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The designer's perception and expert's evaluation: testing techniques for problem exploration on a design methodology framework

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Recife, February 2012

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This dissertation has been submitted to the Communication and Arts Center of the Federal University of Pernambuco as a partial requirement to obtain the degree of Master in Design.

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LUIS ARTHUR LEITE VASCONCELOS

"The Designer's Perception and Expert's Evaluation"

ÁREA DE CONCENTRAÇÃO: DESIGN E ERGONOMIA

A comissão examinadora, composta pelos professores abaixo, sob a presidência do primeiro, considera a candidata Luis Arthur Leite Vasconcelos APROVADO.

Recife, 28 de fevereiro de 2012.

Prof. Fábio Ferreira da Costa Campos (UFPE)

Prof. Walter Franklin Marques Correia (UFPE)

Prof. Marcos Galindo Lima (UFPE)

For the places I’ve visited, landscapes seen, experiences lived,
and the fantastic people I’ve met due to these experiences –
although it might not be much, I know,
I’m quite grateful for what I’ve already had.

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"Aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaahhhhhhhhhhhhhhhhhhh!!!!!"

Frank Dux (Jean-Claude Van Damme), right after
realizing he is sightless and minutes before overcoming
the most difficult challenge ever confronted,
in his complete blindness.

ABSTRACT

Understanding methodology in design as a schematized process composed by a set of steps in order to support problem solving, data mining or search for information activities are commonly performed on an initial step of this process, which can be called as problem exploration. This work focuses on identifying the influences that executing the problem exploration step can cause to the design team, as well to the final developed solutions. To achieve this objective, an initial investigation was performed in order to search for similar studies that could test these influences. After confirming the absence of such researches, an experiment was conducted to test techniques for problem exploration as a way to identify the possible influences of this step within the design process. The experiment was carried out in an undergraduate design class during four months and involved five groups of about six members each, who should develop concepts for problems about they did not have any previous information. Except for the problem exploration step, which could be performed differently, the five groups executed an identical framework of methods for problem solving. All documentation produced by the design teams was evaluated for a selected group of experts. As results for the experiment, it was concluded that the use of such problem exploration techniques gave more confidence to designers when responding to how well-informed they were about the problem after confronting it, and although different groups performed distinct procedures as regards the tested step, no difference on the experts' evaluation for the alternatives could be perceived. This way utilizing problem exploration techniques caused no influences on the final solutions developed.

Keywords: design methodology, design process, problem exploration, data collection.

RESUMO

Compreendendo metodologia em design como um processo esquematizado composto por um grupo de etapas que auxiliam na solução de problemas, as atividades de levantamento de dados ou busca por informações ocorrem normalmente em uma etapa inicial do processo, podendo esta fase ser chamada de exploração do problema. Este trabalho objetiva identificar diferentes efeitos que executar esta fase exploratória pode causar na percepção dos designers, bem como nas soluções finais por eles geradas. Para tal, uma investigação inicial foi realizada para identificar estudos semelhantes que pudessem testar tais efeitos. Uma vez confirmada a inexistência de pesquisas neste sentido, um experimento foi conduzido para identificar as influências da etapa de exploração do problema no processo de design. O experimento ocorreu durante aulas de graduação de um curso de design durante quatro meses, no qual cinco grupos, de cerca de seis membros cada, participaram do processo. Os grupos desenvolveram conceitos para problemas sobre os quais nenhum conhecimento prévio existia. Exceto pela etapa de exploração do problema – que apresentou três possíveis variações de execução – os grupos seguiram uma metodologia idêntica. Ao final, toda documentação produzida pelos grupos foi analisada por avaliadores (experts). As conclusões obtidas apontam para a influência positiva do uso de técnicas de exploração do problema para a confiança da equipe de design, porém tais técnicas se mostraram irrelevantes quanto à avaliação realizada pelos experts, causando assim nenhuma diferença às soluções finais desenvolvidas.

Palavras-chave: metodologia de design, processo de design, exploração do problema, levantamento de dados.

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1. INTRODUCTION

In recent years, the methodology subject as part of the core theory in design gained more importance, establishing itself as a strategic and proprietary area for design research and development (Dechamps & Naya, 1997). Usually, research in this field aims to improve, adopt or create methods for being included in methodological frameworks in order to formalize a structured way for problem solving or generating products.

The methodological models generally define main steps for these frameworks, which can differ among many authors. For instance, Bruno Munari (1998) describes the design process starting from a "problem definition" step, leading to subtasks such as data collection and analysis. Likewise, Bernd Löbach (2001) synthetizes this process into four phases, which comprehends the problem analysis or data collection, generation of alternatives, evaluation of alternatives, and building of the problem solution itself.

Bernhard Bürdek (2006) and Gui Bonsiepe (1984) formalized different structures in which the problem is stated in many of the starting steps of the entire project, defining even more subtasks for dealing with the problem, which represents the importance that doing research and collecting information about the problem might have.

This investigation has its focus on this search for the information inserted on the first stages of the design process. It supports the idea that techniques composing the initial steps of these methodological frameworks – therefore synthetized in this work as the "problem exploration" step – will impact positively on both designers' confidence and their final solutions when put to good use during the design process.

Although there is strong bibliographical support that defends the use of this group of techniques (Bonsiepe et al, 1984; Bruno Munari, 1998; Morris Asimow, 1968; Christopher Jones, 1992; Bernd Löbach, 2001; Neves et al, 2008), it is not guaranteed that different teams, which did not go through this step, would not present the same quality of results or maybe even better solutions than those who went through a structured framework of techniques for problem exploration.

This way the present work aims to deal with this question by doing academic experiments on this field of study and intends to gather scientific evidence that could prove the advantage or possible influences of "following the rules", which is to adopt a methodological framework for problem solving.

1.1 Research Problem

Inserted in the theory of design that deals with the use of methods into the design process, this work focuses on the problem exploration step and its techniques. It deals with the influence this stage can cause on both designers' perception of what they might know about the problem investigated and evaluation for the alternatives they create.

Does the utilization of explicit techniques for exploring the problem during the design process increase designers' perception of the amount of information they might have about such problem? In addition, does this use actually present significant advantages for the final solution when compared with their non-use or the indiscriminate use of *ad hoc* techniques? What are the impacts of using explicit techniques for exploring the problem during the design process?

1.2 Research Hypotheses

This work is based on two hypotheses.

The first defends the idea that distinct design teams, when following three specific procedures, would respond differently if inquired regarding their perception about the knowledge they have over the problem being investigated. More precisely, groups executing a detailed methodology for problem exploration should be more expert on the problem – or at least more confident – after confronting it than those who executed a random procedure for exploring the problem, and even more than those who skipped the problem exploration step.

The second hypothesis advocates that – for a specific scenario – using well-structured techniques during the initial step of exploring and coming up with information about the problem brings perceptible benefits when evaluating the final results, which are generated alternatives.

1.3 Objectives

The general objective of this investigation is bringing to light the influence of using techniques for problem exploration on:

- the confidence or impression designers may have on how well-informed they are about the problem under investigation; and
- the experts' evaluation for the alternatives generated by these designers.

This objective can be achieved by verifying and testing the first step of the methodological process in design – the problem exploration stage – supported by an experiment for collecting data which makes possible comparisons or reveals gains and distinctions coming from the use of structured techniques for problem exploration when compared to not using these techniques.

This way, it is intended to discuss and call into question the importance of using well-structured techniques for projects guided by design methodology.

1.4 Justification

Design literature defends the importance of using methods throughout the design process. Likewise, the "problem exploration" or "search for information" step of a methodological framework in design involves a group of techniques that should be equally defended. Although, with respect to the design team, as well as the final solution developed, the investigation on the influences of following the rules and proceeding according to a methodology is still a nebulous issue.

In addition to it and as commented previously, the present work deals with an old subject of design history that followed the research and development in design theory up to this date, and is still gaining more importance and recognition in other science fields.

As Bürdek (2006) once stated, by discussing methodology the design could be teachable, learnable and thus communicable for the first time, and still today the importance of studying these processes is clear for contributing to the logical and systematic thinking in design.

This way, by investigating the design process and verifying and testing steps that compose it, is to contribute not only to the academic and scientific research but also for the use of design methods in several sectors of industry or to the professional practice of designing. In addition to it, this research will possibly confirm or deny, even for a specific scenario, the main stream of design theory as regards the importance of using design methods.

1.5 General Structure

This document is organized as follows.

The chapter of literature review (2) aims to present the main concepts of this work, as well as all the design theory necessary to understand the applied experiment. The first part of it will discuss the design methodology and the issue of its possible lack of verification and testing. Still in this chapter, theory about techniques for problem exploration, generation of alternatives, and selection of alternatives will be presented.

The next chapter (3) defines the methodology applied for the second part of this work and it details the experiment thoroughly. The following chapter (4) exposes the results and findings of the experimental procedure and discusses its outcomes. Finally, the last chapter (5) presents the conclusions of this investigation, as well as possible future work. In the end of this document it is possible to access the bibliography of this work.

2. LITERATURE REVIEW

This chapter aims to present the necessary design theory for the understanding of the experiment and its results. Initially, the design methodology will be discussed through a holistic view, in order to provide fundamental bases for what is the process of design and the steps it encompasses.

Then, there is an early investigation on the design research scenario, in order to search for related work with respect to verification or testing for design methodology. This investigation, presented in section 2.2.2., shows itself necessary in a second moment for justifying the experiment that will be conducted and described afterwards.

Once the first theory cluster is discussed – an overview of methodology in design –, the literature review gets to the smaller steps of the design methodology framework. It focuses on three main steps of the whole process, which are required subjects for the experiment to be performed, as well as for this work itself: techniques for problem exploration, which is, in fact, the core theory of this work; and techniques for generation and selection of alternatives, for the understanding of the experiment procedures.

This way, it will be presented lately in this chapter:

- problem exploration techniques, presenting general information about this step, as well as a compendium of the techniques available on the literature with proper explanation about its goals, requirements, and use cases; and finally the selection of some of those techniques for the experiment with an appropriate justification;
- techniques for generation of alternatives, presenting general information about this step as well as the selected technique for application in the experiment with an appropriate justification; and
- techniques for selection of alternatives, presenting general information about this step as well as the selected technique for application in the experiment with an appropriate justification.

2.1 Methodology in Design

This section discusses design methodology presented by distinct approaches: the conceptualization for the involved terms, the exemplification of some methodological structures with graphic models, and a historical overview about the research for methodology in design.

Initially, definitions for the term will be explored, when different points of view from respected authors are stated, such as Alexander, Cross, Bomfim, Bürdek, among others. Additionally, design methodology will be exemplified by models – visual structures, which represent schemes for the design process –, and finally, it will be structured a historical overview for this theme.

2.1.1 Defining Design Methodology

For a broader discussion about design methodology or method, it is crucial the definition of its general concept, since many different definitions can be found about the term. It is expected that this lack of a formalized and unified concept, collaborates with the development of different methodological models for design (Vasconcelos, 2009).

According to the Oxford Dictionary, the term "design" dates back to 1588, and there were 3 possible definitions for the term. The first of them defines design as a plan developed by men or a scheme that can be realized. The second definition deals with design as the first graphic draft of a work of art. Finally, the last is the definition of design as an object of applied arts or a tool for the execution of a work (Bürdek, 2006). In this context, the methodology in design can be understood as a set of methods or processes that support the designer on these activities.

For Alexander (1964), the process of design refers to the act of inventing structures or real objects that present a new physical order, form and organization, in response to the function. Still the problem of design deals with requirements that must be defined, but it also presents several interactions and relations between themselves, which turns this definition into a non-trivial task.

Löbach (2001) says that design could be deducted as an idea, plan or project for a solution of a problem. Therefore, design – as a verb – figures as formalizing this idea and transmitting it to other people.

According to Cross, the design methodology is characterized for the study of principles, procedures and the exercise of design, taking into account the final objective, which is to improve the practice of design by presenting an orientation strongly centered on the process (Cross, 1993 apud Kroes, 2002).

Bomfim (1995) defends methodology as the science that deals with the study of methods, techniques and tools and their applications in the definition, organization and solution of practical and theoretical problems, this way defining design methodology as the discipline that lends itself to the application of methods to specific and concrete problems.

Finally, for Roozenburg and Eekels (1996), the design methodology is one field of science that deals with the structure, methods, and rules for developing new products, in a sense of material artifacts and systems. Besides, two approaches can be observed when studying these methods. The first one is a descriptive model – in which the main objective is to reveal the method applied to de logical structure of design thinking – and the second is a prescriptive model – in which the methodology recommends or demands for certain problems the use of specific methods, once one opinion is formed based on descriptive analysis.

Accordingly, after analyzing these definitions, it is possible to formulate a broad and generic interpretation for design methodology based on the previous descriptions, adopted for this work from now on. Thus, it can be understood as a schematized process involving several steps with the objective of supporting the designer (or the design team) on the development or concept of solutions for a determined problem. This solution is understood as an artifact, either a product or a service.

2.1.2 Design Methodology Models

This section illustrates some graphical structures or schemes for design method according to different authors and periods. The first model recreates the non-explicit process of designing, which was considered as the way designers performed their activity until the decade of 1960, when the first explicit models appeared. It is known as the "Black box" (Bürdek, 2006), show in figure 1.

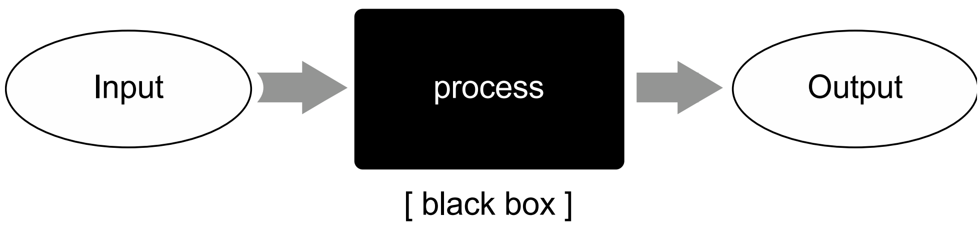

Figure 1. Black box scheme.

From an engineering perspective, Nigel Cross formalized a descriptive model based on essential activities executed by designers in the design process (figure 2). When the process gets to the "communication" phase, the product is ready to be produced (Dubberly, 2009).

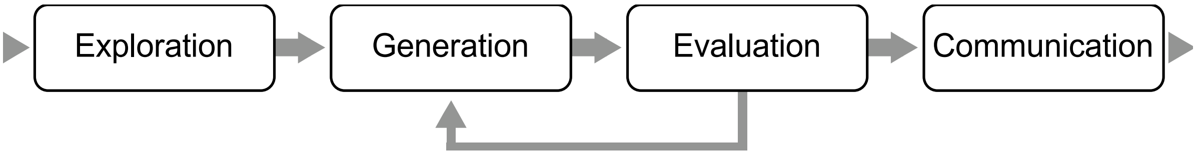

Figure 2. Four Stage Design Process: methodological model proposed by Nigel Cross.

Although this model dates back from 2000, it might be considered more primitive or abstract if compared to Bruce Archer's proposal as regards to the level of granularity of its steps, illustrated by figure 3. Still, even that both models cover the "communication" phase in two different periods – decade of 1960 and the twentieth-first century – this specific phase is not usually represented on design method graphic models (Dubberly, 2009).

Archer commented the constant overlapping and confusion of its stages, with frequent returns to previous stages once difficulties or obscurities are found.

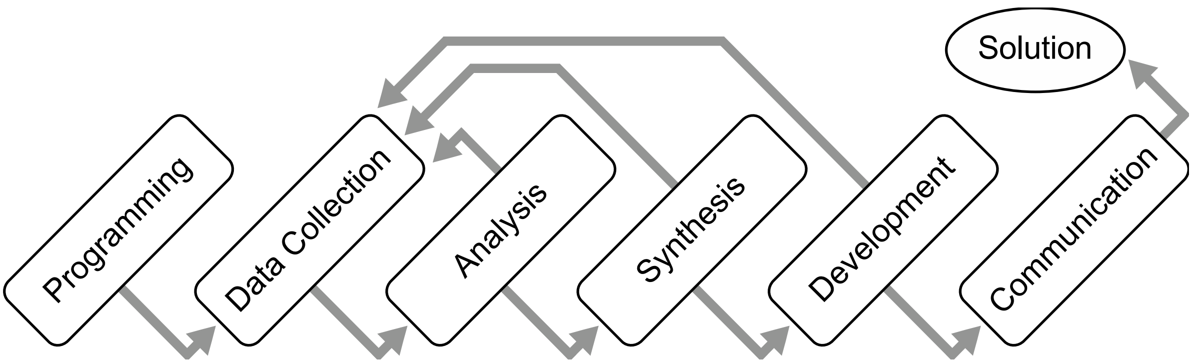

Figure 3. Basic design procedure by Bruce Archer.

The following scheme describes a typical order in the design process (e.g. analysis, synthesis and evaluation). Thomas Marcus and Thomas Maver dissolved the last stage into "appraisal" and "decision", and layered it in three levels regarding to how detailed the progress was (Dubberly, 2009). This interactive structure is presented in Figure 4.

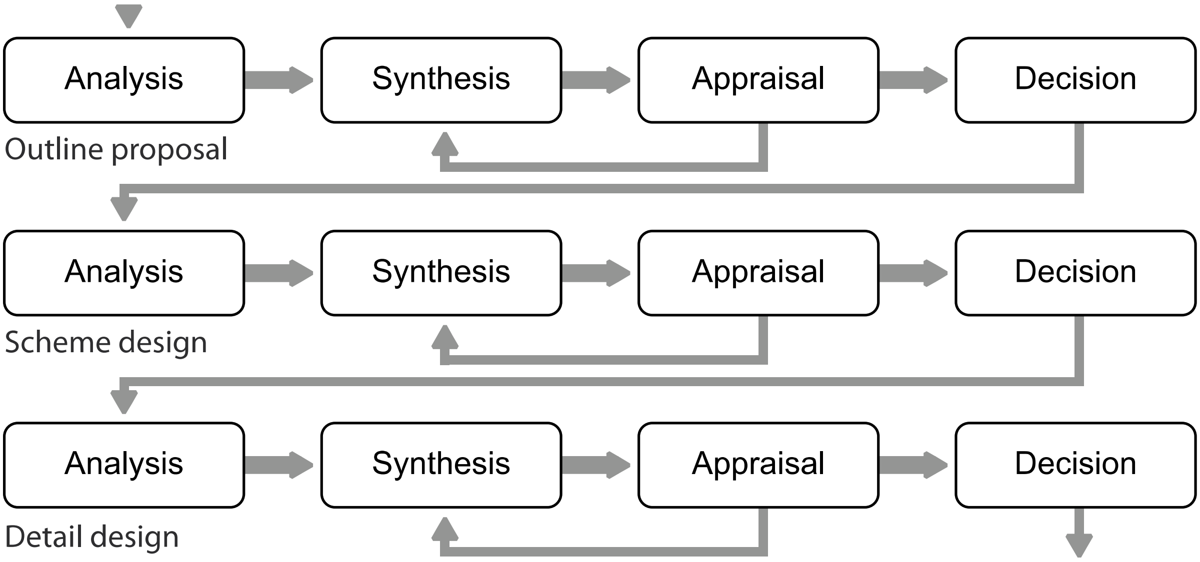

Figure 4. Methodological model after Marcus and Maver: an iterative structure.

As an example of a cyclical model, in figure 5, Bob Borzak formulated this spiral in which the extent to which the progress flows through a more abstract level to a more concrete one, several steps are covered such as the definition of objectives and the establishment of a development plan. Still, for all these steps the process must be submitted to a constant and iterative cycle (Bonsiepe et al, 1984).

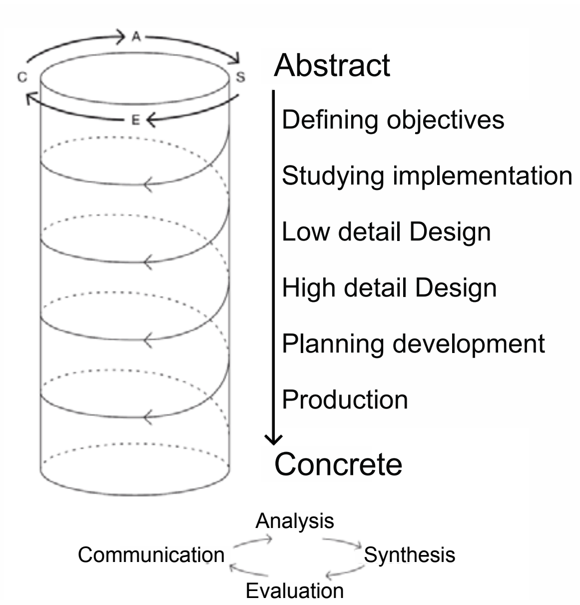

Figure 5. Methodological model proposed by Borzak: a cyclical structure.

Finally, after analyzing several structures for describing the design process, it is possible to get to a common basic process, which designers usually go through. The first activity to be done is to gather as many data as available about the problem to be analyzed – historical researches and analysis of similar solutions or competitors usually take place in this stage. From now on, this stage will be referred as "problem exploration". From the moment the problem is well-observed, alternatives for solving the question can be formulated by using numerous known creative methods. Following, alternatives must be evaluated and then selected in order to come with the best feasible opportunities. Concluding, the moment in which the final alternative is tested, detailed, and all the information necessary for its development is prepared for production.

2.1.3 Historical Overview

Historical research in design theory evidences that until the end of the decade of 1950, design was generally done by individuals and the methods applied were not clear, being called like the "black box" later, which means not visible (Hileman, 1998). Thus, from this decade on, it began the development of design methods as it is known today, from the "black box" into the realm of conscious process (Jones, 1992), mainly in countries in which the industrialization had reached significant levels, such as England or Germany (Bomfim, 1995).

In September of 1962, the "Conference on Systematic and Intuitive Methods in Engineering, Industrial Design, Architecture and communications" took place in the Imperial College, London, and it can be considered as the major mark for a greater discussion about design methods and its development (Jones, 2001).

Still, the Ulm School of Design (*Hochschule für Gestaltung*) played a key role for the development of these methods applying a broad research in design theory and formulating the "Ulm functionalism". The increase of the activities afforded to Designers in industry on the mid-twentieth century is seen as one overriding cause for progress in design methods (Bürdek, 2006).

Furthermore, the increasing complexity of the functional problems and the incapacity of Designers to solve them, as well as the need of a deep background of activities or attitudes that became even more complex to be taken intuitively (Alexander, 1964), were all strong arguments for the need to formulate logical structures as the early design methodologies. Jones also revisited these arguments, but now making use of questions in which he argued mainly about high complexity of new problems, as opposed to the old way of designing traditionally (Jones, 1992).

In this manner, names such as Asimow, Archer, Alexander and Mesarovic were noteworthy for research in design methods in the decade of 1960. Nevertheless, the research was considerably influenced by the aerospace studies, which presented highly complex problems, evidencing its efforts to divide the entire process into small, discreet and well-defined steps (Bürdek, 2006). Hence, design methodology in the decade of 1960 was much more reasoned with logical and mathematical models, focusing on the engineering process instead of taking into account social – and subjective – aspects such as user needs or the product life cycle.

