MIT Press.

SIMON, H., DANTZIG, G., HOGARTH, R., PIOTT,C., RAIFFA, H., SCHELLING, T., SHEPSLE, K., THAIER, R., TVERSKY, A., WINTER, S. 1986. Report on the Research Briefing Pannel on Decision Making and Problem Solving. Washington DC: National Academy of Sciences.

SNODGRASS, A., COYNE, R. 1997. Is Designing hermeneutical? *Architectural Theory Review, Journal of the Department of Architecture*, 2 (1), 65-97.

SNOEK, H., HEKKERT, P. 1999. Directing designers towards innovative solutions. In: JERRARD, B., NEWPORT, R., TRUEMAN, M. (eds.) *Managing new product innovation.* London: Taylor & Francis,pp. 167-180.

SOLOVYOVA, I. 2003. Conjecture and Emotion: An Investigation of the Relationship Between Design Thinking and Emotional Content. *DTRS6 - Design Thinking Research Symposium 6, Creativity and Cognition Studios.* Sidney, Australia: University of Technology.

STOLL, H. 1999. *Product Design Methods and Practices,* New York, Marcel Dekker, Inc.

STOMPFF, G. 2003. The forgotten Bond: Brand Identity and Product Design. *Design Management Journal,* 14(1), pp. 26-32.

SUCHMAN, L. 1987. *Plans and situated actions,* Cambridge, Cambridge University Press.

SUWA, M., TVERSKY, B. 1997. What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4), pp. 385-403.

SUWA, M., GERO, J., PURCELL, T. 2000. Unexpected discoveries and S-invention of design requirements: important vehicles for a design process. *Design Studies,* 21(6), pp. 539-567.

SVENGREN, L. 1995. Industrial Design as a Strategic Resource. *In*: The European Academy of Design, 11-13 April 1995, University of Salford.

TAYLOR, P., RICHARDSON, J., YEO, A., MARSH, I., TROBE, K., PILKINGTON, A. 1995. *Sociology in focus*, Ormskirk, Causeway Press.

THOMAS, J. 1978. A design interpretation analysis of natural English with applications to man-computer interaction. *International Journal of Man-Machine Studies,* 10(6), pp. 651-668.

THOMAS, J., CARROLL, J. 1979. The psychological study of design. *Design Studies,* 1(1), pp. 5-11.

TOPALIAN, A. 2002. Promoting Design Leadership through Skills Development Programs. *Design Management Journal,* 13(3)

TOVEY, M., PORTER, S., NEWMAN, R. 2003. Sketching, concept development and automotive design. *Design Studies*, 24(2), pp. 135-153.

TURNER, R., TOPALIAN, A. 2002. Core of Responsibilities of Design Leaders in Commercially Demanding Environments. *Design Leadership Forum (Inaugural session)*. London: Alto Design Management.

ULLMAN, D., DIETTRICH, T., STAUFFER, L. 1988. A model of the mechanical engineering process based on empirical data. *AI EDAM,* 2(1), pp.33-52.

URBAN, G., HAUSER, J. 1993. *Design and Marketing of New Products*, New Jersey, Prentice Hall.

UTTERBACH, J. ALVAREZ, E. EKMAN, S. SANDERSON, S. TETHER, B. VERGANTI, R. 2006. Chapter one: What makes products great? In UTTERBACH, J. (ED.) Design Inspired Innovation. Singapore, World Scientific Publishing Co. Pte. Ltd.

VALKENBURG, R. 2000. The Reflective Practice in Product Design Teams. TU Delft, Faculty of Industrial Design Engineering.

VAN DER LUGT, R. 2001. Sketching in design idea generation meetings. TU Delft, Faculty of Industrial Design Engineering.

VAN MANEN, M. 1990. *Researching lived experience,* Ontario, The Althouse Press.

VARELA, F., THOMPSON, E., ROSCH, E. 1991. *The Embodied Mind*, Cambridge MA, The MIT Press.

VERMAAS, P., DORST, K. 2007. On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology. *Design Studies,* 28(2), pp. 133-157.

VISSER, W. 1988. Giving up a Hierarchical Plan in a Design Activity. Rocquencourt, France: Institut National de Recherche en Informatique et en Automatique.

VISSER, W. 1992. Designers' activities reviewed at three levels: organization, strategies and problem-solving processes. *Knowledge Based Systems* 5(1), pp. 92-104.

