POLITECNICO DI MILANO

Scoula di Dottorato di Ricerca

Dottorato di Ricerca in Design

XXIV Ciclo

Product Semantics for Eco-efficiency:

Redesigning product characters to communicate Eco-efficiency in home appliances

Coordinatore: Prof. Francesco Trabucco

Relatore: Lucia Rampino

Candidato:

Shujoy Chakraborty

Abstract

Introduction

Research Area: Product Semantics to communicate Eco-efficiency

1. **Objectives ----------6**
   - 1.1. General Objectives
   - 1.2. Specific Objectives

2. **Methodology ----------11**
   - 2.1. Research process
   - 2.2. Research Methods
   - 2.3. Research Tools

3. **Theoretical background ----------20**
   - 3.1. Sustainability and Eco-efficiency in product design
   - 3.2. Key definitions
   - 3.3. Categorizing aspects of Eco-efficiency
   - 3.4. Classifying Eco-efficiency in product design
   - 3.5. Emergence of Semantics in Product Design
   - 3.6. Main concepts of Product Semantics
     - 3.6.1. Communication in Product Design
     - 3.6.2. Human Centred Design
     - 3.6.3. Sense
     - 3.6.4. Meaning
     - 3.6.5. Affordance
     - 3.6.6. Aesthetics
   - 3.7. Product character, characteristics and attributes

4. **Applied Research & Design activity with Whirlpool Europe ----------80**
   - 4.1. INDUSTRIA 2015 research project
     - 4.1.1. Evolution of living spaces and impacts on appliance usage
     - 4.1.2. Social and technological evolution of home appliances

4.1.3. Present Eco-efficient features in home appliances

4.1.4. Integrating different appliance categories for energy saving

4.2. GreenKitchen 2.0

4.2.1. Applying Product Semantic theory to interface design

4.3. Eco-efficient Whirlpool 'Ixelium' cooktop development

4.3.1. Designer's role in the development process

4.4. Eco-efficiency within Whirlpool Product Development Process

5. Multi-disciplinary design workshop: Intensive Program (IP) 2010 & 2011 ----------113

5.1. Teaching Eco-efficient design in a multi-disciplinary environment

5.2. Workshop insights into other product categories

5.3. Interview insights with Philips on Eco-efficient design

6. The emerging issue: Product Semantics for Eco-efficiency ----------124

6.1. Communicating Eco-efficiency through non-instrumental interaction

6.2. Intrinsic and extrinsic product features

7. Redesigning Product Characters through a design process ----------128

7.1. Main stages of the design process

7.2. Methods and tools of the design process

7.3. 1st Design Workshop (IIT, Guwahati, India)

7.3.1. Methodology

7.3.2. Outcome

7.4. Test activity 1: questionnaire with non-expert users

7.4.1. Result and insights

7.5. Data capture- Building a design matrix

7.6. KJ Method- Shortlisting, clustering & ranking of product attributes

7.7. Building mood boards

7.8. 2nd Design Workshop (PoliDesign, Italy)

7.8.1. Methodology

7.8.2. Outcome

7.9. Test activity 2: questionnaire with non-expert users

7.10. Results and insights

7.11. Limits

8. Design guidelines for Eco-efficiency ----------157
8.1. Product characters for Eco-efficient appliances
8.2. Future application within other product categories

9. Conclusions ----------161
9.1. Considerations about the process
9.2. Final discussion

10. Bibliography ----------167
11. Appendix ----------176
11.1. Eco-efficient features of major appliance categories
11.2. Integration of appliance couples
11.3. Result images of IIT, Guwahati workshop
11.4. Questionnaire of IIT, Guwahati workshop
11.5. Moodboards
11.6. Questionnaire results of PoliDesign workshop
11.7. Data analysis of PoliDesign workshop results

...To Tapati and Anand

Acknowledgements

I would like to take this opportunity to express my gratitude to all those who supported and inspired me to complete the long journey of writing this thesis. First and foremost it goes without saying that my parents showed the utmost confidence in my capabilities of undertaking and completing this long endeavour, and for this I'm grateful.