After Ulm, in the following years it is seen not only a serious acceptance of a more scientific and objective approach to the design studies as well as it became a goal. The rational determinism prevailed; there was an attempt to determine the entire process and its minimum components. It was believed that the design process could be explicitly stated, relevant data collected, and an ideal artifact designed (Dubberly, 2009).

Along the decade of 1970, design methods took different orientation. The belief that a single method should be accepted as a general model was overturned. As new people came to the development of methodological models, new approaches emerged, like ergonomic and cost studies and concerns about the user needs (Jones, 1992). Basically, design started to be established as a science as it found support on scientific methodology for an autonomous design methodology to be created.

The next decade continued and spread the changes started in the years before. The rational and deterministic model found increasing opposition, especially when the postmodernism brought new tendencies forth (Bürdek, 2006). The design concept itself was promoted and merged with several disciplines, representing the paradigm shift between design as a natural science to a social science.

The decade of 1990 figures as a period in which the insertion context of a product became more important than the product itself. Besides, new orientations for the processes were needed since significant technological advances took place in these years, like the growing digitalization of products. The old functionalism dissolved itself into new immaterial themes such as usability and interface design, which lack modern procedures (Bürdek, 2006).

Finally, in recent years, models are frequently adapted or even created by companies for local appliance instead of developed by researches or scholars. Van Aken comments this adjustment defending that design methodology should not be centered on itself, but constantly adapted for designers in order to fit the project needs (Van Aken, 2005).

It is important to discuss design methodology as regards to the growth of complexity within the design process, for both scientific knowledge complexity and emergent values about users, culture, and technology, among others that must be taken into account (Vries et al, 1993). Design methods are no longer necessarily linked to the designer himself, but to a multidisciplinary team involving several practitioners and fields of study.

As it can be observed, considerable researches and development in design methods were done along the past years, which could be considered a scientific proof of its importance itself. However, regarding researches that explore specific issues such as some measurable manner to present real benefits acquired from using these methods, there is still much investigation to be done.

2.2 Testing Design Methodology

Although there is considerable acceptance of the importance of practicing design with constant support of methods, most in an academic context, it is not common to identify scientific verification researches to confirm the real effectiveness of design methodology either on the designer's perception of his / her expertise in the problem or on the final solution itself.

The use of methodology in design, the development of new models, and the discussion about its application are subjects widely studied for decades until the present days (Vasconcelos, 2009). Nevertheless, it is important for this field of study that studies and experiments verify and possibly quantify the gain from using methods from such models.

This way, one alternative to deal with this question could be presented by dividing the entire methodological process into its small phases or steps, such as "problem exploration", "generation of alternatives" and "selection of alternatives", and submit each one of these steps to empirical experiments, testing its techniques.

Along these lines, the present section proposes itself to perform an investigation in the international design methodology research scenario in order to verify if methodologies in design are being analyzed and tested in order to verify the effectiveness of design methods.

2.2.1 Why to Test Design Methodology?

In addition to what have been discussed before, as regards to providing reliable data about the beneficial results obtained with their use, testing design methods is crucial for scientific acceptance and further investigation (for establishing metrics and quantifying tangible results, for instance). As for the academy, studies that demonstrate neat and well-structured experiments providing non-questionable results are preferable than those in which results are much more subjective. This way, in order to gather trustable scientific data which bases design methodology, to test its steps and techniques figures as one possible alternative.

2.2.2 Looking for some Testing

This section describes the methodology applied to perform a research on the international literature in order to observe signals of investigation in design methodology worldwide, specially, regarding to its verification.

The methodology adopted for this initial investigation is described next. As for the first goal of this investigation, it list of journals was built, in which significant publications related to design were found. Secondly, a review of these journals was performed, defining then those more relevant for methodological studies.

The research was done with a sample of nine journals from 2006 to 2010, published in the English language and available at the "*Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*" (CAPES – www.periodicos.capes.gov.br) for the period of 2006 to 2010, covering the last five years of publications.

For the definition of the journals selected for this investigation, it was taken into account their Impact Factor (IF) and databases to which they were indexed. After the Institute for Scientific Information – ISI – the Impact Factor is a measure that reflects the average number of citations for the papers published in a specific journal. Usually, the higher the IF, the greater the reliability of a scientific journal.

As it was not found any specific journal for design methodology, and given that this subject figures as a common issue for most journals, the next step of the investigation was the selection of papers that addressed design methods. Therefore, twenty papers were selected from the journals considered as the most representative for establishing a scenario for the design methodology Research.

The selection of articles was performed primarily by using terms such as "DESIGN METHODOLOGY" or "DESIGN METHODS" within the keywords and title search field. After a first draft, all abstracts were read and a final selection was done according to how relevant the paper was for discussing design methodology.

Finally, it was created a table in which information about the papers was organized in such way that a brief description and objective data, such as year, authors and keywords, could be easily observed.

It is important to notice that the portal database used for this research offers full access to some journals while others are excluded. In this manner, other studies with the same objective but making use of distinct resources may lead to different results. Still, similar problem occur as regards to journals that presented free access for their papers and others for which it was necessary to pay.

Likewise, the selection only covered journals of social applied sciences and some engineering fields, thus a different choice for the main resource fields may also lead to important and distinct results.

2.2.2.1 International Journals' Overview

Artificial Intelligence for Engineering Design, Analysis and Manufacturing (AI EDAM) – (http://www.journals.cambridge.org/action/displayJournal?jid=AIE)

The AI EDAM is a North American journal part of the Cambridge Journals, published by The Cambridge Press, which publishes articles mainly related to AI theory and applications and computational systems.

As regards to its relation to design, the journal presents a research in analysis and evaluation of products and systems of AI as well as selection, configuration and the design itself. Besides, process planning, learning and creativity are also common subjects. All these related fields receive objective and mathematical interpretation much more than a subjective approach frequently seen on other design journals since it is a journal natural from the engineering field instead of the applied social sciences.

There are published four issues per year since 1987.

Design Issues – (http://www.mitpressjournals.org/loi/desi)

Published by the Massachusetts Institute of Technology (MIT), the Design Issues journal envelop the fields of history, theory and critics in design, since 1984, been considered a key publication for the design research and the first American academic journal to examine its subjects.

Its issues are published four times per year and the last publications are addressed mainly to aspects like design and society, design history and critics. Among the papers observed, there is a constant approach to design in specific countries and its development and history there. Technology is also a main key point.

Design Studies – (www.elsevier.com/locate/destud)

After more than thirty years of publication, the Design Studies Journal promotes the discussion about fundamental aspects of the design activity and projects, as well as the relationship with correlated fields like architecture, computing and engineering.

It is published six times a year by the Elsevier, Netherlands, edited by Nigel Cross and presents a broad scope of publications in the most diverse design areas. Common themes on its publications are design methodology and education.

International Journal Of Design (IJDesign) – (http://www.ijdesign.org/ojs/index.php/IJDesign/index)

Differently from most of the design journals, the IJDesign is published by the Chinese Institute of Design and intends to presents studies on industrial, visual, interfaces, game, animation and architectural design.

This journal covers several areas of studies in design, such as the core theory; methodological, social and cultural aspects; management and strategy, and ergonomics. The journal is noteworthy for its completely free access, though.

As the first edition was announced in 2007, it can be considered a young journal if compared to others in its field. Three issues are published per year and a significant percentage of its papers are related to new immaterial aspects of design. The user receives special attention on various researches about the emotional, interaction and aesthetics.

International Journal Of Design Sciences and Technology (IJDST) – (http://europia.org/IJDST/)

The IJDST is published by Europia and presents itself as a multidisciplinary forum for dealing with all facets and fields of design from economical to philosophical approaches, going through technology and education.

Although it offers free access for the last three years of its publications, this is not enough data to establish a perceived main stream for the research presented on papers in this journal. Articles from 2008 back, beginning in 1995, have restricted access only for titles and authors.

International Journal of Technology and Design Education (IJTDE) – (http://www.springerlink.com/content/0957-7572)

Since 1990, the IJTDE is published four times per year by Springer and intends to offer critical, review and comparative studies for its readers,

It intends to stimulate the research in design involving technology and fundamental aspects for teaching design by involving history, philosophy, social and psychological studies that addresses issues of concern to design education and technology.

Journal of Design History – (http://jdh.oxfordjournals.org)

The Journal of Design History is part of the Oxford Journals, a division of Oxford University Press and an international publisher of academic and research journals, which publishes over 230 journals covering several subject areas. It plays an important role in the research in the history of crafts and applied arts, as well on visual and material culture.

Publishing four issues per year since 1988, the current stream of its articles – as perceived – are mainly art and material culture – history of societies and its relation to art and design aspects, fashion, interior design and architectural perspectives.

Journal of Engineering Design – (www.informaworld.com/jed)

Published by Taylor and Francis and with a total of twelve issues a year, the JED provides a forum for discussing aspects of design engineered products and systems. It presents papers related to industrial practice, research, theory and many reviews, covering fields such as aesthetics, creativity and innovation, ergonomics, methodology, service and system's design, education, among many others.

Research in Engineering Design – (http://www.springer.com/engineering/mechanical+eng/journal/163)

The main research stream of this journal is related to the design theory, practice and methodology in all fields of engineering. Underlying principles of discipline-oriented research are emphasized as well as the focus on representation and model of design processes.

Likewise most of other journals, the Research in Engineering Design publishes (shortened to RED for this document) its issues four times a year and the first volume dates backs from 1989.

2.2.2.2 Design Methodology Research Scenario

A total of twenty papers were selected for the discussion during this investigation. From all nine journals analyzed, only six of them presented at least one significant article according to research criterions. As it is observed in chart 1 – and already commented by Norman (Don Norman's jnd website 2010) – most of papers selected came from three of all journals: Design Issues, Design Studies and International Journal of Design.

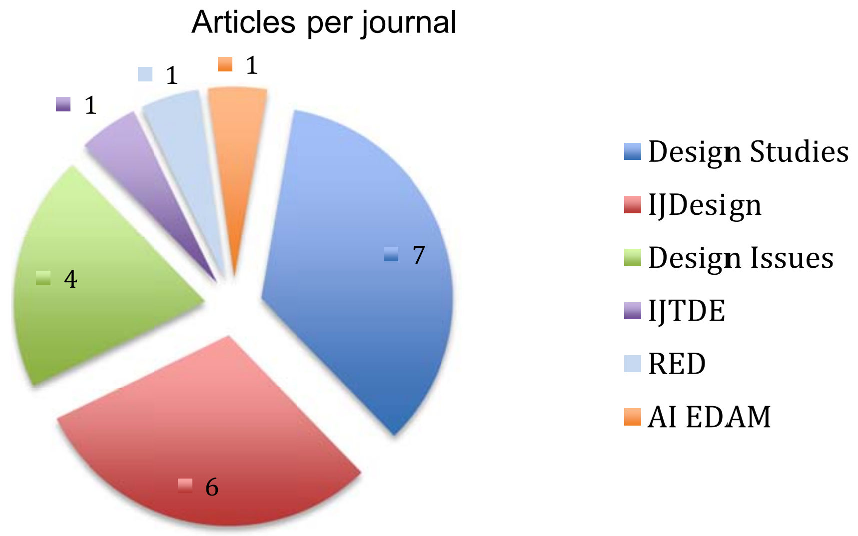

Chart 1. Number of articles selected per journal.

The other three journals from which were not collected articles either did not present relevant publications for this research in the last five years – even it was said that methodological aspects were covered by each journal – or required access, this way being inaccessible.

The following table (table 1) gathers some data to provide information such as title, author, year and the keywords for each of the twenty papers investigated.

Table 1. Brief description of papers used for discussion.

Title	Author	Year	Journal	Keywords
Design Problems and Design Paradoxes	Kees Dorst	2006	Design Issues	design, problems, paradoxes
Theory and design in the first digital age	Rivka Oxman	2006	Design Studies	digital design, design theory, design methodology, design thinking
The design analogy: a model for moral problem solving	Kees Dorst and Lamber Royakkers	2006	Design Studies	design process, problem solving, ethics
The locating of emotion within a creative, learning	David	2006	IJTDE	creativity, learning, emotion, person,

and product orientated design and technology experience: person, process, product	Spendlove			process, product
On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology	Pieter E. Vermaas and Kees Dorst	2006	Design Studies	design methodology, design models, design knowledge, descriptive and prescriptive modeling, philosophy of design
Rigor and Practice-based Research	Michael A. R. Biggs and Daniela Büchler	2007	Design Issues	practice-based design, design research, methodology
Crafting a Place for Interaction Design Research in HCI	Jodi Forlizzi, John Zimmerma and Shelley Evenson	2008	Design Issues	human-computer interaction, engineering design, user interfaces, interaction
A study of the role of user-centered design methods in design team projects	Justin Lai, Tomonori Honda and Maria C. Yang	2009	AI EDAM	design pedagogy, design process, design teams, product design, user-centered design
Affordance-based design methods for innovative design, redesign and reverse engineering	Jonathan R. A. Maier and Georges M. Fadel	2009	RED	affordance, affordance-based design, design methodology
Cross-Functional Cooperation with Design Teams in New Product Development	Bo-Young Kim and Bum-Kyu Kang	2008	IJDesign	cross-functional teamwork, internal design team, effective product development
Design, Risk and New Product Development in Five Small Creative Companies	Robert N. Jerrard, Nick Barnes, and Adele Reid	2008	IJDesign	creativity, design, participation, risk, small companies

Design Thinking and the Experience of Innovation	Barry Wylant	2008	Design Issues	design thinking, creativiy, innovation, economy
Facilitating Dynamics of Focus Group Interviews in East Asia: Evidence and Tools by Cross-Cultural Study	Jung-Joo Lee and Kun-Pyo Lee	2009	IJDesign	cross-cultural study, focus group interview, group dynamics, user research methods
Navigating the Innovation Matrix: An Approach to Design-led Innovation	Steven Kyffin and Paul Gardien	2009	IJDesign	innovation, matrix-based approach, design for research, business value
Extended linkography and distance graph in design evaluation: an empirical study of the dual effects of inspiration sources in creative design	Hui Cai, Ellen Yi-Luen Do and Craig M. Zimring	2009	Design Studies	creativity, conceptual design, extended linkography, design knowledge, design education
Methodology for context-sensitive system design by mapping internal contexts into visualization mechanisms	Eui-Chul Jung and Keiichi Sato	2009	Design Studies	design methodology, design model(s), interface design, system(s) design, context-sensitivity
New product development practice application to an early-stage firm: the case of the PaperPro StackMaster	Tucker J. Marion and Timothy W. Simpson	2009	Design Studies	product development, product design, case study, start-up,design education
Influence of Stakeholders on Industrial Design Materials and Manufacturing Selection	Owain Pedgley	2009	IJDesign	industrial design, materials selection, manufacturing, decision-making, education
Consensus and single leader decision-making in teams using structured design methods	Maria C. Yang	2010	Design Studies	decision-making, teamwork, design methods

Protect and Appreciate – Notes on the Justification of User-Centered Design	Turkka Keinonen	2010	IJDesign	user centred design, user need, usability, user experience, design ethics

2.2.2.3 Discussion

Models of the design process are relatively common, describing a sequence of steps required to design something or just recommended steps. These models are common because designers usually need to formalize and explain what they do so other people can understand (Dubberly, 2010) or an attempt to standardize processes.

However, after analyzing the collected articles, it is noticed that nowadays rather than investigating and discussing the entire process, designers are focusing their effort on discussing stages of the whole model. Probably, after being strongly studied since the decade of 1960 people now are performing depth-based researches rather than breadth-based ones.

Besides, differently from the early years, most of the models now formalized are developed by companies or industries as a local appliance. Several of them figure as modern adaptations for old models, but many others introduce new current concepts or create mechanisms for defining their own model. Companies pursue this goal according to the idea that Design Methodology may lead to minimize risks involving the development of new products (Jerrad et al, 2008).

In the recent years, the user and innovation became a strong keyword for design studies as well for every software company or any industries that deliver new solutions in form of products or systems. Therefore, researches on design methods took over now around user aspects – as it is seen on Keinonen (2010), Lee et al (2009), Forlizzi et al (2008), and Lai et al (2010) – and the creative process – as it is seen on Maier et al (2009), Kyffin et al (2009), and Wylant (2008) papers.

Keinonen discusses about pitfalls on centered-user design, emphasizing both its importance and difficulties found by designers during the process. Lee shows the influence of different contexts like cultural or social on methods for dealing with users. Forlizzi describes the evolution of human-computer interaction, the invention of graphical user interfaces and the main challenges for guarantee accessible experience.

Maier uses an explicit theory of affordance to formulate prescriptive models with more scientific rigor for innovative solutions, redesign and reverse engineering. Kyffin shows how using design methods properly may lead to innovation in distinct paradigms. Wylant discusses the influence of the context in which the designer is inserted on his / her generation of alternatives.

As for design methodology testing, no research in this sense was found. It is possible to observe current researches that divide methods into their minimal parts like specific techniques and test it, but for the whole process or even bigger stages, there was no result with this investigation.

Finally, regarding to research clusters in this field around the world, chart 2 illustrates the grouping of articles collected per country in which the work was realized. As some of the authors develop studies in two different countries for the same line of research, number of countries in this chart is slightly higher than twenty.

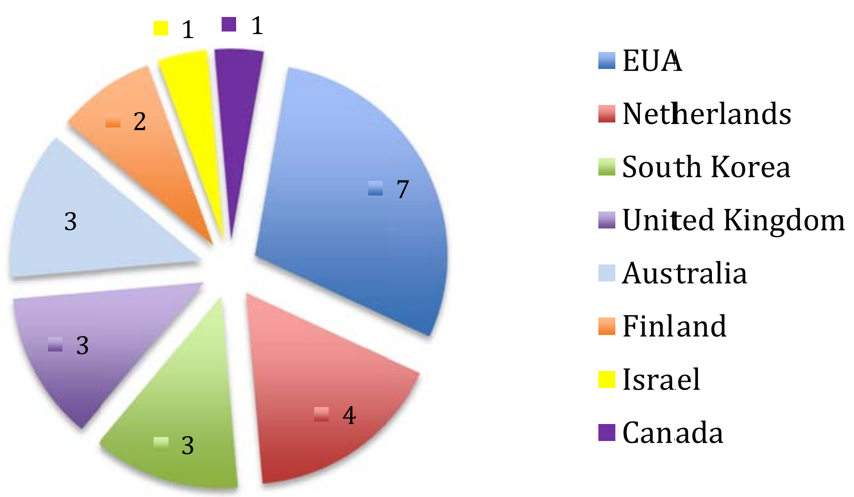

Chart 2. Number of articles selected per country.

In this section, it was performed an investigation in international scientific design journals in order to establish a scenario for the research in this field. Several articles from many journals were analyzed to achieve this objective. As conclusions, it is possible to affirm that apart from the absence of researches centered on scientific verification of design methods, recent studies about this subject differs from those in the early years of design methodology development.

The entire process is being dissolved into smaller steps that now are performed by companies and industries rather than by a designer or a small team. Besides, there is a huge cluster of research around user aspects such as interaction, interfaces and usability as well as around creativity and innovation.

Once it was observed that even though some research about design methodology is being made and published in journals around the world, no research towards the verification and testing of the selected theme could be found in this first investigation.

This way, it is proposed a research aiming the verification of the contribution of problem exploration techniques during the process of design, for both the design team and solution itself. This verification will be possible with a structured experiment described in subsequent sections. Before explaining all the experiment's structure, theory about techniques of a design methodology framework will be presented.

This work has preceding investigations as motivation and related work, not found on the journals' research driven previously. The research concluded by Melo (2008), Correia (2010), and Ferreira (2010) present a similar approach to this investigation, although the focus has been on techniques for generating alternatives.

2.3 Techniques for Problem Exploration

As it has being discussed before in section 3.2.1.2, after analyzing several methodological models, a consensual macro-structure comes to light and it presents an initial step for the process in which the design team investigates issues about the problem they are designing for.

By observing important contributions for this field, design authors such as Bruce Archer (Bonsiepe et al 1984), Bruno Munari (1998 & 1997), Morris Asimow (1968), Christopher Jones (1992), Briggs and Havlick (Dubberly, 2009), and Bernd Löbach (2001) state in their scheme some techniques or tools for recovering requirements, people, and activities information – although through different approaches. This regular statement from distinct key authors confirms the importance on dealing with aspects when designing a product.

Developing a new product includes identifying a problem – thus an opportunity –, researching the market and analyzing competing products, observing their characteristics, trying to predict trends, getting in touch with the user and the public the product is being designed for, much more than defining shape and function.

Baxter (2000) explains that to know the problem it is being designed for and planning a solution in shape of a product is one of the most difficult activities when developing new products. It involves self-discipline for covering this step not to rush too soon into sketches and ideas. The argument for spending valuable time in this moment is grounded on the time and money spent afterwards in case changes must be made for the concept.

On the other hand, leaving theory aside and getting into the practices, Norman (2011) argues that doing research first is sometimes not possible, and even more, it should be avoided in some cases. Projects commonly start behind schedule and it can make no sense to do research when other steps of development are already running. Besides, once a project is announced, many directions are pre-settled by executives, shareholders or stakeholders, causing the research stage to be skipped.

A similar point of view was expressed previously by the same author when discussing about the length of project schedules. At the same time designers look for iterative and quick methods and rapid tests, they claim for investigating the historical evolution of a product, field studies, and user observation, which usually take a lot of time and effort. Especially when the project had already begun, the focus should be on getting rid of lengthy, linear and inflexible schedules, and for that, these research practices should be done outside the product process (Norman, 2006).

Notwithstanding, according to Neves et al (2008), with the advances on cyberculture, it is perfectly feasible not only to make use of quick and cheap methods taking advantage on internet and search engines, on the very beginning of a project, but these tools also can be applied for newly-started and ongoing projects for presenting easy and fast appliance.

2.3.1 Techniques Chosen

A total of seven techniques generally found in design literature on the first step of methodological frameworks (observe authors list in section 2.3) were chosen to be part of the experiment conducted. The techniques chosen encompass both users' and products' aspects, including wider contexts such as market and narrower issues such as engineering.

Neves et al (2008) suggested a set of web research based techniques for the steps of problem exploration, generation of alternatives, selection of alternatives, testing the alternatives, and solution description. It was defined as "XDM – eXtensible Design Methods". This proposal figures as a primal motivation for the selection of techniques for this work, although the techniques chosen slightly differ from the XDM initial framework. They are:

- Market Research;
- Historical Evolution;
- Competitor Analysis;
- Trend Prediction;
- Research by Immersion;
- Defining Personas; and
- Reverse Engineering.

It can be observed that most of the techniques chosen (or similar variations) are also tasks defended by Bruno Munari in his two books, in 1981 and 1989. Moreover, it is important to make clear that many other techniques can be found on design bibliography and may be applied during this initial step.