VISSER, W. 2006. *The Cognitive Artifact of Designing* Mahwah, NJ, Lawrence Erlbaum Associates.

VISSER, W. 2009. Design: one, but in different forms. *Design Studies*, 30(3), pp. 187-223.

VON STAMM, B. 2003. *Managing Innovation, Design & Creativity*, England, Wiley.

WALKER, J., CHAPLIN, S. 1997. *Visual Culture: An Introduction*, Manchester, Manchester University Press.

WALSH, V., ROY, R., BRUCE, M., POTTER, S. 1992. *Winning by Design, Technology, product Design and International Competitiveness*, Oxford, Blackwell Business.

WALSH, V. 1995. The evaluation of design. *International Journal of Technology Management,* 10(4/5/6), pp. 489-509.

WALSH, V. 2000. Design, Innovation and the Boundaries of the Firm. *Design Management Journal, Academic Review*, pp. 174-92.

WALTON, M. 2003. Building a case for added value though design. R*eport to Industry New Zealand.* Wellington: NZ Institute of Economic Research (Inc.).

WALTON, T. 2000. Design management as a business and academic discipline. *Design Management Journal, Academic Review*, 1, pp. 5-8.

WALTON, T. 2002. Exploring the Fundamental Relationship between Design and Good Business. *Design Management Journal*, 13(1), pp. 6-9.

WARD, T., SMITH, S., FINKE, R. 1999. Creative Cognition. In: STENBERG, R. (ed.) *Handbook of Creativity*. Cambridge: Cambridge University Press

WEISS, L. 2002. Developing Tangible Strategies. *Design Management Journal*, 13(1), pp. 33-38.

WILLIAMS, T., SCHAAF, W., BURNETTE, A. 1999. *A History of Invention: From Stone Axes to Silicon Chips,* London, Litlle, Brown and Company.

WINOGRAD, T., FLORES, F. 1986. *Understanding computers and cognition*, Norwood New Jersey, Ablex.

WINOGRAD, T., FLORES, F. 1996. *Computers and Cognition. A New Foundation for Design,* Norwood, New Jersey, Ablex.

YATES, J., VEINOTT, E., PATALAN, A. 2002. Hard Decisions, Bad Decisions: on Decision Quality and Decision Aiding. *In*: SCHNEIDER, S., SHANTEAU, J. (eds.) *Emerging Perspectives on Judgment and Decision Research.* Boston, MA: Cambridge University Press

APPENDIX A

GLOSSARY

Constructionism - Constructionist learning is inspired by the constructivist theory were individual learners construct mental models to understand the world around them. Nevertheless, constructionism grasps that learning can happen most effectively when people are also active in making tangible objects in the real world. Being so, constructionism is related with experiential learning and builds on some of the ideas of Jean Piaget.

Constructivism - Constructivism is a psychological theory of knowledge (epistemology) which argues that humans generate knowledge and meaning from their experiences. Constructivism is not a specific pedagogy, even though it is frequently confused with constructionism, an educational theory developed by Seymour Papert.

Declarative knowledge - Declarative knowledge is knowing “that” (e.g., that Lisbon is the capital of Portugal), as contrasting to procedural knowledge is knowing “how” (e.g., how to cycle a bicycle). Declarative knowledge is further divided into: a) Episodic knowledge: memory for “episodes” (i.e., the context of where, when, who with etc); usually measured by accuracy measures, as autobiographical reference. b) Semantic knowledge: Memory for knowledge of the world, facts, meaning of words, etc. (e.g., knowing that the first month of the year is April (alphabetically) but January (chronologically).

Heuristic - from the Greek “Ε□ρίσκω” for “find” or “discover”) is an adjective for experience-based techniques that help in problem solving, learning and discovery. A heuristic method is particularly used to rapidly come to a solution that is hoped to be close to the best possible answer, or ‘optimal solution’. Heuristics are “rules of thumb”, educated guesses, intuitive judgments or simply common sense. In more precise terms, heuristics stand for strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines.

Intuition - is the apparent ability to acquire knowledge without inference or the use of reason. “The word ‘intuition’ comes from the Latin word ‘*intuerl*, which is often roughly translated as meaning 'to look inside' or 'to contemplate'." Intuition provides us with beliefs that we cannot necessarily justify. Intuition is one of Swiss psychologist Carl Jung's four 'psychological types' or ego functions. In this early model of the personal psyche, intuition was opposed by sensation on one axis, while feeling was opposed by thinking on another axis. Jung argued that, in a given individual, one of these four functions was primary — most prominent or developed — in the consciousness. The opposing function would typically be underdeveloped in that individual. The remaining pair (on the other axis) would be consciously active, but to a lesser extent than the primary function. This schema is perhaps most familiar today as the Myers-Briggs Type Indicator.

Phenomenology - "Phenomenology" comes from the Greek words *phainómenon*, meaning "that which appears", and *lógos*, meaning "study". In Husserl's conception, phenomenology is primarily concerned with making the structures of consciousness, and the phenomena which appear in acts of consciousness, objects of systematic reflection and analysis. Such reflection was to take place from a highly modified "first person" viewpoint, studying phenomena not as they appear to "my" consciousness, but to any consciousness whatsoever. Husserl believed that phenomenology could thus provide a firm basis for all human knowledge, including scientific knowledge, and could establish philosophy as a "rigorous science". Husserl's conception of phenomenology has been criticised and developed not only by himself, but also by his student Martin Heidegger, by existentialists, such as Maurice Merleau-Ponty, Jean-Paul Sartre, and by other philosophers, such as Paul Ricoeur, Emmanuel Levinas, and Alfred Schütz. (Wikipedia)

Positivist epistemology - Rests on three dichotomies. First, the separation of means from ends, since instrumental problem solving is seen as a technical procedure to be measured by its effectiveness in achieving a pre-established objective. Second, the separation of research from practice: Practice as application to problems of research based theories, verified via controlled experiments. Third, the separation of knowing from doing, action is only an implementation and test of technical decision.

Pragmatism - is a philosophical movement that includes those who claim that an ideology or proposition is true if it works satisfactorily, that the meaning of a proposition is to be found in the practical consequences of accepting it, and that unpractical ideas are to be rejected. (Wikipedia definition)

Qualitative data - is descriptive data from observation or unstructured interviews (Taylor et al., 1995 p632)[53].

Quantitative data - is data in numerical form, often derived from questionnaires or structured interviews.

Creativity criteria – the extent to which the concept presents something partly or wholly novel either in material, formal, technical , constructive, or use terms;

Decision Making Process criteria – the adequacy of decisions that are taken along the process resulting in consistent moves towards a coherent solution (s)

Ease of Installation and Maintenance criteria - Allows a friendly installation and maintenance without the use of special tools and / or specific technical training.

Energy Efficiency criteria - Degree to which the Project makes a rational and efficient use of the total energy used for its operation.

Feasibility criteria –The extent to which the design can be achieved or put into effect, the degree in which the design is doable.

Overall Quality criteria - Overall judgement of the designing.

Production costs criteria - Suitability between production costs and the value perceived by the market.

Prototypicality criteria – the extent to which the design is prototypical for its class of products. What Purcell (1984) named goodness of example and refers to the referent you have for a category of objects regardless your judgement if it is a good or bad example of a category; If you feel that the concept is the best example

53. Taylor, P., Richardson, J., Yeo, A., Marsh, I., Trobe, K. and A. Pilkington (1995). Sociology in focus. Ormskirk, Causeway Press.

of your image of a litter-disposal system you will use 10 to grade it; if you feel that it is the worst example you should use 1.

Quality of the communicative interaction criteria - the potential to visually and verbally stimulate intervention so as to guarantee the total understanding of the ideas, contexts, concepts and technical solutions which make up the product design.

Reflection-in-action (Schön) - Comprehensive conversation with the materials of a situation that allows to reshaping during the working process.

Reflection-on-action (Schön) - "Lessons learned," reflection on tacit understandings and assumptions to achieve deeper understanding motivations and behaviours.

Strategic adequacy criteria – the extent to which the concept integrates and aligns the formal, technical and constructive aspects with business aspects i.e. the extent to which the product is able to assume a correct market positioning, contributing for brand consolidation and company's reputation.

Tacit Knowledge - is a term coined by Michael Polyani that identifyes a pre-logical phase of knowing as Tacit knowledge comprises a range of conceptual and sensory information and images that can be brought to bear in an attempt to make sense of something.

Technical rationality (TR) - Professional activity consists of instrumental problem solving activity made rigorous by the application of scientific theory and techniques.