This selection of seven techniques was made based on previous researches that confirmed their quick appliance for short projects and the good results that can be achieved with their use (Neves et al, 2008). Finally, this number of selected methods seemed appropriate for the experiment context – an extensive list should be avoided for the short cycles of activities and a small number of techniques would be questionable as a resource for differentiation of procedures.

2.3.2 Market Research

First of all, it is important to notice the difference between the two known terms that are normally applied for the same purpose. According to Bradley (2010), when using "market" instead of "marketing", it is being referred to only part of the studies which the marketing research covers, which means that for design disciplines, only a subset of the aspects involved in marketing research is practiced. This subset of aspects, known as marketing metrics, represents the study of specific market places and their users' profile, and which, how and how much products they may use – in other words, measurements.

As regards to its role in design methodology, the market research step takes place initially at the very beginning of the whole process. Its first goal refers to identifying the commercial objective of a product, establishing a business opportunity and market niches. Specifications about features the product may have, from a commercial view, as well as all financial aspects and investment arguments should be documented. Differently from a project specification document, in which aspects such as shape, function, technologies are covered, market information should be organized in an opportunity specification document. Generally, the project or design specification and the opportunity specification documents are conceived by differently specialized teams within a bigger development crew (Baxter, 2000).

To have reliable market data is fundamental for justifying the project's development. For Roe (2004), the success on developing new products is only achieved with a heavy investment in market research. Before the product goes to the streets and to ensure that all the possible optimization have been done – in order to guarantee the best chance of long-term success upon launch –, it should be pre-tested among potential end-users through market research.

From a more pragmatic view, when performing a market research for developing new products, designers intend to estimate the market for economical relevance which supports the project (Neves et al, 2008). In case the scenario discussed previously can't be properly settled, an easy, quick, and cheap way to achieve good results may be using the World Wide Web in order to gather information such as sales charts, market reports and user groups' opinion. Through the use of specific keywords in search engines, relevant data including texts, schemes and images can be investigated, providing small developer teams with low budgets enough information for starting a project. This technique also should provide the team with initial findings about the project's target group.

Figure 6 shows an example of a sale chart found on the internet to present sales for the video game industry between January and March of 2008. By analyzing this image, for instance, it is perceived a considerable increase of the Nintendo consoles' sales when compared to other consoles. It could suggest, among other possible interpretation, an interesting opportunity for developing games for these specific two consoles.

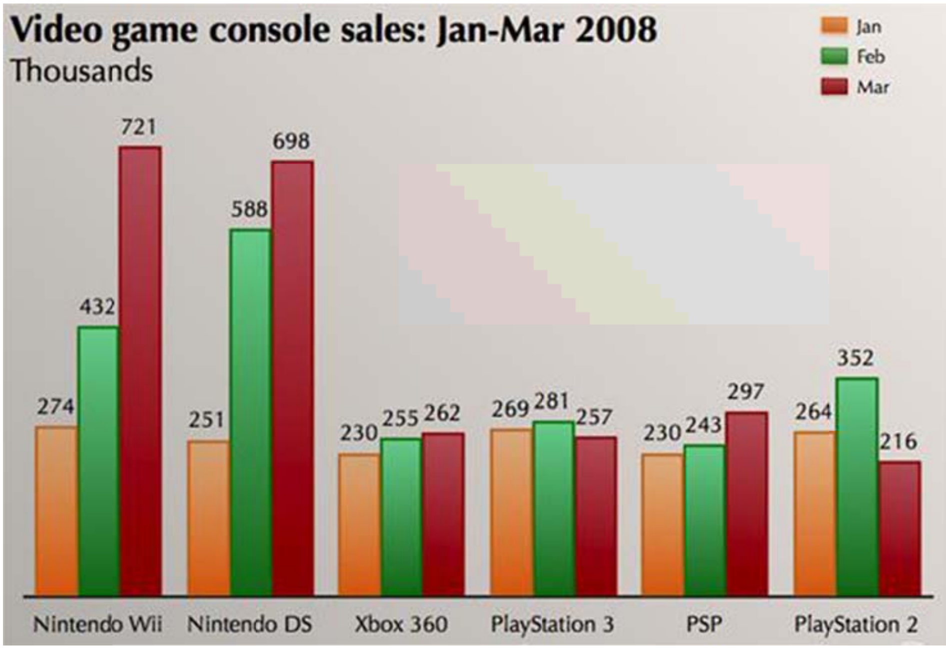

Figure 6. Video game console sales' chart (The Seventh Generation Consoles: Wii, n.d.).

2.3.3 Historical Evolution

According to Danto (2008), historical sources never bring a straightforward string of facts. The way history is written is very different from natural sciences' writing or from a quantitative analysis, for instance. When researching history, patience is needed to filter documents taking into account the original authors, their origins, and stories.

Different sources of information will be available when conducting a historical investigation. Researchers should look for primary sources initially, as they are more reliable. Primary sources are original materials commonly from the period involved and have not gone through someone else's interpretation, such as journals, government statistics and speeches. Using primary sources raises the probability of bringing original and new information for your research. Otherwise, secondary sources come from interpretation of other researchers about the investigated subject, analytical works, and comments (Raimes & Jerksey, 2011).

In design, performing historical research for identifying a specific product evolution over the years can be done in a different way – it is more objective. As the investigated subject is a product, unlike many other historical issues with several correlations, variables, and a more subjective interpretation, it is easier to isolate the evolution of the object in question by researching its creation, models that came later, and changes on shapes and features. Besides, the product itself may act as a document.

Although the market research must be performed as soon as an idea of a project, a solution, or an identification of a problem comes to mind, and even that some information about users, competing products, and trends may be also found when going under a market research, there is no neat guided link between this and the other techniques chosen. It works like simultaneous starting point for other steps.

Historical (or chronological) research on the evolution of a product, adversely, provides the designer a clear line of thoughts through which he or she can guide the problem exploration step. Several similar products will be investigated when going under a chronological research, and as the researches approach the current date, a special subset of the newly developed products will be object of study of the competitor analysis technique.

Neves et al (2008) argues that the main result expected from the use of this technique is a document containing images, relevant facts, products' characteristics, and dates. This data should preferably be chronologically organized in a shape of a time line, as illustrated by figure 7. Moreover, yet supported by digital means of research, stock photos, digital encyclopedias, and manufacturers' websites, among other sources, can figure as valuable evidence for documenting information about the historical evolution of a product.

Figure 7. Timeline of video games consoles (Kotaku, 2010).

2.3.4 Competitor Analysis

After researching the historical evolution of the selected product, in which the higher number of analyzed objects is desirable, the last entries of the time line may give designers information to start researching on competing products. A second research focused only on recent years and months is also recommended.

Once enough data about products was collected, a parametric analysis should be structured to organize and refine the information. This analysis aims to compare the product under development with existing ones, based on relevant parameters for the project. These parameters can be (Baxter, 2000):

- quantitative – parameters that are expressed by numbers, such as size, height, speed, price, durability, etc.;
- qualitative – parameters that deals with subjective aspects for comparing products, generally based on user opinion, such as comfort, usability, fun, ease, human factors, etc.; and
- for classification – parameters that indicates certain characteristics of a problem based on several possible classes. An example could be the television displays: Plasma, LCD, LED, OLED, CRT, etc. Or even a presence of given characteristics, such as remote control or not; internet access or not.

For Baxter (2000), when analyzing competitors the design team should have three primal objectives:

- to describe how existent products compete with product under development;
- to identify and evaluate innovation opportunities; and
- to establish goals for the new product in order to provide it with better competing chances.

Finally, the author states that the competitor analysis should be performed in two distinct levels. The former level refers to users and their needs. Consumers must evaluate products according to specific requisites of use. The latter one concerns to technical requisites of the project. This way, designers must evaluate products according to what is desirable from a parametrical and functional view.

As important as the establishment of functional characteristics, or qualitative and quantitative parameters of the researched products, is the visual information. Shapes, sizes, and features can be easily analyzed in a reference panel of similar products. Figure 8, for instance, displays a selection of several video game controllers with different models even for the same console. To have this visual information is crucial to design something completely new or to find inspiration on the finest aspects of each entry.

Figure 8. Visual research result for video game controllers (Kantaroth, 2008).

An interesting tool to perform a competitor analysis is shown by Kim and Maubourgne (2008). The Strategy Canvas is defined by the authors as “a diagnostic and action framework for building a compelling blue ocean strategy”, in which “blue ocean” is a term for a market place with almost no competing products or with irrelevant competition. Figure 9 shows a Strategy Canvas for wines, a chart in which horizontal axis presents the range of parameters the industry invests in and competes on.

By analyzing the chart according the product’s parameters settled, it is possible to identify market spaces with no competition for wines with: average price, no enological terminology and distinctions in communication, young, and very low complexity, represented by the yellow tail. Although, these characteristics does not seem to bring the new wine much quality. This way, innovative parameters can be brought into the wine profile, such as “fun and adventure” or “easy drinking”. Then a new wine profile is created as well as a new place in the market.

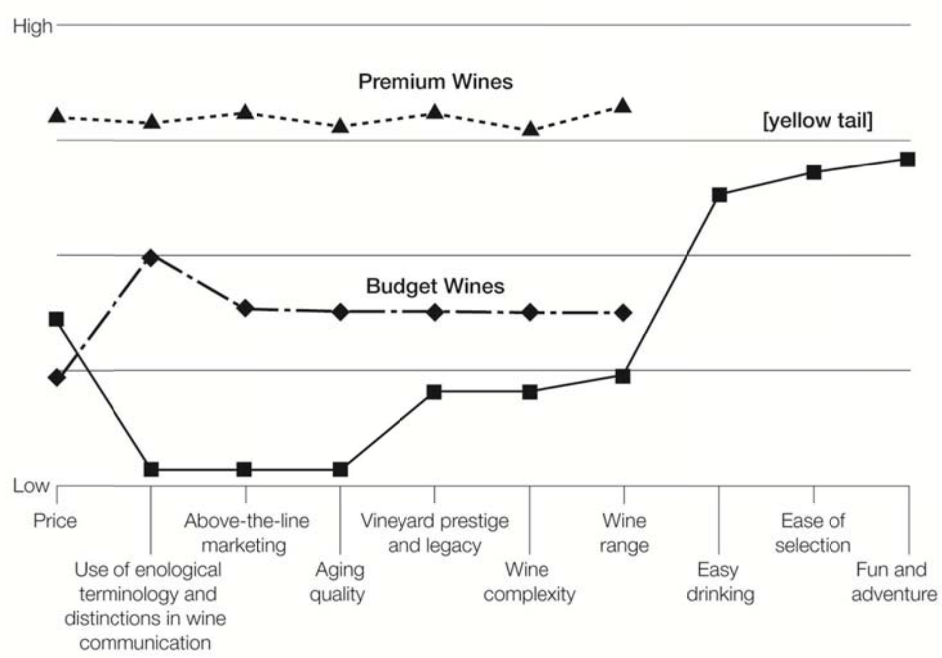

Figure 9. An example of a Strategy Canvas for wines (Kim & Mauborgne, 2008).

Another important author for the design theory who also defended the research for similar products or competitors was Bruno Munari (1998), in one of his methodological models first proposed in 1981; Munari placed this activity on the third of the ten steps presented in his model.

Again, information about competing products on the internet is easily found. By using key words related to the project to be started, it will not be difficult to find images as well as negative and positive aspects of similar products or quantitative characteristics.

2.3.5 Trend Prediction

After investigating competing products as regards to shapes, function, embedded technology, and other aspects taken into account on the previous analysis, it is trivial to identify an evolutionary line for the class of products relevant to your project. Although, to predict a trend requires a similar but entirely new research, now regarding what the future might bring to your product and also demand of it.

Trend prediction is supported by the idea that evolution is not random. The evolution of a set of products follows specific stages and patterns that can be predicted. Knowing these patterns helps solving innovation problems and also defines strategic opportunities for the use of certain technologies (Silverstein et al, 2009).

The same way the fashion industry is organized in such manner that slight changes are introduced each year to determine new trends on fashion shows, this way establishing colors and materials; it is possible to observe a similar behavior in almost any other product industry. For instance, clothes or MP3 players that could last for at least 5 years are soon considered obsolete, pushing customers to consume not only based on new features or improvements but also in accordance to social and style trends, although in other industries than fashion this style effect commonly take more time to be perceived (Baxter, 2000).

The trend prediction technique intends to foresee future directions for products, technologies or even theirs users. For Silverstein et al (2009), predicting trends works as a knowledge-based tool for extrapolating systems' behavior for the next years or decades, and once these evolution tracks are well established, the innovation for the project can be better planned. A current example for systems or services is the decrease of human involvement, as well as the increase touch interfaces over buttons for digital products.

One interesting tool for the prediction activity is to draw and analyze S-curves (figure 10). For a given product or technology, S-curves move from conception to retirement, sometimes rapidly and sometimes slowly, and after this, the solution tends to decay in value. Thus, innovation is needed when it comes to this point.

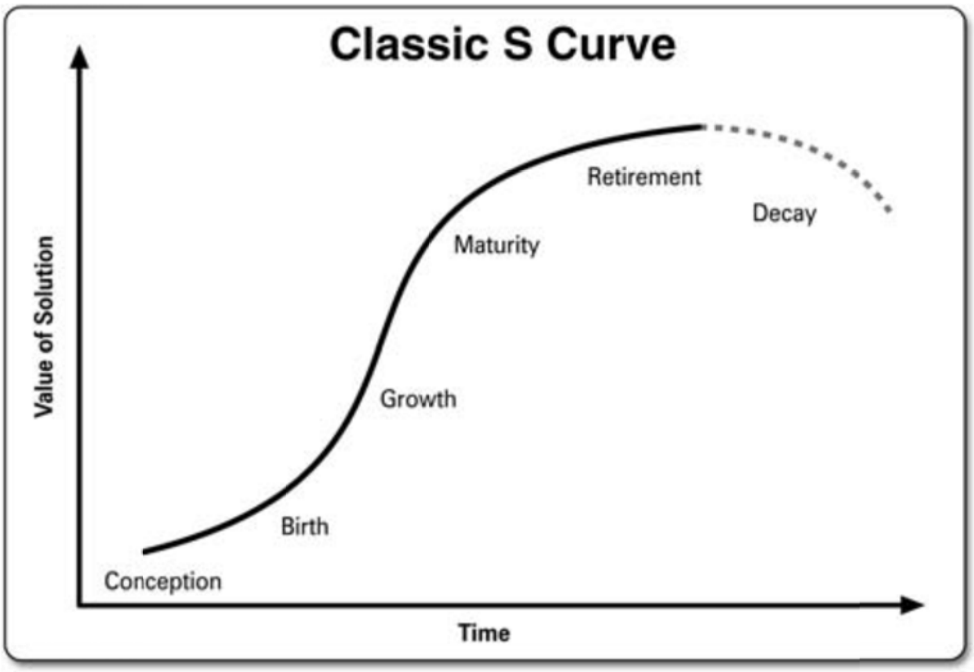

Figure 10. A classic S-curve (Silverstein et al, 2009).

Although the amount of knowledge gathered and time spent in order to apply this technique may be considerably large, knowing the right time for embedding specific technology into the product and realizing some concepts are outdated is crucial for a great market reception for the concept developed (Silverstein et al, 2009).

Another useful way to deal with the data collected during an investigation on trends is to organize a reference panel with the last created products and cutting-edge technology. Figure 11 presents a panel with pictures of thirteen different layouts for kitchens with distinct products, colors, and materials.

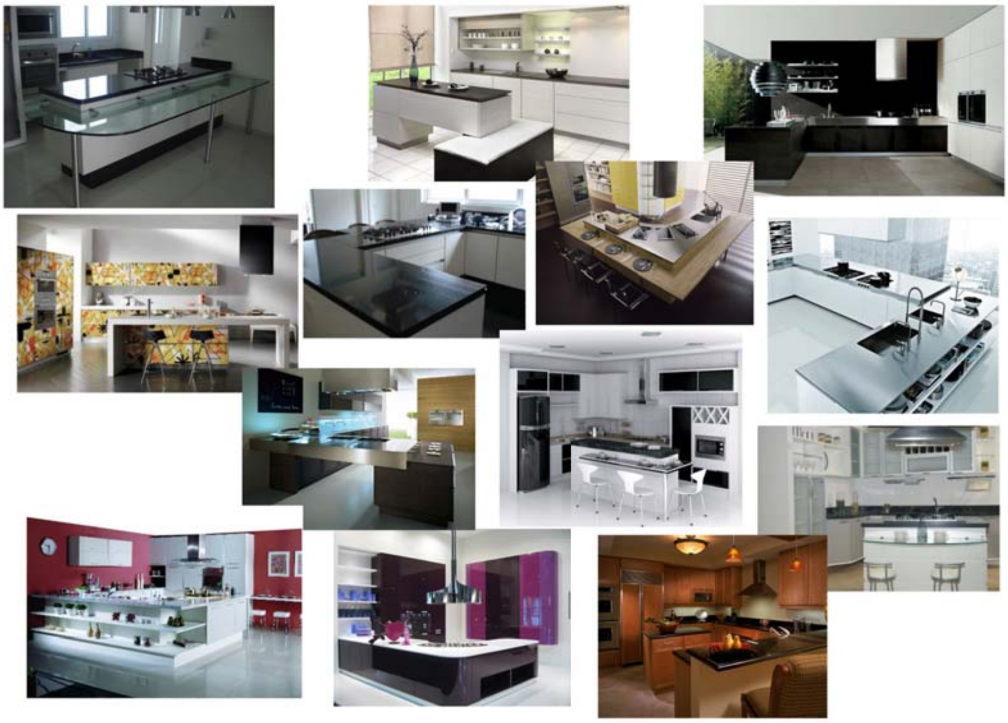

Figure 11. Panel of references for modern kitchens (Azevedo, 2011).

Once more, Neves et al (2008), suggests using the internet for gathering information on trends. There must be documented similar products that consumers want and the main innovation on technology related to the product.

2.3.6 Reverse Engineering

As the other methods presented so far, this is the last of a set of techniques for problem exploration basically focused on the project or product itself.

Wang (2011) defines reverse engineering as the process of measuring, analyzing, and testing in order to rebuild a copy of a product to retrieve a past event. It is reinvention, reproduction, but also an attempt to preserve the design of the original product or part.

Another interesting definition for reverse engineering is presented by Raja and Fernandes (2008), in which this process is explained by defining initially what is engineering. The authors contextualize engineering as a process of designing, manufacturing, assembling, and maintaining products or systems. Therefore, there is the forward engineering – the traditional process that moves from high-level abstractions and logical designs to the product itself (its physical implementation) – and the reverse engineering – the duplication of an existing part or a product without documentation, drawings, or computer models. Reverse engineering may also be defined as the process of obtaining 3D models from scanning a product or its parts.

Nowadays, reverse engineering is found on manufacturing, industrial design, pharmacy, and many other industries. When a car is launched, for example, competing manufacturers may disassemble a model in order to learn about its functioning and how it was built.

In addition to the last example, there are many reasons for using this technique (Raja & Fernandes, 2008):

- the original manufacturer no longer exists or no longer produces it;
- the original documentation was lost or never existed;
- recreating data for refurbish parts of a product for which the old data was lost or became obsolete;
- inspection or comparison of a fabricated part to its 3D model description;
- bad features of a product that need to be eliminated;
- strengthening good features for long-term usage;
- analyzing features of competing products;
- creating 3D data from a real model;
- architectural and construction documentation; and
- many others.

From the cases presented previously, the main reason taken into account in this document for describing this method and its application on the design context is the one which refers learning about assembling and functioning. Nevertheless, Chikofsky and Cross II (1990) stress that doing reverse engineering is a process of examination, not about change or replication.

Setting aside huge companies with high budgets, small projects focused in innovative devices can gain valuable information by disassembling either direct or indirect similar products – this process can be also known by product teardown. By doing so, the team can understand more about inside components, their sizes and interrelationship, how mechanisms work, and even shape aspects.

For projects with even more constraints as regards to schedule and investment, this method can be performed with the support of common online knowledge. Manufacturers' webpages, forums, users' communities, tutorials, and online videos are some of the available online content for gathering data about reverse engineering. Figure 12 exemplifies results for online research about portable media devices. It shows images of a tutorial for disassembling a Zen Vision MP4 (from Creative).

Figure 12. Steps show how to disassemble a MP4 player (Anythingbutipod, 2006).

2.3.7 Research by Immersion

Until now, the market was observed to justify the development of a product and identify market places for insertion; origin and evolution of products were investigated for acquiring information about how a set of objects behaved over the years and why; competing products were analyzed in order to identify relevant characteristics, and their strong and weak aspects; trends involving technology, shapes, functioning, and market were identified;

and were detailed technical aspects about the product, such as components, sizes, energy source, and assembling.

This technique also aims to find product data regarding to its use, but now the users are at the main focus of the research.

In 1970, John Chris Jones brought, for the first time, user aspects into discussion of the methodological models formulated that time (Vasconcelos, 2009). For his design methods proposal, Jones considered interviewing users and analyzing their behavior on what himself named the "Divergence" stage, the first of his three step framework (Jones, 1992).

A very used tool and commonly applied on this step is the task analysis, a technique for exploring user-product interactions through observation and detailed analysis. The analysis' results are applied for developing new concepts strongly concerned about user-product interfaces (Baxter, 2000).

For Neves et al (2008), this class of research investigates positive and negative relations between users and artifacts that are similar of the product under development. Again inserted on the cyberculture context, virtual communities and social networks are both relevant sources of information based on users' comments or interviews. This alternative figures as a very good option for projects in which there is no availability of use for similar products to be analyzed *in loco* for team members, either for budget issues or target group constraints – a solution for disabled or impaired people when there is no one in this condition at the team, for instance.

2.3.8 Defining Personas

Pruitt (2006) argues that everyone designing a product should always keep in mind the needs of every person who will ever use it. In theory, every decision and the final result would fully satisfy every consumer who uses it when having real information about users. However, in practice it is very difficult to get the whole team thinking about users.

To obtain real information about a target group, perhaps the most obvious approach – finding actual users and asking them – will not work for many reasons. The main one states that being a victim of a particular problem does not automatically bestow on one the power to see its solution. Designers should never let users directly affect the solution, although actual users are always valuable resources and deserve considerable attention (Cooper, 1999).

To deal with this issue, Cooper (1999) suggests a tool for organizing and presenting information about a project's target group: the personas technique. The author defines personas as imaginary people who represent real ones throughout the design process. Even though they are imaginary, personas should be defined with significant rigor and precision, they must perfectly figure as hypothetical archetypes of actual users. Still according to the author, project goals and personas are mutually defined by each other.

Pruitt (2006) gives some reasons that support the use of the personas technique. Two of them were considered more relevant for their insertion on this work:

- the first one is related to what have already been discussed on the first paragraph of this section: while designing, the more natural tendency is to be self-centered, not user centered. People usually tend to approach to a product based on their own needs and desires, even when themselves are not actually potential users for the designed product. Another common pitfall is to seek only for users who think exactly like the people in charge of the project while performing some user researches. Self-centered design results in inadequate products.
- second, as users are very varied, it takes great effort to understand their needs, desires, preferences, and behaviors. Besides, sometimes trying to cover some users' needs in given a situation necessarily means conflicting with pleasing others.

Expected results for a well-applied persona technique are pictures of the created persona and a detailed list of hobbies, activities, musical preference, food habits, etc. The persona needs a profile and a face, a physical materialization which will be observed by the designers, not to create different interpretation among the building team. Other pictures are also recommended to illustrate places the persona generally goes to, friends, pets, or objects he or she utilizes every day, as illustrated by figure 13.

According to Neves et al (2008), designers should define users based on all the information collected during the problem exploration process to describe and formulate personas with social and cultural characteristics of those users.

This technique consolidates and concludes all the searching for information process started on the market research. The entire process covered both product and user aspects with the objective to provide a broad and reliable amount of information for people involved on a design project.

By following the steps presented in this section, it is expected to designers to present a more structured knowledge and, with that, to be more capable of creating better solution for investigated problems and moving through the next steps of the complete framework.

Figure 13. A simple persona panel: user appearance and daily use objects (Travis, 2010).

2.4 Techniques for Generation of Alternatives

In his book, "Design Methods" (1992), John Chris Jones presented a model proposed in 1966 by Watts. One strong characteristic of this model is the lack of information about its steps. The 3 step framework covers the analysis, synthesis, and evaluation stages, and probably it figures as the most condensed methodological model ever formulated to design. Although, by observing the work of Vasconcelos (2009), it can be said that most of the investigated models derive from this primitive structure.

The problem exploration step and its techniques are inserted on the first stage, "analysis"; the generation of alternatives and all the creative methods are part of the "synthesis" stage; and finally, the techniques for selecting alternatives are performed at "evaluation" – a process in which alternatives are selected immediately after the being evaluated.

Understanding the design as a process of generating solutions means to comprehend the synthesis stage as the core of it. Accordingly, although some of the analyzed methodological models do not specify techniques for generating alternatives or even name it into the framework, every model has a mandatory stage of creation.

Names such as Morris Asimow (1968), John Chris Jones (1992), Donald Koberg and James Bagnall (Dubberly, 2009), Bernhard Bürdek (2006), Cal Briggs and Spencer Havlick (Dubberly, 2009), Bernd Löbach (2001), Gui Bonsiepe (1984), Bruno Munari (1997), John Gero (1990 & 2007), Nigel Cross (Dubberly, 2009), and Neves et al (2008) define a specific step for creation of solutions. It grants this step a considerable importance on the whole process.

According to Bomfim (1995), the appliance of techniques capable of raising creativity in order to accelerate the process of ideas generation dates back to the decade of 1930. Over the years, these techniques were improved and even new methods were developed deriving from the old ones. Furthermore, these techniques can be divided between those which explore the creative process and the ones focused on exploring the logical process.

For Baxter (2000), once under the creation step the designer should be focused on the ideas, only. The practical restrictions must be left aside for a posterior stage. The search for these ideas should also happen outside the problem domain, this way finding really innovative ideas. Several are the techniques Baxter presents in his book, and he creates three categories for them: techniques that explore ideas inside the problem domain only, by looking at the product itself and changing feel aspects; techniques that explore ideas beyond the problem domain, by looking for free association; and techniques that propose a shift between the two scenarios, going from the problem domain to broader domains by using lateral thinking.

Neves et al (2008) assert that the main goal of the techniques for generation of alternatives is to expand the range of possible solutions for an artifact. Among the suggested techniques, the author mentions the brainstorming technique, coined by Alex Osborn in 1953 in his book "Applied Imagination"; the morphological box, first introduced by Zwicky and Wilson (1967); analogies and metaphors, a technique in which the designer should formulate free associations between the given problem and distant areas of knowledge or concepts, such as "what if my product could be just as transparent as a wet glass?"; and the brainwriting method, a constructive and collaborative reunion focused on evolving the ideas previously taken, which was the chosen method for the experiment.

2.4.1 Technique Chosen

The choice of the brainwriting technique, more precisely the 6-3-5 method is due to its extensive reference in many books and articles, being defended by several authors such as Silverstein et al (2009), VanGundy (2005), Jay (2000), Baxter (2000), and Bomfim (1995), among others.

The technique, also known for its quick, easy, and well-structured appliance, is recognized for being one of the best ways to guarantee a large number of ideas in a group (VanGundy, 2005).

Since it is a method for generating and evolving several ideas at the same time (Jay, 2000), the 6-3-5 version of the brainwriting was chosen as the technique to help the design teams to generate ideas during the creation process. Others techniques for creating ideas were not applied in the experiment for different reasons further discussed when explaining the experiment. As for this step, the author of this work believes this method can handle the generation of alternatives properly.

2.4.2 Method 6-3-5

Jay (2000) defines the brainwriting as a silent version of brainstorming, one of the most famous creative technique, in which members of a group offers ideas as they think of them, being as inconsequent and imaginative as they want to. In brainstorming, the ideas are said out loud enough to a specific member of the team to write them down on a flipchart or board. In brainwriting the generation of ideas occurs differently.

By simply taking the verbal interaction out of the process changes the method a lot. In fact, this is one of the most important characteristic of this technique. It removes the possibility of the group leader favoring any participants as well as offers a quiet atmosphere for both talkative and introspective people, providing equality as regards to this aspect.

Still according to the author, the brainwriting is not only a written version of brainstorming. It has a strong emphasis on building on each other's ideas. This way, it can even lack a little in spontaneity, but gives everyone an equal input.

Although the ideas can be registered in many different ways, such as cards, boards, or paper strips, the idea behind the brainwriting is basically the same: each group member does his / her own annotation for a predetermined period of time (Baxter, 2000).

One of the possible variations of the brainwriting technique, the method 6-3-5 can be understood as a more structured approach to it. As the name suggests, it means a team of six people generating or building up three ideas in cycles of 5 minutes.

Using this technique is particularly helpful when team members hold back because of the group makeup or the domination of certain participants is perceived. This way, a chance for everyone to express their ideas is given without commentary or criticism (Silverstein, 2009).

VanGundy (2005) discusses the history of the 6-3-5 method and presents three variations for the same process. The first one was created by John Warfield and others; Horst Geschka developed the second version; and the last one was originated by creative consultants in Germany and Holland and further improved by Tudor Rickards at the University of Manchester. The development of these techniques occurred basically on the seventies. They almost do not differ from each other, except the third variation, which is slightly more structured and presents no time limit.

The 6-3-5 method described next – and hence utilized in the experiment – has it basis on the first two variations commented previously.

Bomfim (1995) explain how this technique happens. The team should meet in a room and compose a circle. Each participant is given a sheet of paper with three columns and a pencil. On the paper, each one must register three different ideas – one for each column – in words, draws, schemes, formulas, etc. This step cannot last more 5 minutes. Right after finished this step, the form is evenly passed to the neighbor on the right. Now, each member must read the ideas created so far and register three ideas more. These ideas can be either completely new or derive from previous insights, by improving, questioning, or changing feel details. The cycle repeats itself until after 30 minutes each participant receives his / her on sheet of paper.

Figure 14 illustrates a form employed on a 6-3-5 session after it was finished. The problem in question was that thirty-five percent of the people who begin the registration process on a website fail to complete it before leaving, this way: how to reduce the number of booking transactions not completed on this website?

Brainwriting 6-3-5	**Job To Be Done:** Reduce number of booking transactions not completed on our web site	Date: 30-Oct-07 Team: 1 Member: Elizabeth
1	2	3
Provide login before starting the process so customer can restart at the appropriate point.	Provide paper catalog with quick codes to identify course and use with client profile to make booking.	Send automated e-mail to find out why transaction wasn't completed and offer help.
Store user details locally so the system recognizes them.	Make web site search function more accurate and user friendly.	Follow up with phone call on incomplete transactions.
Allow multiple customers to book the same course with minimum effort.	Allow customers to amend their course selection details rather than having to start again.	Provide a way to hold course bookings for 24 hours until payment is made.
Reduce the number of fields customers must complete.	Make web site easier to use.	Provide customers with incentives (bonus materials or special pricing).
Allow customers to book multiple courses during the same transaction.	Simplify online ordering process.	Give discounts for bookings completed with a single transaction.
Provide user with booking history and list of incomplete transactions when they login.	Add a pop-up window to alert users that they are closing the browser without completing the transaction.	Recommend courses based on the user profile.

Figure 14. Example of a 6-3-5 board after all cycles are done: three initial ideas that could be followed by another three completely new ideas or improvements of past solutions (Silverstein, 2009).

2.5 Techniques for Selection of Alternatives

Techniques for selecting alternatives are usually explained and taught together with those for generating alternatives, due to how close both steps are placed on methodological models. These two stages sometimes even occur simultaneously, since some techniques for generation of alternatives involve selecting the best solutions concomitantly.

Nevertheless, in accordance to the selected techniques for both steps, it was decided to detach them into two different sections of this document, once they present clear beginning and ending, making any parallel process impossible.

According to VanGundy (2007), although generating ideas is an underlying task for the design process, it is not a sufficient condition for innovation. Creation involves more than just coming with ideas to give a problem a solution. Ideas somehow must be decreased in number, assessed, and further narrowed down so that one or more potential solutions can be implemented. To achieve this, techniques of selection are crucial and must be applied.

However, it is important to distinguish between selection and evaluation. Fundamentally, the difference lies on the sequence of both activities. The process of evaluating an idea precedes the idea selection, since some basis is needed for choosing among alternatives before any choice can be made. Then, after applied this basis, the selection process can happen with much less effort for choosing (VanGundy, 2007).

Although generally ideas are selected with little consideration – designers often select among alternatives without any conscious awareness of possible criteria for helping them – and it can even work out very well in some situations, it can be disastrous when looking for high-quality solutions. All criteria must be well-established and understood for everyone involved in the process in order to increase the odds of choosing the best alternatives. Until now, the evaluation process took place when analyzing alternatives according to such criteria.

Afterwards, once the number of ideas was narrowed to a small group of the greatest solutions, the selection step takes place. To perform both steps the best way possible, VanGundy (2007) suggests guidelines to structure the entire process. The author divides it six minor steps.

- Assess Participation Needs: a considerable amount of time of each participant will be needed, the importance of selecting a high-quality solution must be specified, all participants must experience the evaluation and selection process according for their own professional development and accept the solution selected.
- Agree on a Procedure to Use: everyone involved must agree on a specific procedure to be followed for evaluation and selection.
- Preselect Ideas: when a team has large number of alternatives, they need to be reduced to a more workable number. There are many *ad hoc* approaches for performing this preselection and many others can be found on design literature.
- Develop and Select Evaluation Criteria: the design team should attempt to make explicit all the criteria it will be used, such as innovation or feasibility.
- Choose Techniques: the choice of techniques must take into consideration the ability of a technique to screen a large number of ideas, suitability for using the explicit evaluation criteria and weightings for each one of them, and feasibility of running it on time.
- Evaluate and Select Ideas: apply one or more techniques getting to one a just a little more alternatives for possible implementation and testing.

For Baxter (2000), the most important procedure during a project is to think on all the possible solutions and to choose the best one among them. Techniques for ideas' generation produce all the possible solutions; techniques for selection aim to find the best one. To complete this task it is necessary to have both product specifications and evaluation criteria well-defined.

As the author comments, many practitioners think that the creative part of the entire process ends with the step for generation ideas, which is generally a mistake. Being creative during selection is also necessary, once this step provides a great opportunity to expand, develop, and combine ideas to reach the final ideal solution.

Many other authors – basically the same commented on section 2.4 – place an evaluation and / or selection step into their frameworks, some of them defend the use of specific techniques. Neves et al (n.d.) defines a circular structure for what he named "2nd generation methods" and a similar model called XDM. The former encompasses selecting an idea, testing it, and describing it as the last three steps of the process, while the latter changes the testing step by the evaluation of alternatives. For this document, as introduced previously, the first model will be taken under consideration.

2.5.1 Technique Chosen

The technique chosen for being applied in the experiment was the Pareto analysis. This technique is based on the Pareto principle and its use guaranteed very satisfactory results when applied to students on academy, which is exactly the scenario for the experiment.

Although several references may be found on the Pareto principle, the Pareto analysis method for selecting alternatives is not very commented in design literature. Therefore, the technique will be supported mainly by the work of Juran and Godfrey (1998), one of the main references to the Pareto principle, and Souto Maior et al (2008).

The Pareto analysis technique can be found in two different variations on design literature: one suggests it should be utilized as a supporting tool for identifying relevant problems and solving them; the second variation – the one brought to discussion in this document – defends the execution of this technique during the selection of alternatives.

2.5.2 Pareto Analysis

The Italian economist Vilfredo Pareto observed in 1906 a series of phenomenon basically related to wealth, in which roughly 80% of the effects come from 20% of the causes. For instance, at that time he described the lands' distribution in Italy as if 80% of all lands in the country were owned by only 20% of the population.

Although, according to Juran (1975), the term "Pareto principle" was coined by himself, when he referenced Pareto's findings in wealth for a broader appliance – as general, universal. Almost one hundred years ago, Juran observed that quality issues were unequal in frequency, and a relative few of the defects accounted for the bulk of the defectiveness. Thus, he stated the principle of the "vital few and trivial many". However, thenceforth this idea became known as the Pareto principle. Figure 15 illustrates graphically the idea behind this principle. It is important to notice that many other correlations could be applied for this chart, such as "problem x impact" or "alternatives x points", as will be explained later.

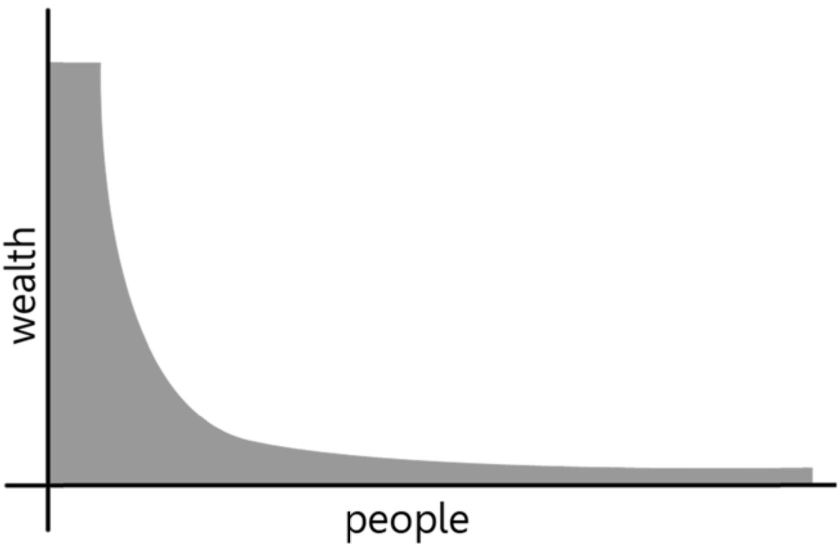

Figure 15. Pareto principle represented by a long tale: about 20% of the people on a given population hold almost 80% of all available wealth.

Juran and Godfrey (1998) defines the Pareto analysis as a tool mainly used to establish priorities by dividing effects into what they call "vital few" and "useful many". A diagram of this analysis should present (1) contributors to the total effect ranked by its magnitude, (2) the magnitude itself of each contributor expressed numerically, and (3) the cumulative-percent-of-total effect of the ranked contributors, as can be observed in figure 16. There are several other models for displaying information of a Pareto analysis.

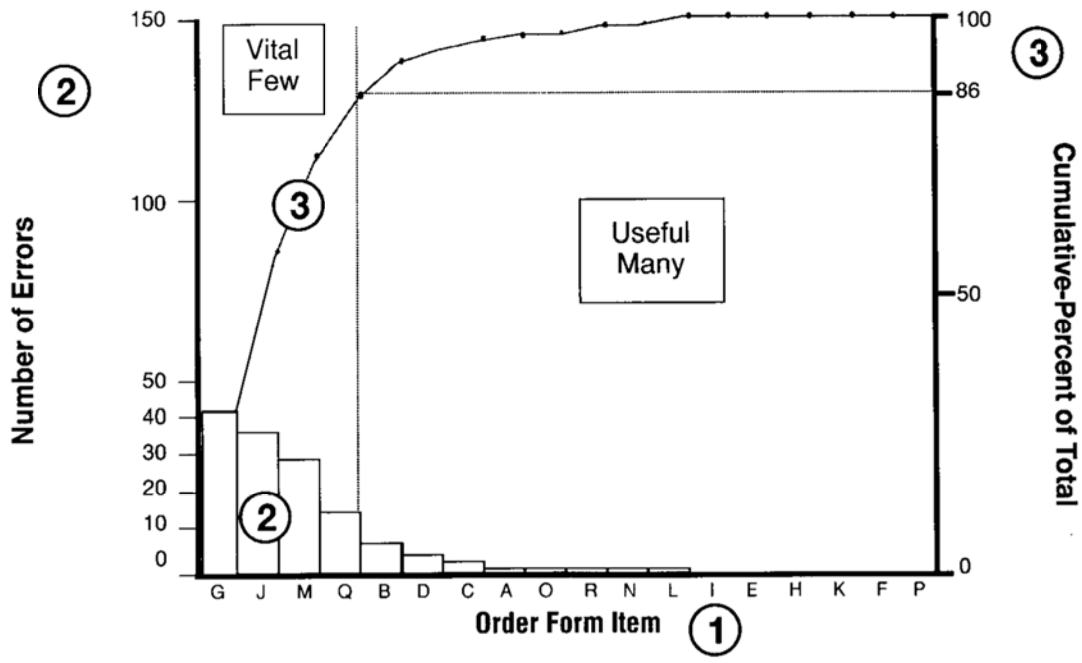

Figure 16. Diagram of errors on order forms. It follows the Pareto rule once the contributors G, J, M, and Q are responsible for 86% of the errors' amount (Juran & Godfrey, 1998).

By analyzing the diagram it is possible to understand this technique as a tool for problem solving. It identifies the problems involved on a specific scenario, and then ranks them by their importance (magnitude). Thus, those few problems responsible for most of the causes – and then the most critical ones – should be taken as priority for being solved.

Regarding the problem of selection ideas, the Pareto analysis suggests that if we score among several alternatives according to a reasonable criterion, the alternatives with best ratings will represent about 20% of total solutions analyzed. This way, the range of possibilities is narrowed down to small number and choosing one of them is made much easier. Even more, the alternative with the best score can be chosen immediately (Souto Maior et al 2008).

The steps for using this technique are four:

- list, and group if necessary, all the alternatives previously generated;
- define a criterion (one or more) to be taken into account for the process of selection;
- assign a number of points to the alternatives according to this criterion – each team member has a limited amount of points to score alternatives and the number of points to distribute is generally 20% higher of the total of alternatives together, in order to decrease the odds of draws between alternatives.

- the highest scores guarantees the solutions with best benefits, therefore those or that one to be chosen.

Finally, after selecting the alternative, the project comes to the stage of testing and developing prototypes, before any formal documentation or industrial production could be done.

3. RESEARCH METHODOLOGY

This chapter describes the methodological approach which directed this work as well as the setup for the experiment carried out. It also presents the results and discusses the main findings observed after analyzing the experiment outcomes. In order to guarantee quality and reliability of its results, the entire procedure followed established scientific standards. Research characteristics and all steps involved for this process will be detailed next.

- Research type and scope

Initially, it is important to notice that two different researches were carried out in two separate moments. The early research aimed to provide a minimal grounding for this work, which referred to the lack of scientific publication as regards to design methodology testing. This was essentially a bibliographical research based on publications of the considered most important design journals.

The final research is defined as an experimental and descriptive research, presenting also both literature exploration and results interpretation steps. This research aims to confirm the two hypotheses of this work, which deal with the influence on using problem exploration techniques on the designers perception of their expertise on the problem and the same influence on how well-evaluated are the alternatives generated by them.

As the first research was already performed and its results discussed previously in sections 2.2.2.2 and 2.2.2.3, the present section will focus its description on only the last research.

- Method

It was applied the Hypothetico-deductive model for part of this research, once the hypotheses will be put to test through an experiment to get to conclusions. First, an observation is made in design literature as regards to the presence of the problem exploration step in several methodological models; this observation is deduced and molded into a hypothesis; an experiment is organized to confirm if the predicted consequence is observed; and finally conclusions can be taken.

- Scenario

The scenario chosen for applying the experiment was elected due the ease and feasibility needed. The experiment took place inside the academy, at the Federal University of Pernambuco – UFPE – with design students who were already taking classes of techniques for generating and selecting alternatives during the semester. The activity given was similar to those the students usually do every semester and the theme chosen belonged to the digital artifacts context, which is the regular scenario for the projects carried out semiannually in class.

Since the object to be investigated is the problem exploration techniques, the scenario chosen was formidable because all participants were supposed to have the same knowledge about other techniques involved in both the design process and the experiment. This way, the task of isolating the use or non-use of problem exploration techniques could be done more easily.

- Research Population

In addition to the arguments for the scenario election commented before, the choice of the public involved in the experiment is justified for the origin of the studies in design methods, which is the academy. Thus, about thirty students from a design course in Pernambuco – Brazil – were participant of the experiment, performing research of investigation, applying knowledge learned in class, and designing solutions during weekly meetings for about four months.

Even though the participants were still students, from now on they will be called and treated as designers, once the figure of the designer is seen as the person who carries out projects, who plans and develops solutions, and no title is required for that.

- Data collection

This research will make use of the following methods for data collection for its accomplishment: bibliographical investigation in design literature (books and journals); methods for gathering information from participants, such as questionnaires and self-reporting scales; methods for observing systematically the collected data; analysis and comparison of the experiment's results; and methods for evaluating these outcomes.

3.1 Research Structure

For a better understanding and visualization of the entire process involved in this research, all the steps and the activities done for each one of them will be explained next, from the experiment planning until getting to the conclusions of this investigation. The procedure can be structured in a seven major steps scheme. The time taken in order to complete each step is also listed.

- [1] Experiment planning (four weeks):
  - definition of objectives and scope for the experiment;
  - definition of environment and public;

definition of steps and cycles;

definition of techniques for generating and selecting ideas;

adjustments and changes into the methodology;

preparation of a list of ideas for projects to be executed; and

identification and organization of all resources needed for the execution.

- [2] Investigation and teaching (two weeks):

design literature review on methods for problem exploration;

selection of the set of techniques chosen for being taught to students and applied in the experiment;

classes' planning and organization of all teaching material needed; and,

lectures about the design process.

- [3] The experiment itself (six weeks):

pilot experiment-1 – selection of the ideas of projects to be execution;

pilot experiment-2 – confirmation of the three selected ideas;

questionnaire-0 application and first cycle of activities;

lecture about techniques for exploring the problem;

questionnaire-1 application and second cycle of activities;

lecture about techniques for exploring the problem;

questionnaire-2 application and third cycle of activities;

lecture about techniques for exploring the problem;

questionnaire-3 application; and

lecture about techniques for exploring the problem;

- [4] Recording and analysis of former results (one week):

recording, observation, and analysis of the questionnaires' results;

quantitative comparison of the collected data; and

preparation of the material to be submitted to experts' evaluation.

- [5] Evaluation (one week):

selection of parameters for evaluation;

selection of experts for evaluating the designed alternatives; and

elaboration of digital questionnaires sent to evaluators.

- [6] Recording and analysis of latter results (one week):

recording, observation, and analysis of the evaluation forms' results;

quantitative comparison of the collected data; and

statistical analysis;

- [7] Conclusions (one week):

interpretation of the two separate group of results;

establishment of correlations between them; and

conclusions.

As can be observed, the research in which the experiment was inserted took about sixteen weeks for its completion. From all seven steps listed previously, the one with more activities and therefore the most important for being discussed and detailed is concerned with the experiment itself. This step will be scrutinized on the following section.

3.2 Experiment Setup

This section aims to describe the entire experimental procedure. However, before getting to details of each activity executed, it will be commented the overall process applied in this experiment.

In order to test how the utilization of techniques for problem exploration affected the final solution of a design process, five groups of six designers each were participants in this experiment. The choice of five groups composed by six members each is based on the structure already established for class activities and for allowing a perfect match to the 6-3-5 technique execution. Each group should follow a similar framework of methods except for the first step of the process, which could take three different procedures:

- designing without methods for collecting data (with no methods – WNM), which is skipping the problem exploration step,
- designing with random methods for collecting data (with random methods – WRM), which is searching for information without a defined methodology or criteria; and
- designing with structured and detailed methods for collecting data (with structured methods – WSM), which is searching for information following a defined methodology that was properly explained.

This way, although the steps of creating alternatives and selecting them were still the same for all five groups and the same techniques chosen were applied, the process differed substantially as regards to the problem exploration step.

Even though the participants were supposed to present similar level of knowledge and expertise on problem solving activities, different groups should be submitted to different scenarios in order to avoid bias related to more capable groups of participants. Thus, the groups should execute three cycles of projects for all three scenarios: WNM, WRM, and WSM. Nevertheless, for guarantying reliability for the experiment, the problem under investigation should be the same, this way presenting equal levels of difficulty for all scenarios. Finally, applying the same problem to all groups for three cycles of development would possibly induce gain of knowledge about the given problem, hence compromising the whole experiment. So, how to avoid that?

It was assumed that, once the negative aspect about using the same problem repeatedly was the gain of knowhow, it could be found three different ideas for projects that presented a similar underlying characteristic for being applied on the experiment: the knowledge participants had about the investigated problem before starting the project. To achieve that, a massive brainstorming was performed focused on producing ideas for projects; problems to be solved.

After selecting the considered best ideas for execution in the experiment, a total of sixty four alternatives figured as possible problems to be confronted by the participants. The criterion for selecting the ideas was to pick those with non-trivial resolution. All sixty four problems are shown in table 2.

Table 2. Sixty four problems: the selected alternatives and possible ideas for projects.

1 – Self-cleaning dishes	2 – Multipurpose and adaptable cutlery	3 – Height adjustable pillow	4 – Supermarkets without lines
5 – Smart hospital beds	6 – Portable sound box	7 – Retro mobile phone	8 – Electronic waitress
9 – System for home security	10 – Adaptable mouse	11 – Innovative pressure cooker	12 – Portable videogame
13 – Remote control car	14 – Anti-mosquitos system	15 – Subaquatic camera	16 – Interactive business card
17 – Smart curtain for windows	18 – Socks for preventing fatigue	19 – Innovative alarm clock	20 – Permanent painless tattoo
21 – Bikes for trails	22 – Bikes with falls prevention	23 – Portable bike	24 – Autonomous ironing system
25 – Portable desk	26 – Anti-theft backpack	27 – Adaptive Cap	28 – Innovative wristwatch
29 – Massage chair	30 – Smart closet / wardrobe	31 – Reusable paper	32 – Smart and cheap clothes
33 – System for supporting blind people on public transports	34 – Backpack for teenagers at school	35 – Management system for cars at Universities	36 – Super comfortable wheelchair
37 – Mobile phone charger with no need of electric energy	38 – System for home food supply	39 – System for preventing car collisions at roads	40 – Condom with ultra-fast application
41 – New contra conceptive	42 – New device for human-computer	43 – A mechanism which shaves you	44 – Device for monitoring vital

	interaction	according to pre-selected beard models	signs regularly
45 – Innovative sound system for cars	46 – Smart system for cooling rooms	47 – Smart communication system for rooms	48 – Identification and monitoring system for luggage at airports
49 – Mp3 players for hearing impaired people	50 – System for prevention and monitoring of fires in forests	51 – System for prevention and monitoring city flooding	52 – Security device against car thieves
53 – System for water reuse at home	54 – Device for supporting blind people on shopping activities	55 – System for helping drivers on parking lots	56 – Smart shopping carts
57 –Digital Projector with very low energy consumption	58 – System to reduce waiting on doctors' offices	59 – System to make the service on gas stations faster	60 – System for home lighting without electric energy
61 – System to dry people when leaving swimming pools	62 – Silent packs for candies	63 – Glasses with smart lenses	64 – System for testing products bought on the internet

These sixty four ideas were put to the participants' evaluation. They should score each one of them from zero to ten regarding how well-informed they were about the suggested problem in order to identify those with low and similar scores. The ideas were generated regardless how innovative they were. There is no specific reason for defining this number of sixty four alternatives. While a large number of alternatives would raise the probability of identifying three similar ones, an extensive list would also tire participants while scoring each one of the ideas of problems.

In the pilot experiment-1 (table 3), the sixty four ideas for project were presented to the designers and they were asked to score them individually. As expected, the problems got low ratings. However, after analyzing the results and comparing average scores and the standard deviation for the evaluation of each alternative, it was perceived that the data was slightly inconsistent. The standard deviation was considered high, which indicates that the ratings for the same alternative were too discrepant. This could represent the presence of outliers among the participants, what could harm the need of homogeneous groups as regards their expertise on each problem.

Despite of any inconsistency on the results, it was clearly possible to identify the alternatives with lower averages and standard deviations. These alternatives were: 24 – an autonomous ironing system; 43 – a mechanism which shaves you according to pre-selected beard models; and 61 – a system to dry people when leaving swimming pools.

Table 3. Pilot-1: First speech caused acceptable averages but significantly high standard deviation scores.

	Problem 24	Problem 43	Problem 61
Average	2	1.8	1.4
Standard Deviation	2.4	2.5	1.8

A possible cause for these results was identified. The speech applied when asking the participants to score alternatives was too complacent and possibly gave space to multiple interpretations.

To confirm this hypothesis, again the participants were asked to respond to the list of problems and rate them, but now a stricter speech was applied. The designers should respond now according to if they have ever investigated about the suggested problem or its technologies or if they had significantly knowledge about it, either theoretical or practical. As expected, averages and standard deviations presented lower results and from all alternatives evaluated, again the 24, 43, and 61 were those with lower and more similar results, as can be observed in table 4.

Table 4. Pilot-2: Second speech caused lower averages and standard deviation scores.

	Problem 24	Problem 43	Problem 61
Average	0.7	1.0	0.5
Standard Deviation	1.1	1.4	0.7

Finally, the identification of these three problems solved the question of using similar challenges (but not identical) in each one of the three cycles of activities through which the designers should go. Still, once the choice of the three problems selected for the experiment was properly detailed, it is easier to understand the next cycles of activities by observing table 5.

White WNM cells represent cycles in which there was applied no method for exploring the given problem, and therefore regular results are expected; light gray WRM cells represent cycles in which there was applied any random method chosen by the participants for exploring the given problem, and therefore better results are expected; and at last, dark gray WSM cells represent cycles in which there was applied the selected set of seven techniques for exploring the given problem, and therefore the best results are expected from these cycles.

Table 5. Different procedures of each group regarding to each problem given.

	Problem 24	Problem 43	Problem 61
Group 1	With No Methods (WNM)	With No Methods (WNM)	With No Methods (WNM)
Group 2	With No Methods (WNM)	With Random Methods (WRM)	With Structured Methods (WSM)
Group 3	With Random Methods (WRM)	With No Methods (WNM)	With Structured Methods (WSM)
Group 4	With Random Method (WRM)	With Structured Methods (WSM)	With No Methods (WNM)
Group 5	With Structured Methods (WSM)	With Structured Methods (WSM)	With Structured Methods (WSM)

The disposal and combination of the three different procedures among groups and problems are described next:

- groups 1 and 5 work as control groups: they perform the same process for all three cycles of activities. Accordingly, based on the second hypothesis of this work, group 5 should always present better solutions than the mean of other groups' results and group 1 should behave on the opposite direction;
- group 2 executes the three different procedures: it is expected that this group presents better results over time once it is going from the non-use of methods to the use of structured techniques;
- group 3 executes the three different procedures: it is expected that this group produces good, regular, and better results in this order; and
- group 4 also executes the three different procedures: it is expected that this group produces good, better, and then regular results in this order.

It is important to notice that there is no combination such as WRM after WSM in order to prevent possible bias. Groups executing random research after performing structured research are likely to apply the knowledge learned previously even that it is not on their purpose. Nevertheless, there was found no problem on arrangements like WNM after WRM or WNM after WSM, once groups following the procedure with no methods at all were explicitly asked to skip the problem exploration stage, hence presenting no risks of biasing.

Concluding, all the argumentation for the experiment can be summarized below:

- the three cycles of activities performed during the experiment provides it the three different procedures to be executed by the participants;
- the particular ideas for projects (problems 24, 43, and 61) guarantees that no group took advantage on any knowledge acquired on previous cycles of designing solutions;
- the selection of the problems based on the information the designers had before starting the projects ensure that all cycles presented equivalent challenges as regards the problem exploration step; and finally,
- making use of five distinct teams throughout the experiment execution aims to cancel any difference on skills among groups;

3.2.1 The Three Cycles

All three cycles of activities had theoretical and practical works inside and outside the class environment.

The first cycle began with the division of groups in class. Then, the questionnaire-0 (Q0) was applied, which is quite similar to those utilized in pilot experiments 1 and 2. Now, the designers were asked to respond only to the three problems using the same criterion of pilot experiment-2, when a stricter speech was applied. This step was important to collect a final score for each problem and recording it for future comparisons. The Q0 defines what the average rate is for each problem according to each group before any activity is done. This is crucial for responding to the first hypothesis of this work, which deals with the feeling of knowledge gaining by the participants.

After responding to Q0, it was properly explained to all participants what should be done for the week – each cycle had one week duration. The overall design process was explained and illustrated as well as every step detailed with the support of graphical schemes. It was described the four step procedure they should carry on:

- each group performs the first step according to its number (1, 2, 3, 4, and 5);

- the second step for the generation of alternatives should be completed by applying only the 6-3-5 technique for all groups;
- the third step for the selection of alternatives should be completed by applying only the Pareto analysis technique for all groups;
- each group details the selected solution for the problem 24 on two sheets: one should present written specifications involving fundamental aspects such as shape measures, functioning, and resources; and the second sheet should present visual representations for the final alternative.

As for the first step, following exactly the suggested order for the seven techniques taught was not a requirement. The designers should proceed as they preferred and divide the work if they wanted to. The only mandatory rule was that everyone on the group should be aware of each technique's results before getting to the idea generation. In other words, even that one team member did not perform any historical research, all documentation for this method should be carefully read and understood by everyone on the group.

After this explanation for all teams and responding to any remaining doubt about the process, a thirty minutes lecture was given to group 5 in which the selected theory about all seven techniques was covered and practical examples were given.

One week later, the first cycle ends with the acquisition of the documentation from the five groups. Simultaneously, the second cycle starts with the appliance of Q1. This questionnaire now aims to gather information about the perception of how expert on the problem might be each group.

After responding to Q1, the cycle repeats itself, although now with different a problem (problem 43) and the lecture was also given to group 4. Again, the second cycle ends after receiving the documentation and the third cycle starts with Q2. Once more, participants respond to their amount of knowledge on the last problem. Finally, the problem 61 is given to the designers and groups 2 and 3 receive information about the problem exploration techniques.

After finished the third cycle, the participants should score the three problems for the last time on Q3, and the lecture is given now to group 1 in order to provide the same knowledge for every group, even though there is no activity to be executed anymore.

Concluding, as regards to the two hypotheses of this work, the process can be summarized as:

- the application of the four questionnaires (Q0, Q1, Q2, and Q3) searches for confirmation to the first hypothesis of this work; and finally,

- using three different scenarios (WNM, WRM, and WSM) provides to the experiment the confirmation or disproving of the second hypothesis of this work.

These three cycles of activities provided all the data necessary for the next step of the experiment, which is the experts' evaluation of what was produced by the designers: a descriptive document with details and sketches of the solutions. The preparation of the material to be sent for evaluation could be done simultaneously with the analysis of the self-reporting questionnaires to which the participants responded, the Q0, Q1, Q2, and Q3.

3.2.2 The Evaluation Process

To complete the evaluation process, the produced material corresponding to the conceptual alternatives created by all groups should be properly organized. All sketches were digitalized and saved to image files as well as the paper sheets. This way, with a folder structure formerly organized by problems and then by groups, image and text files were sent to over thirty potential evaluators. From the thirty-four people asked to take part in the procedure, twenty-one were actual respondents for the experiment.

The choice of the evaluators or experts happened in accordance to the experience had on developing solutions, criticizing concepts and products, or a vast knowledge on product development and technologies. This way, people from industrial design and related areas, such as informatics or engineering were chosen considering the requirements listed above.

Digital forms were applied in order to obtain responses from the selected experts. All the information necessary for evaluation was sent by emails which include a compressed file with all alternatives and a link for the digital form.

As for the criteria involved on evaluation, four parameters were chosen for being identified as overall aspects for defining satisfactory alternatives. They were: originality, adaptability, feasibility, and adherence to the problem. In case any of these parameters did not show itself clear enough to the experts' understanding, a descriptive phrase was added to each one of them, as can be observed in figure 17, taken from the digital form.

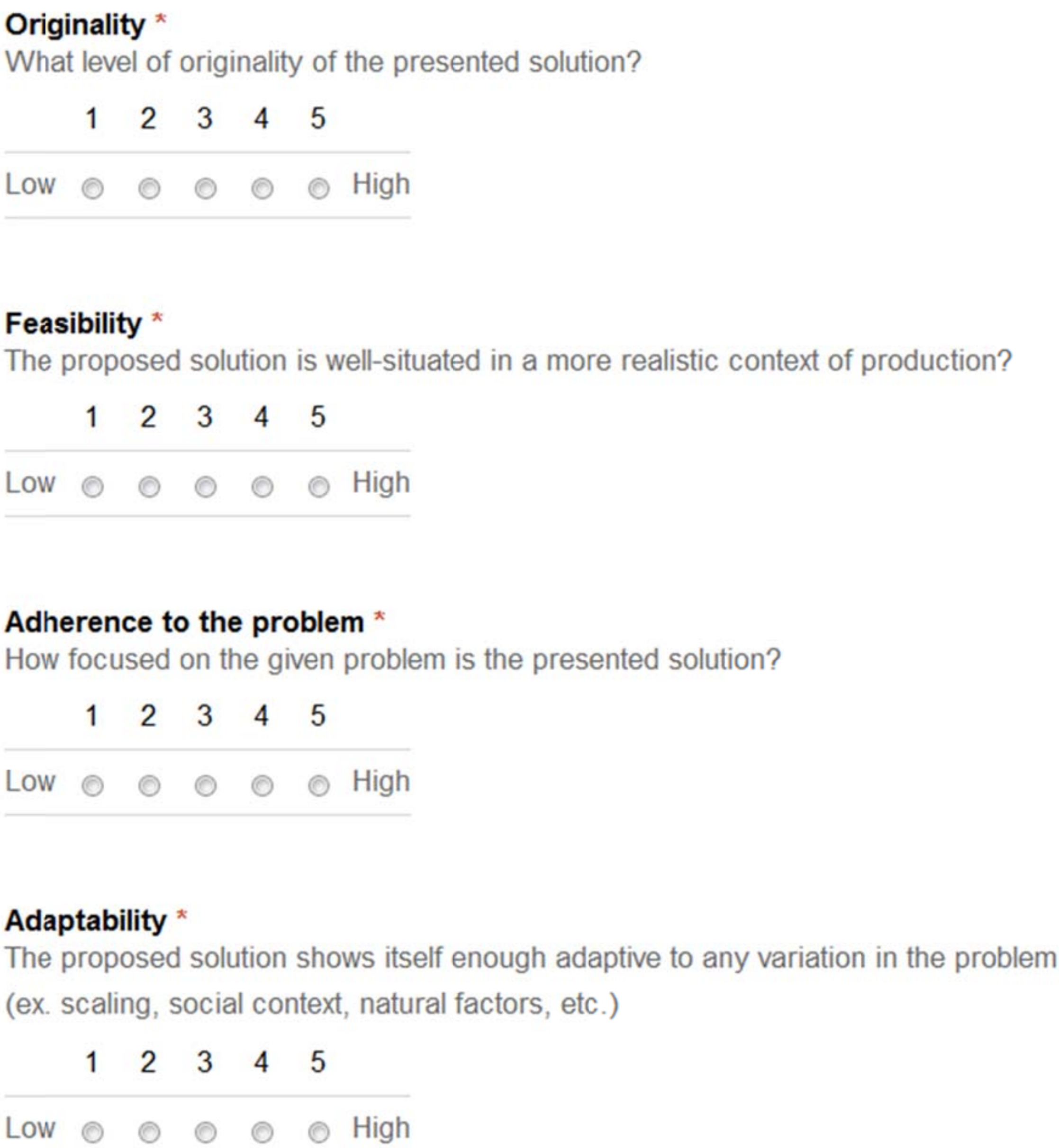

Figure 17. The criteria established for evaluation and all descriptions to help understanding.

A five point scale was utilized for respondents to choose between a high evaluation, which represent five points, and a low evaluation, represented by just one point. According to Stevens (1946), there are four types of scales for measurement:

- nominal scales, in which numerals are used only as labels or type numbers, and letters or words would also serve;

- ordinal scales, in which the data is put on an ordinal scale by rank-ordering. Each variable for measuring a given characteristic should belong to a class, and different classes are ordered according to a rank;
- interval scales, which is quantitative in the ordinary sense of the word and it gives support to almost every statistical measures for presenting quantitative attributes; and
- ratio scales, which are possible only when is possible to operate all four relations: equality, rank-order, equality of intervals, and equality of ratios. They are commonly used in physics or engineering and an absolute zero is always implied for this type of scales.

The scale adopted for measurement is from the interval type, and it was based on two known scales for measurement and self-reporting which are the Likert scale and the semantic differential scales, both interval scales as well.

Likert scales are commonly employed in questionnaires with several statements (Likert items) for which the respondent must indicate a degree of agreement or disagreement (Likert, 1932). Semantic differential scales, on the other hand, are scales in which the respondents indicate their attitude towards the object, using an itemized scale, with no statements but only two opposite parameters for placing respondents opinion between them (Brandalize, 2005). Both are discrete visual analog scales and they usually present an odd number of points in order specify a midpoint, which is neutral.

Before situating their opinion between 1 (low) and (5) high for each parameter, the experts indicated the problem under analysis and the group being evaluated. At the end of the form, one last scale was placed in order to identify if the different procedures taken in the three cycles of activities could cause any influence on how well-detailed the designers could describe each alternative. This way, the evaluators should also opine about the quality of the material received for evaluation for each problem and group (figure 18).

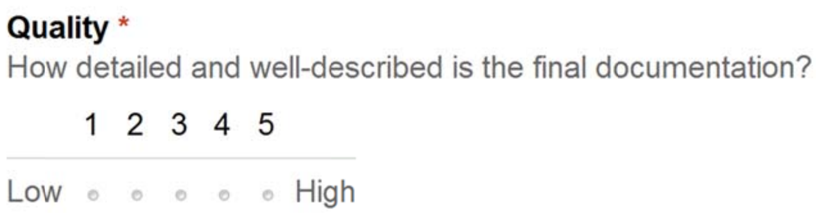

Figure 18. The quality criterion and its description to help understanding.

All twenty-one respondents executed the same procedure fifteen times in order to evaluate each one of the three problems of each group. Once finished the experts' evaluation, all results were collected and recorded in digital spreadsheets. Finally, all data was analyzed and the results are presented in the next section.

3.3 Experiment's Conditions

For a perfect understanding of the experiment arrangement and its results, it is critical to define all the conditions and restrictions involved, especially as regards to the replication of the process executed for this work.

First of all, the problems selected for the experiment had one important characteristic in common: they were chosen based on the lack of previous relevant information the teams had about them. The three problems presented at the same time the worst scores in pilot experiments and more suitable standard deviation.

In addition, problems or short detailed ideas for projects were given to the participants. There was no fully detailed briefing with general information such as target audience, budget, or shape constraints. This was a pragmatic choice, once using long and itemized briefings would cause fatigue when being analyzed by participants in order to identify those similar, as well as it would possibly bring more variables into the procedure.

Finally, the experiment schedule was definitely short. This way, all cycles were one week long and a very fast execution of the explained techniques was needed. Moreover, once the time for creation was short, the time for documentation and description was also tight. Thus, the level of details required for the solutions' description was not high. Two sheets of sketches and verbal description were enough to evaluate ideas or concepts. No final products were taken under evaluation for this experiment.

4. RESULTS

This chapter presents three groups of results: the initial responses to the four questionnaires employed to verify designers' perception, the alternatives created during the cycles of activities, and the final experts' evaluation for all alternatives.

4.1 Qn Results

The following four tables (table 6, table 7, table 8, and table 9) show the scores each group gave to each problem in four separate moments. Each cell represents the average mean of ratings of all members within a group. Again, white cells correspond to the procedure with no support of methods (WNM), light gray cells correspond to the procedure with random support of methods (WRM), and finally, dark gray cells correspond to the procedure taken with a support of structured methods (WSM).

For all questionnaires, the question asked for participants was always the same, regarding the amount of relevant knowledge the designers had about the given product or system at the time of responding the questionnaire. As commented previously, they should choose from zero to ten on a discreet visual scale.

It is important to notice that these first scores presented in table 6 can slightly differ to those presented in table 4 (pilot experiment-2). This is due to the subjectivity on responding to such question, what would possibly cause variation to responses every time responding to the questionnaire.

Table 6. Results for questionnaire-0, before any designing activity.

Questionnaire-0 (Q0)	Group 1	Group 2	Group 3	Group 4	Group 5
Problem 24	2.5	0.7	3.2	3	0
Problem 43	1.8	0.7	0.7	2	0.2
Problem 61	0.5	0	0.5	1.8	0

Table 7. Results for questionnaire-1, right after the first cycle of activity was executed.

Questionnaire-1 (Q1)	Group 1	Group 2	Group 3	Group 4	Group 5
Problem 24	3	2.7	8	8.4	6.8
Problem 43	1.2	1	2.2	3	0.2
Problem 61	1.2	0.5	1.3	0.8	0.3

Table 8. Results for questionnaire-2, right after the second cycle of activity was executed.

Questionnaire-2 (Q2)	Group 1	Group 2	Group 3	Group 4	Group 5
Problem 24	3.6	5	7.5	8.8	6.7
Problem 43	2.8	5.8	1	9	6.5
Problem 61	1	0.3	1.2	3.7	0.5

Table 9. Results for questionnaire-3, right after the third cycle of activity was executed.

Questionnaire-3 (Q3)	Group 1	Group 2	Group 3	Group 4	Group 5
Problem 24	3.8	5.2	5.3	7.7	6.5
Problem 43	1.8	6	6.7	7.8	5.8
Problem 61	2.4	6.8	6	6.7	5.7

4.2 Cycles

The fifteen alternatives generated by the participants are introduced in this section in both visual and textual versions. Initially, all solutions for problem 24 will be presented ordered by group numbers. Then, solutions for problem 43 and 61 are described following the same order. The textual descriptions will be condensed in order to provide here only the main idea behind each proposed concept.

Some of the sketches also contain textual information. Although these details could have been important during evaluation, they were considered not relevant for an overall understanding of each alternative in this document, thus not translated.

- Problem 24 – Group 1: a flat and hard surface has a magnet piece beneath it, and an iron piece located above it moves due to magnetism. The surface presents a system of coordinates in order to specify the iron movements. Size, tissue, raised prints, are settled before the process starts. The iron is heated by a rechargeable battery. The idea is illustrated by figure 18.

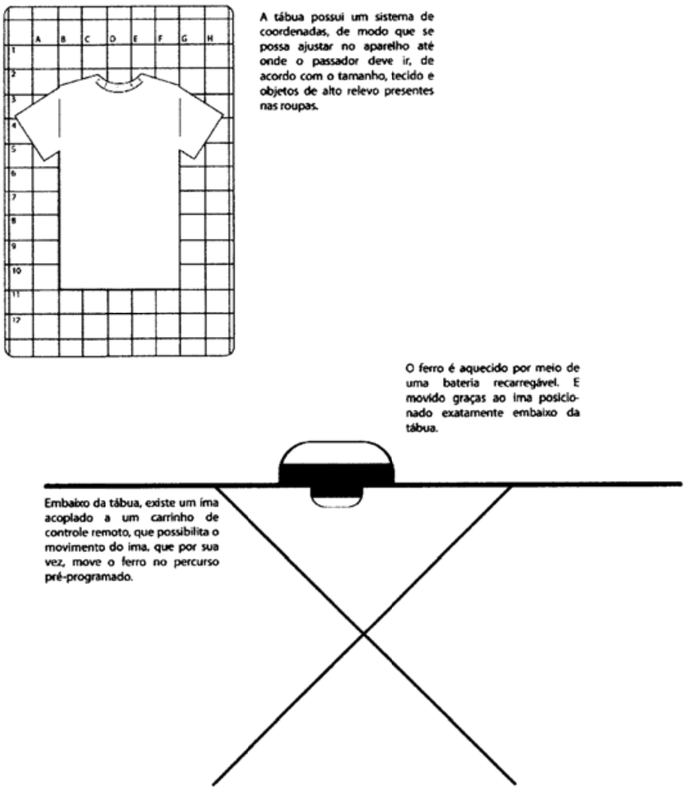

Figure 19. An autonomous ironing table.

- Problem 24 – Group 2: compressing rolls that can be placed anywhere at home. Small pores all over these rolls release water steam. The system is attached to a clothesline which leads the cycles. It requires electrical energy supply and the temperature and number of cycles are defined by the user. The idea is illustrated by figure 19.

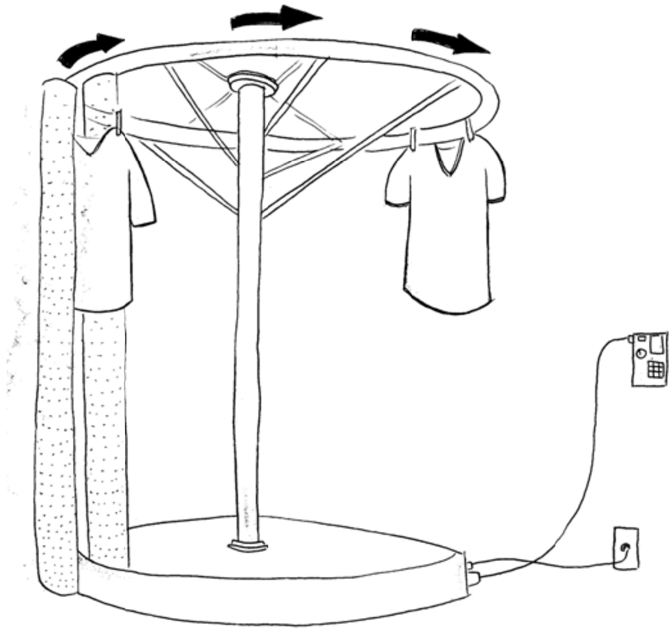

Figure 20. Steaming compressing rolls.

- Problem 24 – Group 3: it works like a smart wardrobe. In addition to the normal compartments, several wholes for air flow are found all over the structure, and specific temperatures could be defined to dry and "iron" clothes. The steam has a twofold role: smoothing clothes and sanitizing them. Clothes are hanged normally for this system. It has also a notifying system based on social networks to inform when the process is finished. The idea is illustrated by figure 20.

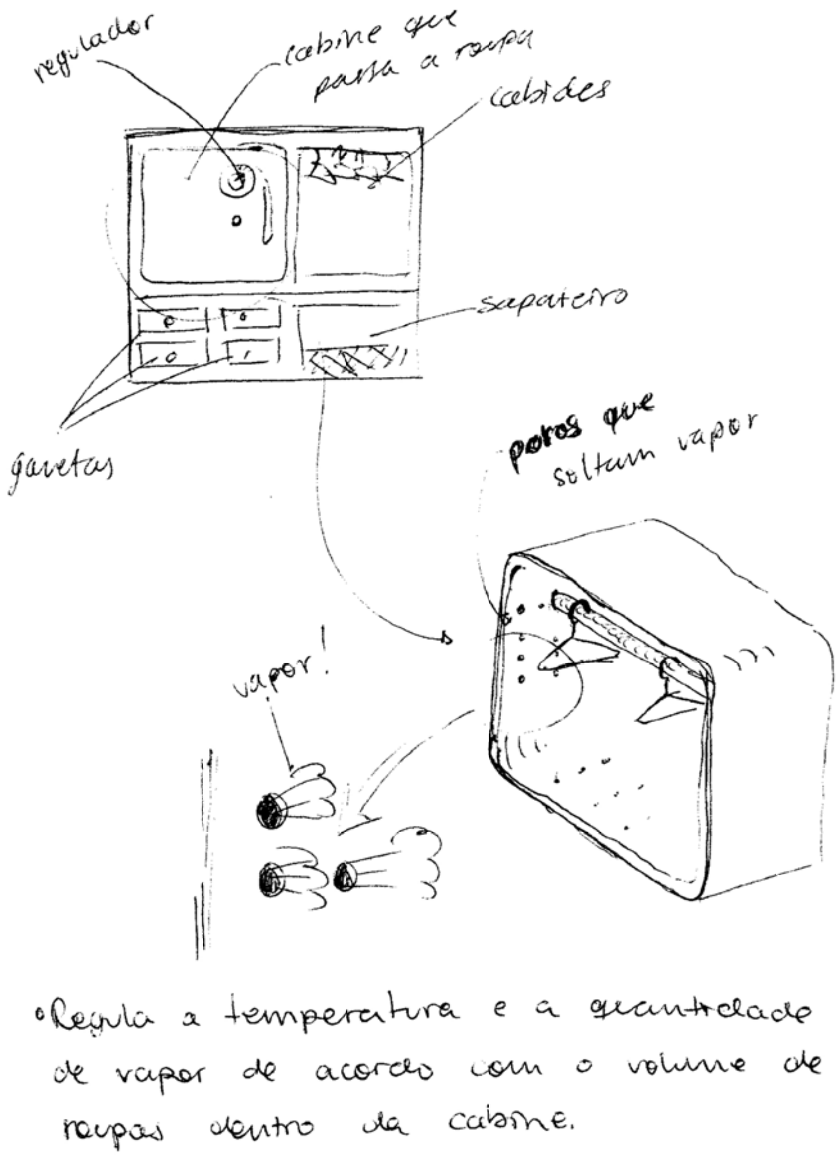

Figure 21. Smart small wardrobe.

- Problem 24 – Group 4: it looks like a portable wardrobe with a retractable clothesline. It can work with seven clothes at a time organized for levels of kneading. User can set the kind of tissue is being used choosing the most suitable program for it. Cooling and heating through a steam system is also a feature of this solution. The idea is illustrated by figure 21.

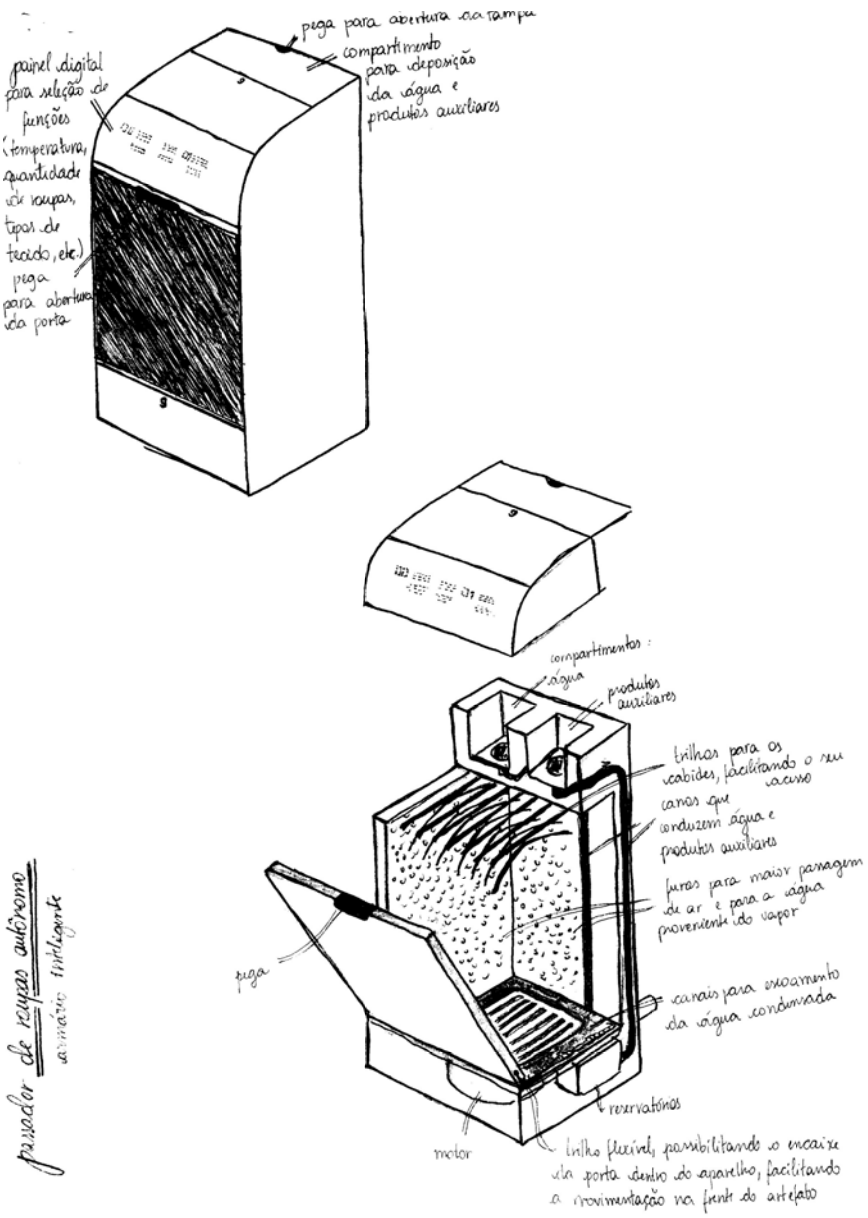

Figure 22. Automatic ironing machine.

- Problem 24 – Group 5: a water pump for releasing steam is connected to several covers which involve the clothes. These covers are hanged on a system similar to clotheslines. The pump has a display for interface with users. Several different programs can be defined by this interface. It user electrical energy and takes one hour to complete the process. The idea is illustrated by figure 22.

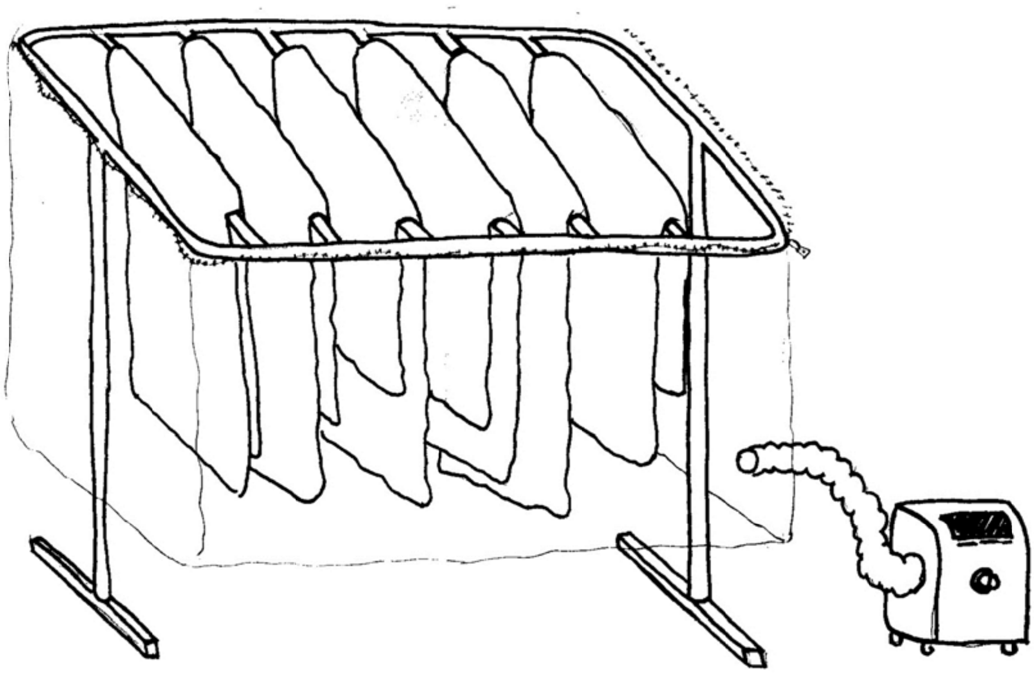

Figure 23. Steaming drying rack.

- Problem 43 – Group 1: thin and malleable sheets which can be cut, bent, or stretched in order to adjust themselves to user's face. These sheets are made out of a gel that after being stick to a wet face reacts in few minutes and causes the facial hair to fall. The product comes with several varied sheets for different beard shapes. The idea is illustrated by figure 23.

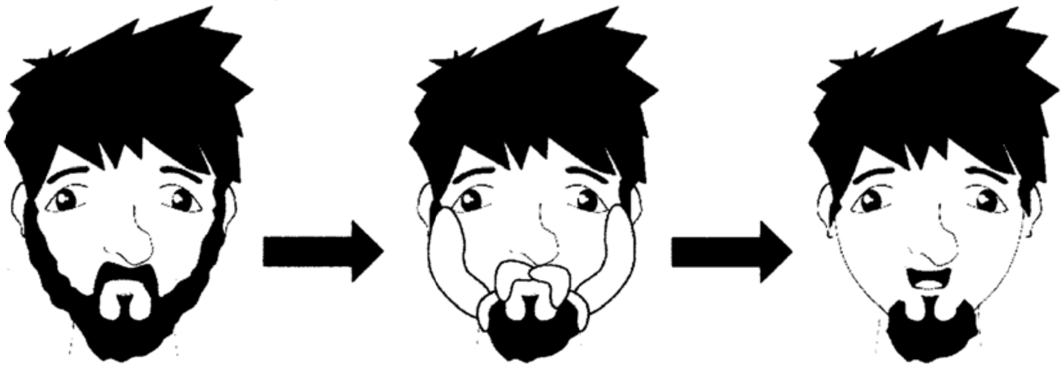

Figure 24. Gel sheets.

- Problem 43 – Group 2: in front of a mirror embedded with face detection and 3D reconstruction, the user has his face digitalized and he can modify his beard to a large variety of models. It also allows the user to test the result of any selected beard model is his face. After selecting, the information is transferred to a shaving mask, which can work based on depilatory cream or razors. The idea is illustrated by figure 24.

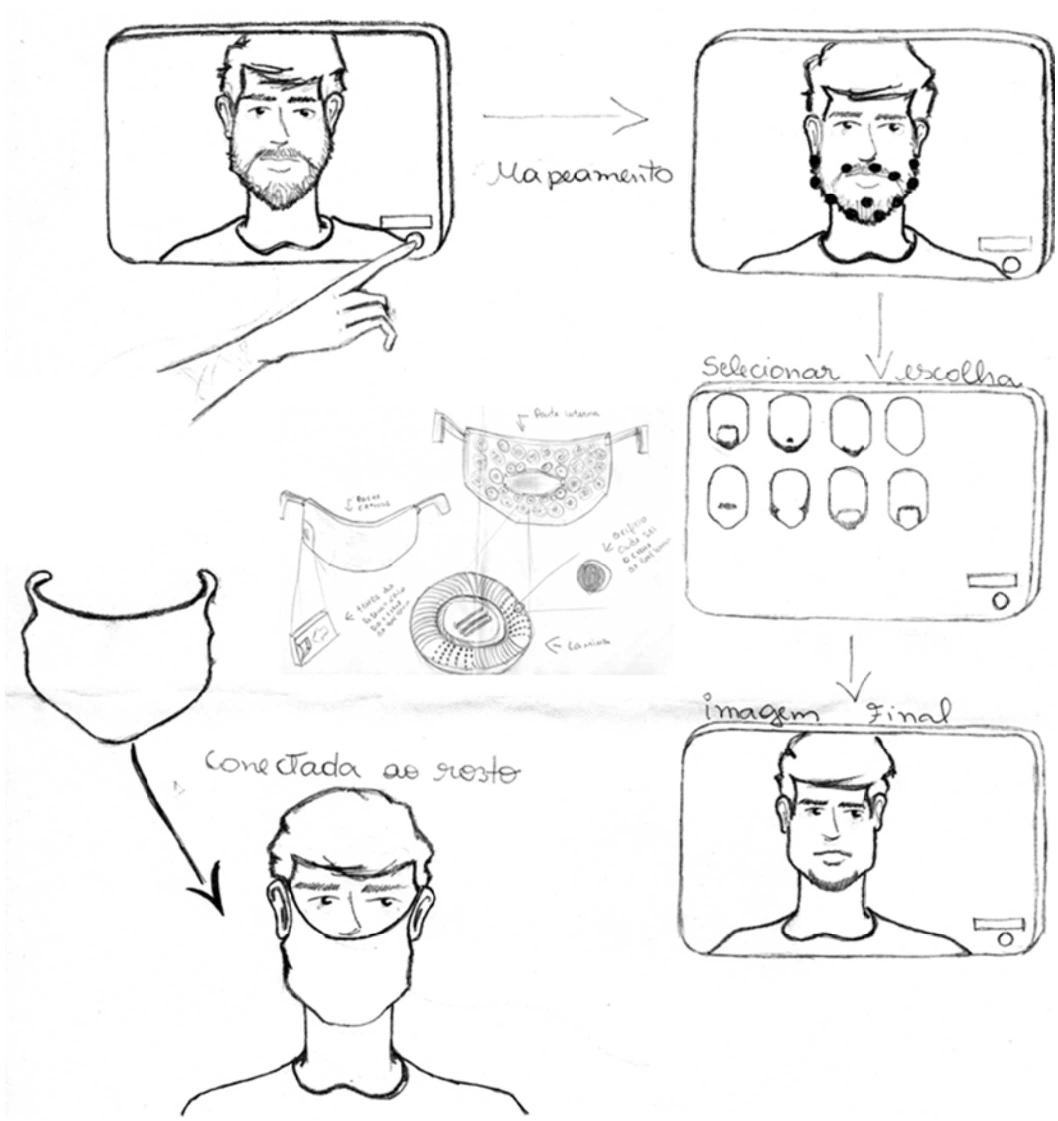

Figure 25. Interactive mirror and shaver mask.

- Problem 43 – Group 3: a software will perform face detection of the user face through a silicon mask connected to the computer. According to how the user has defined his beard on the computer, the mask releases depilatory cream only on the specified areas. The software can also suggest beard designs which are more suitable for each face. The cream is released by micro pores inside the mask and it takes a few minutes to get done. The idea is illustrated by figure 25.

Figure 26. Shaver mask aided by software.

- Problem 43 – Group 4: it is a mask which works like a shaver. On the inside of it, a flexible metal structure composed by several razors adjusts itself to users' faces. The process then is similar to what happens with other shavers: the hair which goes inside the structure is cut. The micro razors are found all over the inside structure and they operate on demand, depending on the beard model chosen. This choice is made on a small display. The mask is also composed by an adjustable strap. To be attached to the user's head. The idea is illustrated by figure 26.

Figure 27. Smart mask.

- Problem 43 – Group 5: an anatomical mask designed to provide a quick shaving by adjusting itself to different faces. An inside optical system maps the faces and the process can be done with small razors or with a depilatory gel. The idea is illustrated by figure 27.

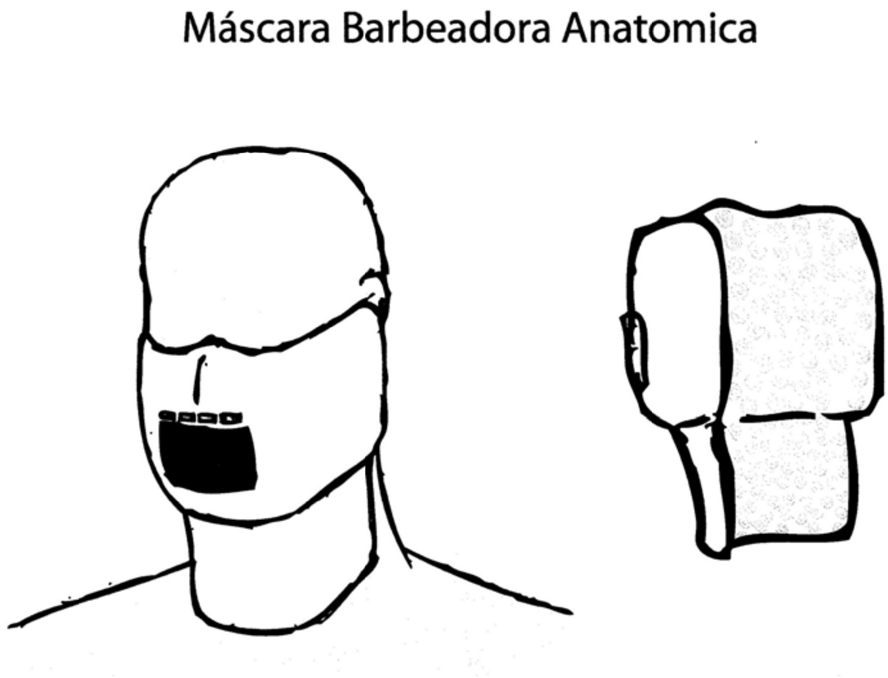

Figure 28. Automatic anatomic shaver mask.

- Problem 61 – Group 1: the product is like a modern chamber in which people are exposed to a hot air flow all over their bodies. The process should take less than five minutes. The idea is illustrated by figure 28.

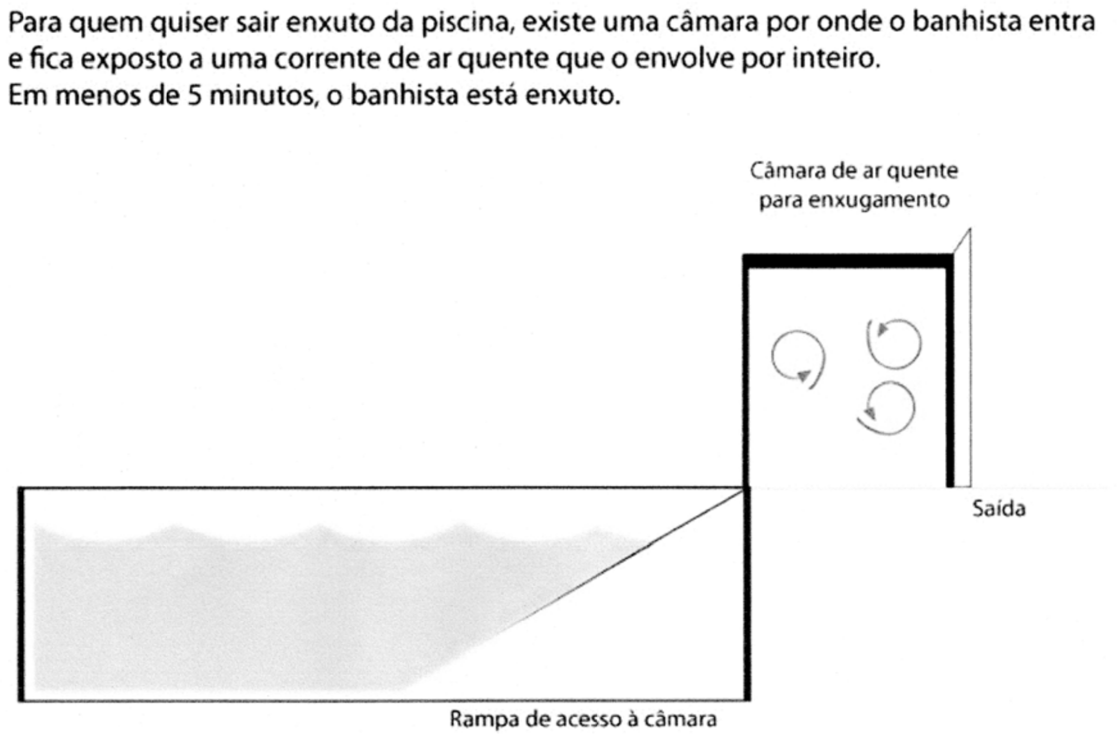

Figure 29. Drying chamber.

- Problem 61 – Group 2: with a similar technology of automatic hand dryers, a portal dries a wet person in a few minutes. Every time someone goes through it, sensors detect movement and activate the high-speed hot air gushes. It uses solar energy from panels located above the portal. The idea is illustrated by figure 29.

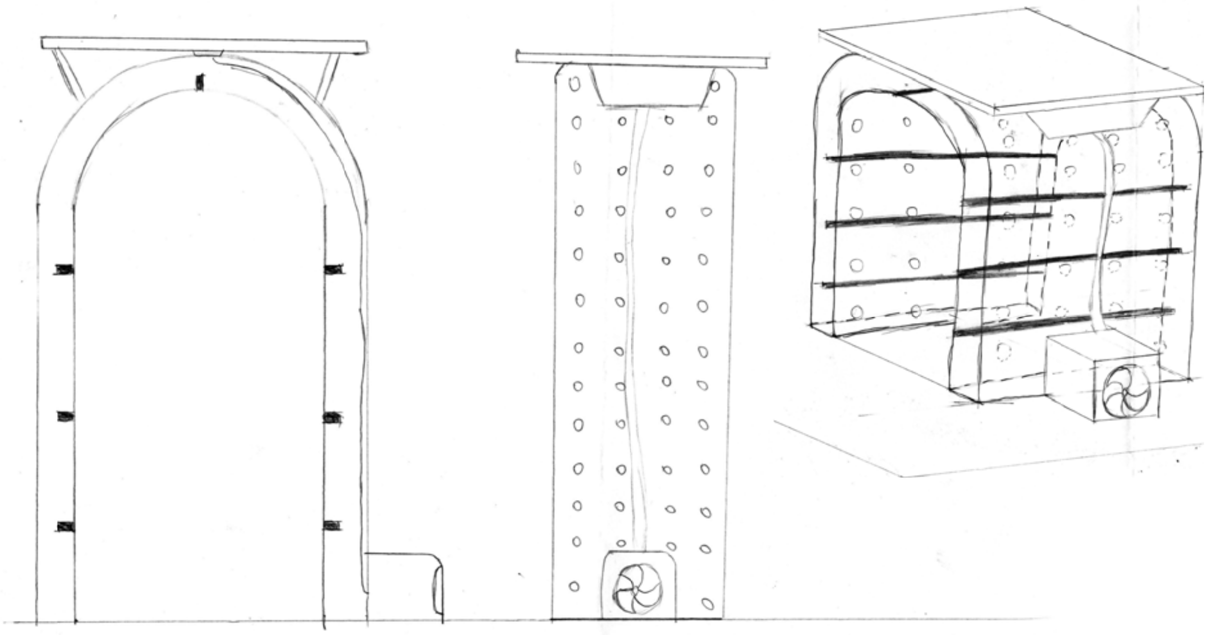

Figure 30. Drying portal.

- Problem 61 – Group 3: a system located on swimming pool exits (close to the borders) that releases hot air in order to dry people as soon as they leave the water. The air flow and temperature are controlled according to external factors, such as weather, or customers' needs. Users activate the system manually and also define temperature and air flow speed. The idea is illustrated by figure 30.

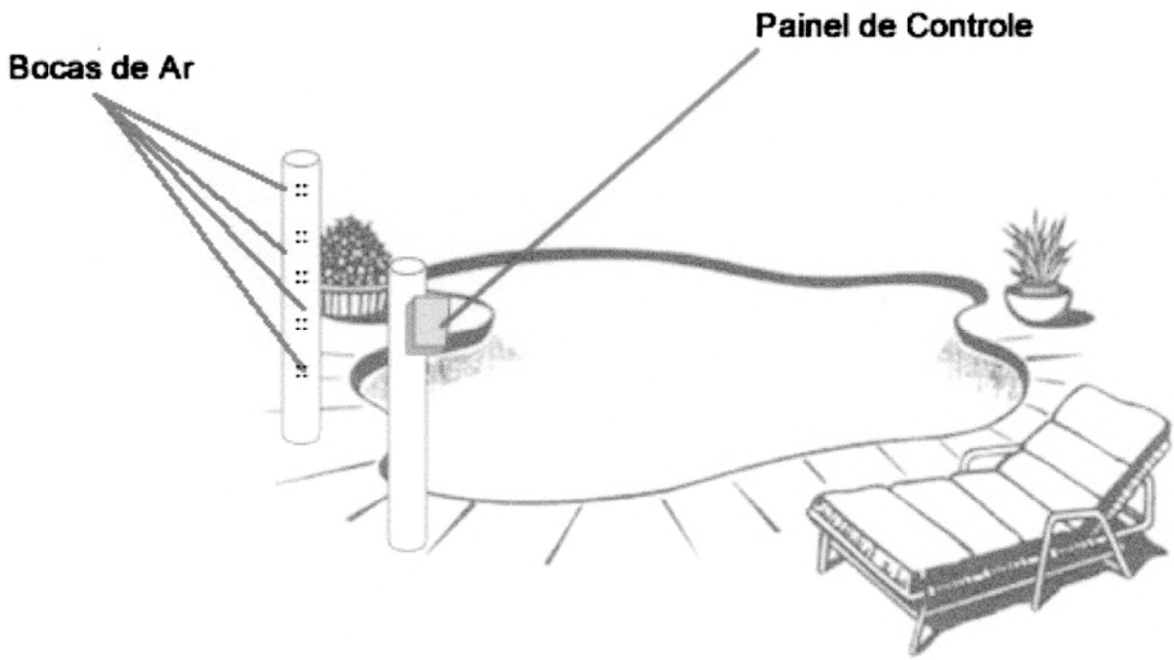

Figure 31. Drying ducts.

- Problem 61 – Group 4: with similar functioning to hand dryers, the system is placed underground close to the exits. It is composed by a metal panel with several small orifices from which the air flows and a fan system located beneath everything. The idea is illustrated by figure 31.

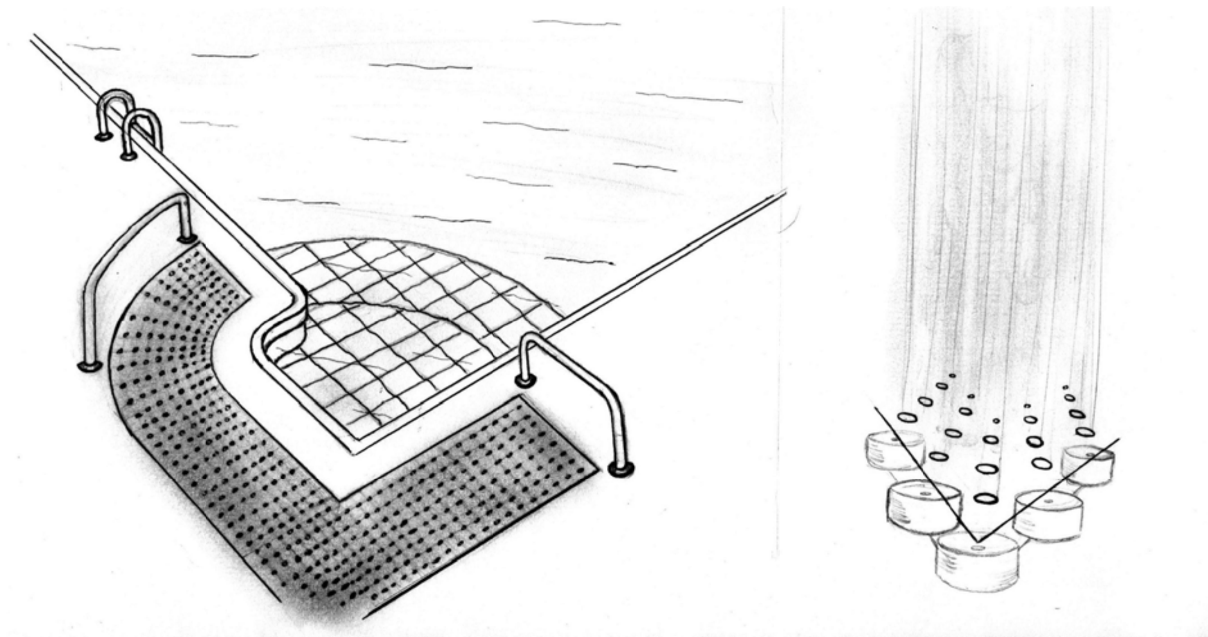

Figure 32. Drying floor.

- Problem 61 – Group 5: the product is composed by a cylindrical chamber with three rings which moves vertically. The system dries people by powerful air gushes that comes from tiny orifices on the rings. The air direction is always top-down in order to help water draining. It uses solar energy and takes thirty seconds to complete the task. The idea is illustrated by figure 32.

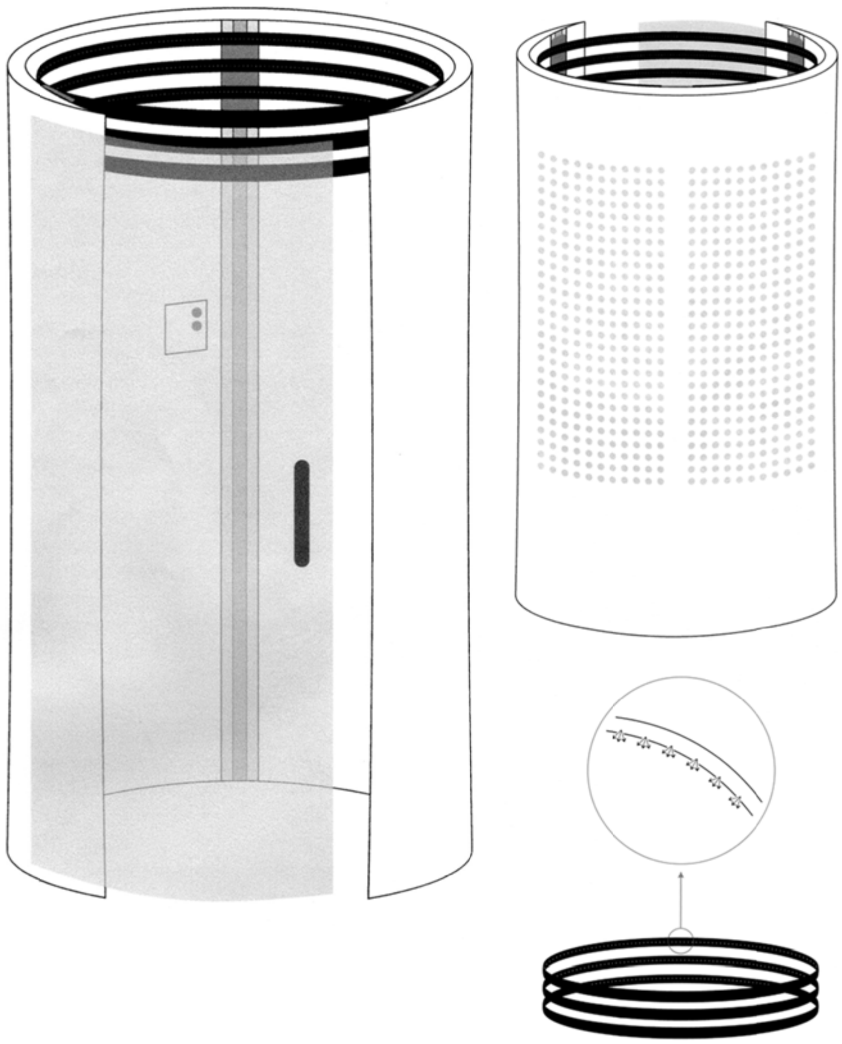

Figure 33. Drying rings.

4.3 Evaluation

The data collected with the evaluation of each group's alternatives are condensed and presented in this section.

Charts 3, 4, and 5 indicate the average scores experts gave for each parameter of evaluation regarding each group. Chart 3 introduces the results for problem 24, on the first cycle; chart 4 for problem 43, on the second cycle; and chart 5 shows the evaluation for problem 61, on the last cycle of activities. Lines demonstrate the performance of each team.

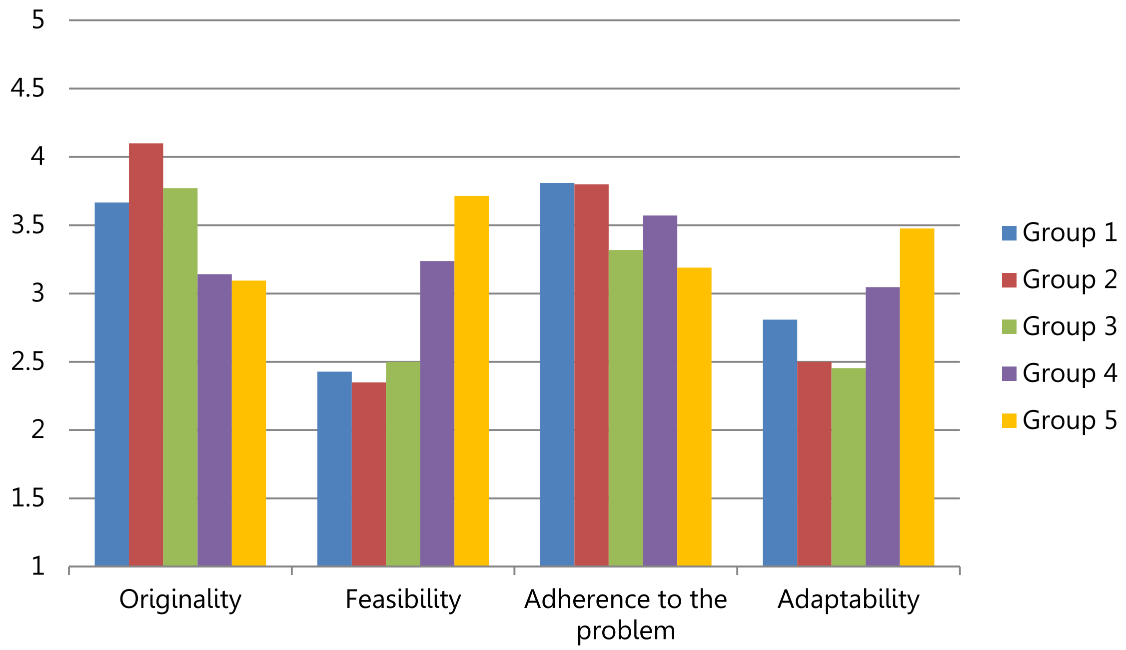

Chart 3. Each group's performance for problem 24.

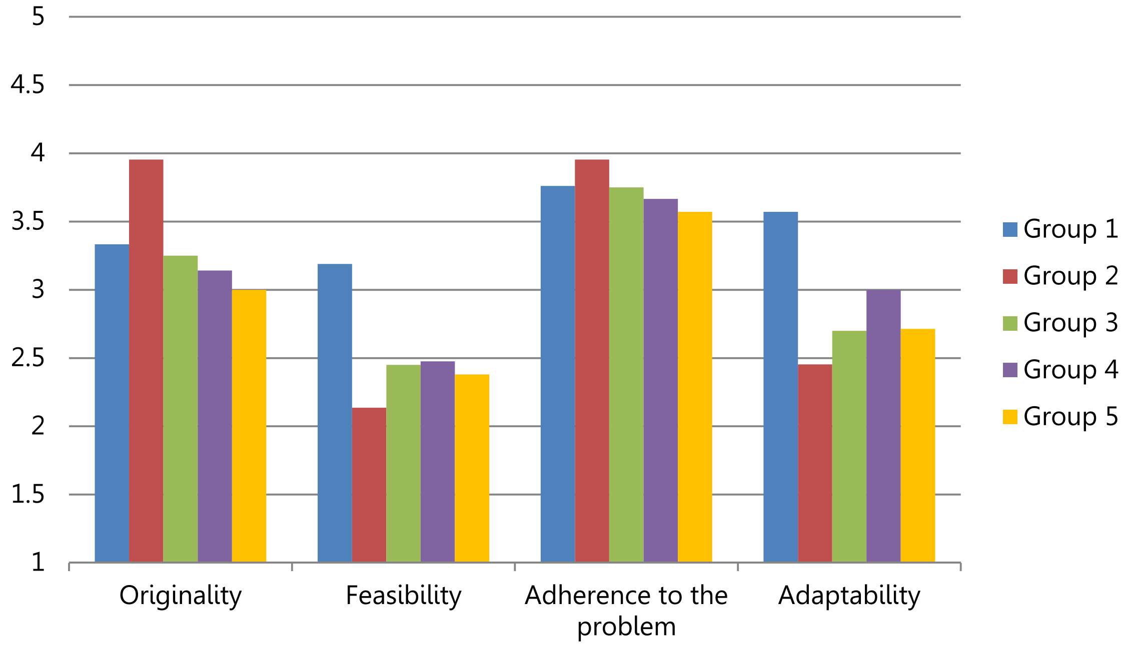

Chart 4. Each group's performance for problem 43.

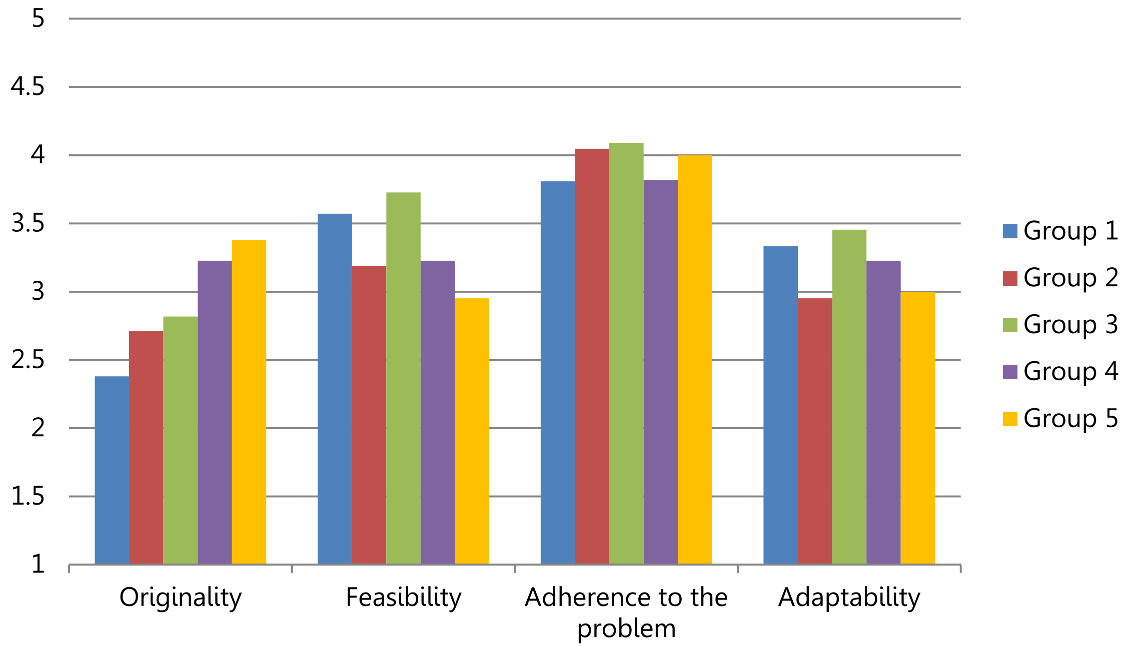

Chart 5. Each group's performance for problem 61.

Chart 6 shows the behavior of all evaluation criteria regarding the average scores each group was given for the three cycles. The two criteria of adherence to the problem and originality were better evaluated for experts, whereas the feasibility and adaptability received lower scores.

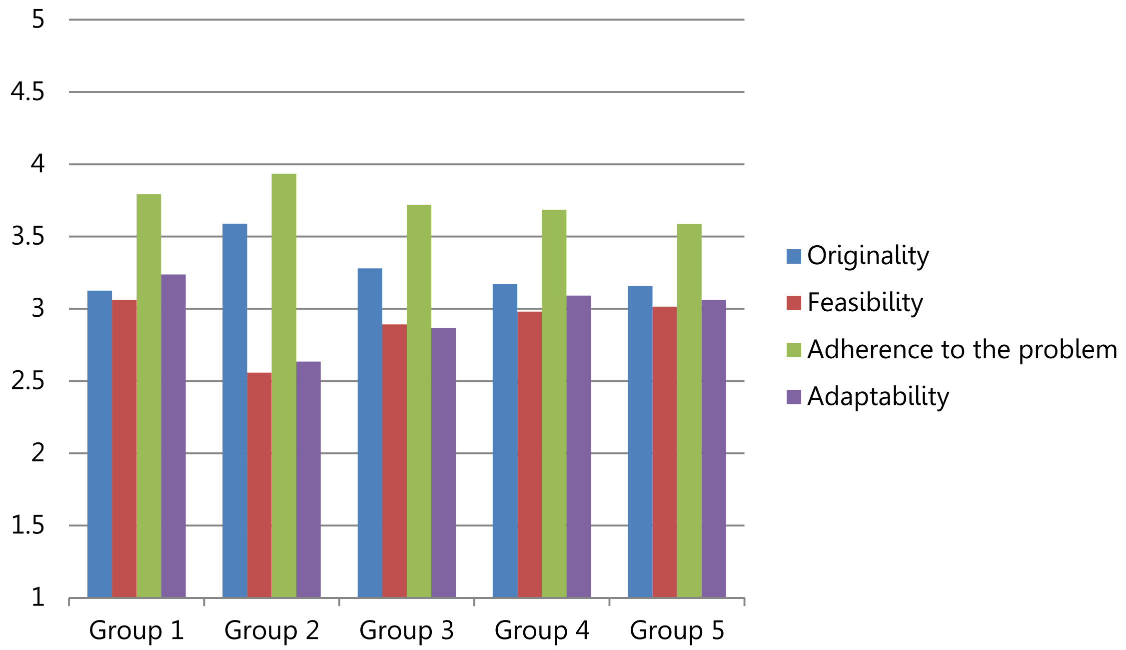

Chart 6. Average criteria scores per group (considering the three moments).

4.4 Findings and Discussion

As shown previously on tables 6, 7, 8, and 9, the scores of each group – based on the average score each team member gave individually – changed every cycle due to the activities executed. Table 10 summarizes the difference presented on the results according to changes on cycles.

The results presented on the first line, for the problem 24, are obtained from the subtraction of the Q0 results from Q1 results for the same line. Likewise, the problem 43 results are obtained from the subtraction of the Q0 results from the Q2 results for the same line, and for problem 61 results, subtracting Q0 from Q3. By doing this, it is guaranteed that the perception each team has on the knowledge acquired after each procedure will be quantified. This way, each number on table 10 represents the gain of information perceived by team members after finishing a round of searching and designing activities for each problem.

Table 10. Relative scores for participants' perception of information gain.

	Group 1	Group 2	Group 3	Group 4	Group 5
Problem 24	0.5	2	4.8	5.4	6.8
Problem 43	1	5.1	0.3	7	6.3
Problem 61	1.9	6.8	5.5	4.9	5.7

By instance, even that no activity of problem exploration had been executed by group 1, for each cycle, when compared to the base questionnaire-0, the group suggested gain of relevant information about the problem. A possible reason for this finding might be due to the fact that even when designers don't do any research about the problem, just thinking about a solution and designing for it causes the impression of data acquisition.

For absolute values, it can be noticed that white cells, again representing the WNM procedure, usually present lower scores than light gray cells (WRM), and the dark gray cells (WSM) hold the highest scores. In addition, when observing each line individually, designing supported by structured methods for problem exploration will always presents greater values than the two other procedures, as well as designing with random methods for problem exploration will always presents higher values than designing with no methods.

It can be concluded with these results that, for this experiment's conditions, whenever a group perform a framework of methods for exploring the problem, designers in this group will feel more expert on the problem investigated than when searching for information randomly and much more than when leaving this step aside, which is using no methods, performing no problem exploration.

As regards the expert evaluation, although charts 3, 4, and 5 may present a general tendency when analyzing the groups' results for the four criteria established for evaluation, a rigorous observation can identify divergence among each group's behaviors. Notwithstanding, when observing the average ratings each team received for the same criteria chart, now considering the three moments, all groups produce very similar results and behavior, as can be observed in chart 7.

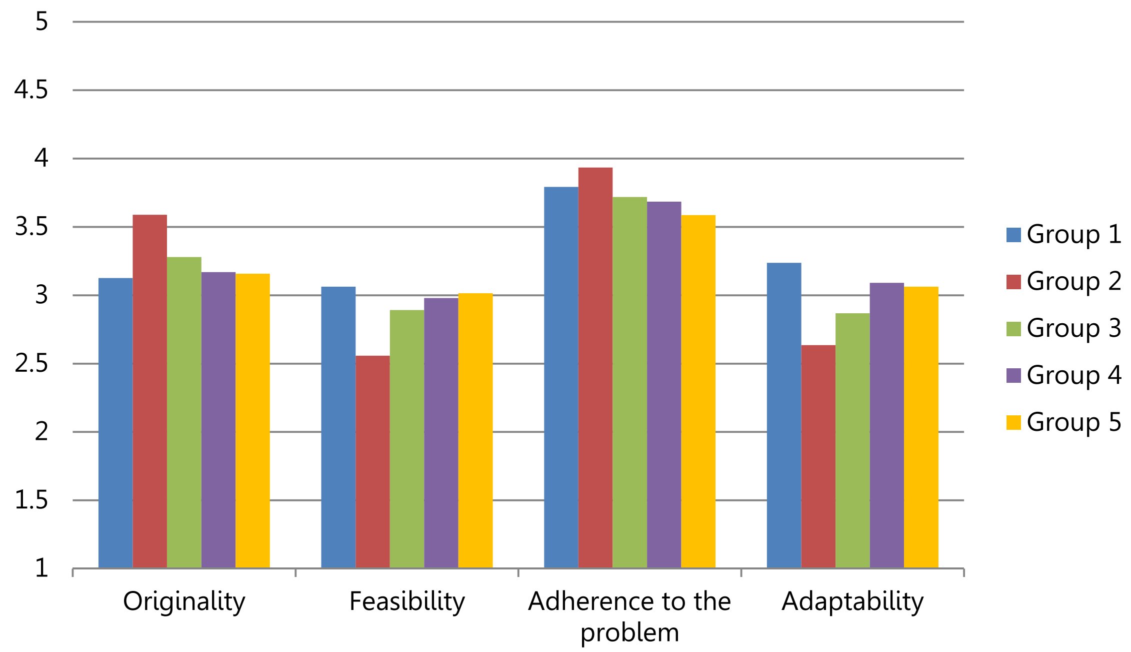

Chart 7. Each group's average performance (considering the three moments).

As particular case for chart 7, the group 2 stands out among the common order of the others groups for presenting a less linear behavior. Nevertheless, looking carefully, higher scores for originality and adherence are compensated by lower scores on feasibility and adaptability.

Scores for group 1 and 5 must be taken into account separately, once they represent the two control groups for the experiment – the first one skipped the problem exploration step and the latter followed the most rigorous procedure every cycle. It can be perceived a very similar performance for both groups, which indicates no relevant differences on experts' evaluation between them.

To confirm such results, chart 8 summarizes the average scores for all three different procedures taken. The three cycles of activities were considered. Regardless the group, procedures executed with the WNM model produced almost the same results of when executing the WSM model. Likewise, the WRM model presented no significant differences from the two others.

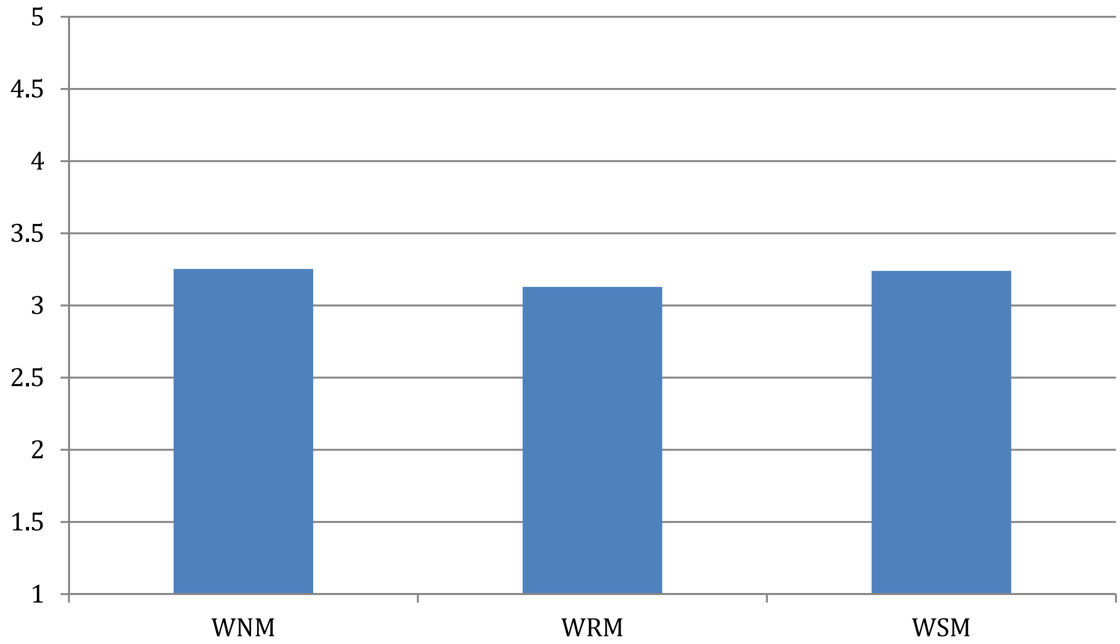

Chart 8. Average scores of the evaluation criteria per problem exploration procedure (considering the three moments).

For a statistical approach it was decided to apply the odds ratio (Hollander and Wolfe, 1999) to describe the strength of the association between the results of group 1 and 5. This method estimates the ratio of the odds of an event occurring in one group to the odds of it occurring in another group. For this specific context, it measures the odds of each group to be better evaluated by experts than the other one, according to each criterion.

The ratio calculation requires a test in order to verify if the odds are statistically equals to one, i.e., whether the odds of being well-evaluated are the same for both groups or not.

Since it requires two binary data values, it was decided to group the results into good and regular according to the received scores. Good results are scores which are over the rating midpoint, which are 4 or 5. Regular results are all other scores bellow 4, which are 3, 2, and 1. Table 11 presents the sum of the good results for each criterion considering the three cycles. This way, a total of sixty-three responses (twenty-one evaluators responding for each problem) were taken into account for each cell. For example, from sixty-three different results, twenty-two were considered good for group 1 when considering the originality. Likewise, 21 from 63 were considered good results for group 5 when considering adaptability.

Table 11. The considered good scores for groups 1 and 5 regarding the four criteria.

	Originality	Feasibility	Adherence to the problem	Adaptability
Group 1	22	24	39	29
Group 5	19	18	35	21

Adopting a significance level of 95% for the tests, which is the common significance adopted for this kind of statistical analysis by the scientific community, all results were not significant. In other words, when comparing the good outcomes of group 1 and 5, the odds ratio demonstrated that there are no statistical differences between their results.

Table 12 estimates odds ratios e P values, i.e., the probability of rejecting the hypothesis that both results are equals. Therefore, P values greater than 0,05 (according to the significance level of 95%) indicates that both groups have the same odds of receiving good scores for the created solutions. As it can be observed, no P values smaller than 0,05 were obtained, thus both results can be considered the same.

Table 12. Statistical results: odds and P values between groups 1 and 5.

	Originality	Feasibility	Adherence to the problem	Adaptability
Odds Ratio	1,24	1,53	1,3	1,7
P value	0,28	0,12	0,23	0,07

Once again, considering the specific scenario for this experiment, it can be concluded that, regarding the experts' evaluation, executing a detailed framework of techniques for the initial step of the design process presented no significant differences when compared with designing without techniques for problem exploration.

To confirm the conformity of groups and problems, charts 9 and 10 demonstrate average scores each group and problem received regarding all four criteria and the three cycles. Chart 9 indicates that all groups obtained similar results, guarantying homogeneity of competences among groups. The same way, chart 10 shows homogeneity as regards the average ratings each problem scored. It supports the idea that in spite of the different problems confronted, they were similar when considering the difficulty of designing for them.

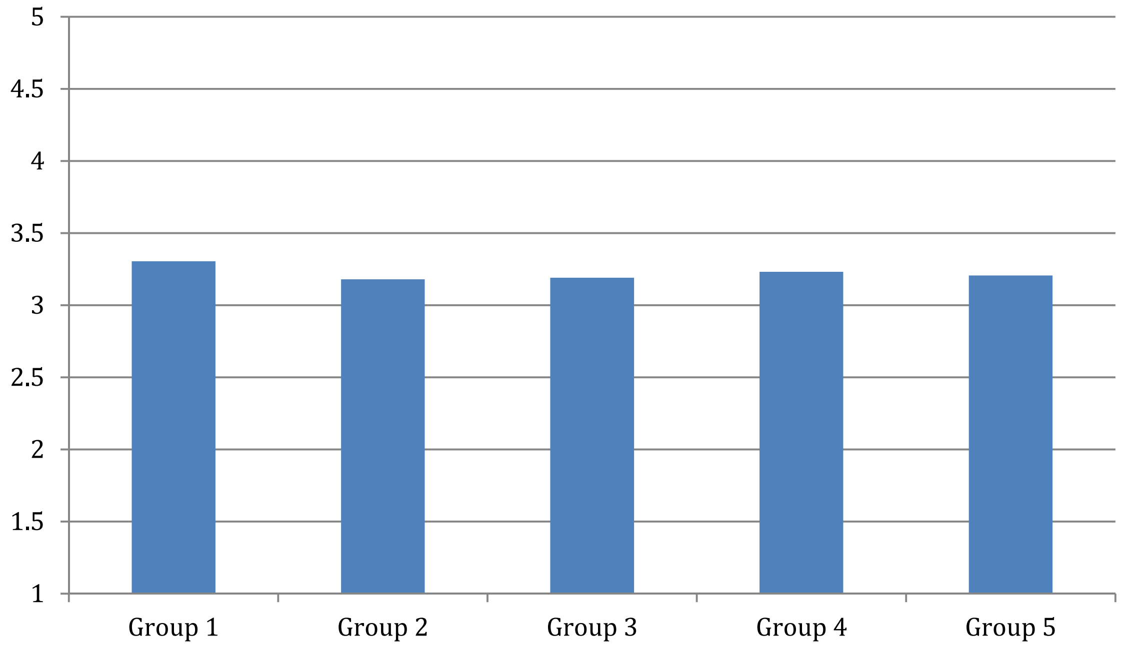

Chart 9. Average scores of the evaluation criteria per group (considering the three moments).

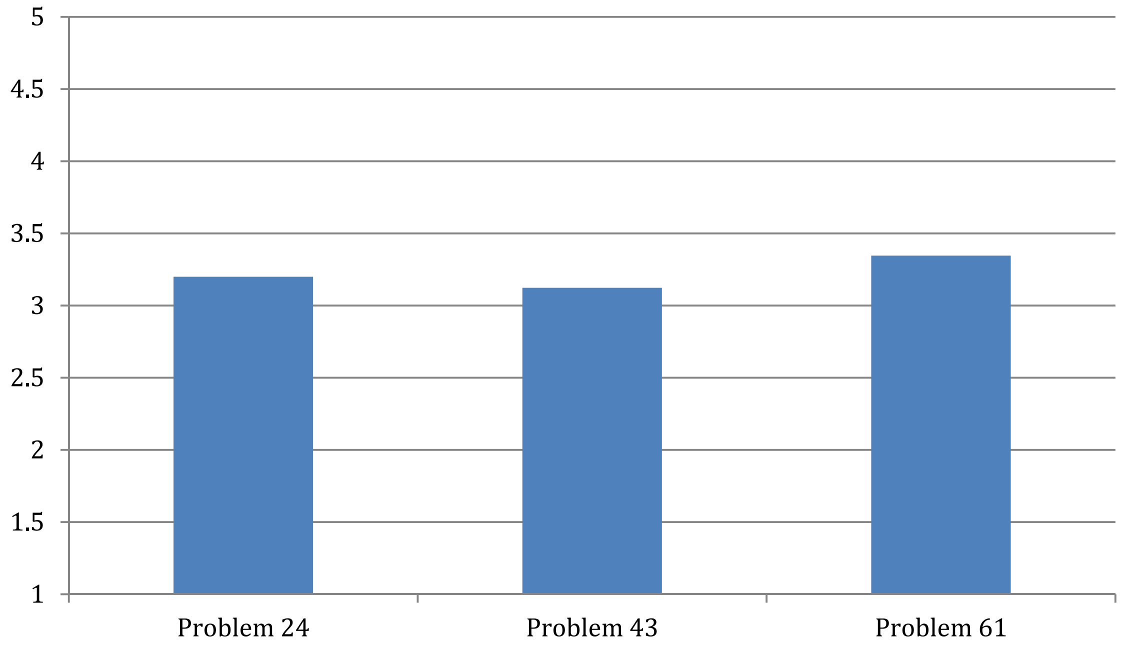

Chart 10. Average scores of the evaluation criteria per problem (considering the three moments).

As regards the behavior of each of the four parameters for evaluation, after analyzing the chart 6, it is possible to infer that groups were quite concerned about the specific problem while designing solutions as well as creative for the alternatives – the two better evaluated criteria. However, since it was not asked a final and functional version of the problem but its concept only, the feasibility – and this way the adaptability as well – was deprecated as a project requirement.

Finally, chart 11 summarizes the results for the last parameter of evaluation, which was not taken into account for discussion so far: the quality of the presentation or how well-organized and described was the documentation provided for evaluation. As commented previously, the reason such parameter was included on the evaluation form was to identify if the three different procedures (WNM, WRM, and WST) could cause visible influences on the detail level for each moment.

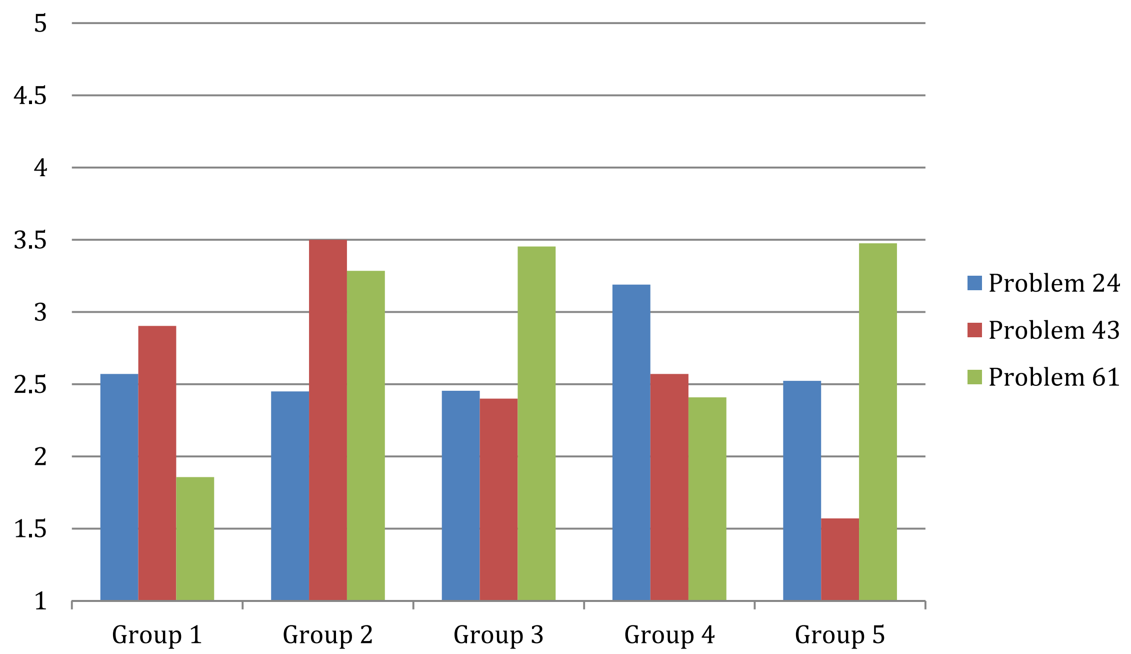

Chart 11. Scores given for the documentation's quality criterion.

As can be observed, crossing the data of this chart with table 5, it is not possible to establish any dependence between the quality criterion and different use of methods for problem exploration.

5. CONCLUSIONS AND FUTURE WORK

The discussion about design methodology is at the same time old and modern. The same reasons for its start, in the early sixties, are still up to date as regards the need of turning the design process into something teachable and learnable, therefore communicable and understandable.

Over the years, design frameworks with well-structured models were developed, discussed, modified, and adapted in order to provide both the academy and practitioners a better understanding of the creation and problem solving process. These models, usually organized by several steps and activities, defended the adoption of a procedural framework to be followed by designers.

However, as confirmed at the first part of this work, for the same design literature it is hard to find researches that systematically proved the real importance of using design methods. As Bomfim and many others suggested, methodology in design comes to support designers while developing products but its adoption does not guarantee success for sure. Even so, the same authors do not specify the gains that executing structured procedures may provide to the final solution.

As it was confirmed for the first hypothesis of this work, despite the influences on the final solution, using design methods for the step of problem exploration during the design process clearly affects designer's perception of the knowledge they have about the problem which was confronted. It may happen either for increasing one's confidence during the process or maybe even for assuring real difference on the amount of information each group had after performing the three procedures: without going through problem exploration, with the support of random research, or with the support of a defined methodology for research about the problem.

Notwithstanding, regardless whether for the increased confidence or real information acquisition, when submitting the alternatives generated by the five groups to the evaluation of experts, no matter the procedure each group executed for each problem, it was not possible to identify any influence of the use of techniques for exploring the problem on the final solutions. Thus, the second and last hypothesis of this work was refuted.

This work discussed design methodology from an experimental and descriptive approach. From the two hypotheses tested during this investigation, the first one was confirmed as true and the last one was disproved. This way, the main contributions of this work are two: it reveals the opposition between designers' expertise on the problem and the evaluation of alternatives they create for it; and it generates indicia that the use of methods, at least for the problem exploration step, brings no significant advantage for final solutions. However, it is important to take into account the specific scenario for which was planned the executed experiment.

Besides, although experts' evaluation may not identify any advantages of using techniques as regards the alternatives, the author of this work believes that the use of methods clarify the ideas during the process, providing an organized plan of action to support one's task of designing products – this way, acting like a checklist for guiding the process. In addition to it, the documentation of the entire process is also valuable for defending the idea for a market scenario, since it provides a visible procedure which was undertaken, instead of a "black box" process with no arguments or visible logic.

When considering projects with highly-detailed briefings and presenting high budgets and longer schedules, the outcomes of using techniques for problem exploration during the entire developing process may be entirely different. Once this work dealt with an academic scenario for its experiment, it is desirable that similar tests occur now on industry, for real market scenarios.

Finally, apart from the tests on industry, future works for this research are the application of similar experiments for all other steps of the design process. Early researches already indicate relevant gains of using creative techniques for the step of generating alternatives. However, the evaluation and selection step remains not investigated.

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