This thesis in its present form would not have come about without the guidance, valuable insights and endless patience shown by my tutor Lucia Rampino. The thoughtful criticisms and suggestions of my external reviewer Anna Meroni have only served to make this research much more robust. My research group of course deserves a special place of mention especially- Prof. Trabucco, Roberta Gorno and Sara Colombo; I am grateful for all the consideration which you showed me and your discussions which enriched and clarified my point of view. A special mention must also be made of Silvia Ferraris for always giving me her timely opinion and support in various challenges which I have faced during the course of my thesis.

From Whirlpool Europe I thank especially Stefano Vaglica for being a great mentor and giving me all the technical knowledge I required about appliance manufacturing and engineering to complete this research. To my other colleagues, of whom there are too many to name individually, I thank you all for answering my queries while working within the Global Product Development Centre despite the intense deadlines you all had to cope with.

A vote of thanks to Avinash Shinde and the M.Des students of the Indian Institute of Technology (IIT), Guwahati and Riccardo Gatti and the Master in Design Engineering students from Poli.design (Politecnico Di Milano) for participating with so much enthusiasm and energy in my research.

Finally a personal thank you to Niko, Alokeparna, and Gabor for being great friends ready to offer timely critical advice whenever I needed it.

To the many other friends, family, and colleagues whose names I have not mentioned here only due to the limitations of this document or just plain oversight, I am deeply indebted for your contribution and time.

Abstract

Currently the communication of Eco-efficiency in home appliances is very weak as this industry has only concentrated on the technical attributes (technology content) of appliances, overlooking the appearance attributes of their products. Eco-efficiency is the production of goods and services which meet human needs while reducing environmental impacts (Schmidheiny, 1992). This thesis investigates the encoding of Eco-efficiency as a meaning in product forms using the Product Semantic theory, and proposes that this linguistic shortcoming i.e.: ambiguity in exact usage context of Eco-efficiency, is also reflected in the design approach towards Eco-efficient home appliances, as according to Krippendorff (2006) parallels have existed between transmission of meanings through design and the link with language. What cannot be clearly defined in language is difficult to translate into design. When the meaning of what a product has to communicate is not clear to the consumer then he or she will have difficulty in assessing the product and will therefore appreciate the product less (Blijlevens, Creusen, & Schoormans, 2009). From a point of view of language the term 'sustainable development' (and by its derivation 'sustainable design') is a semantically empty term (Vezzoli & Manzini, 1989) due to large scale improper usage. Byrnes (2010) goes on to state that sustainability and by its extension Eco-efficiency is too much of an abstract concept. What human beings cannot visualize clearly ie: electricity for instance, they cannot internalize properly.

This thesis will explain the application of product semantics to extract product characters which successfully communicate Eco-efficiency as a meaning to consumers in home appliances. The final output is to derive a ready to reckon set of design guidelines in the form of a set of 6 product characters-*Futuristic, Feminine, Unconventional, Practical, Simple, Smart* -which appliance designers can apply. Extracting these characters is an attempt to throw some light into the issue of communicating Eco-efficiency in EuP's (Energy using Products) by demonstrating the application of product semantics in home appliances and endeavoring to lay a foundation for future research into other allied product categories.

The aim of this research is to attribute the above characters to communicate Eco-efficiency through the appliance intrinsic features using a non-instrumental interaction paradigm. Intrinsic product features are physical attributes– form, geometry, colour, proportion, & composition, as opposed to extrinsic features which are strictly related to a manufacturer's marketing identity, packaging, and branding (Lee & Lou, 1996). Non-instrumental product interaction is based on the 'Design as a process of communication' model proposed by Crilly, Moultrie & Clarkson (2004) - which in turn was inspired by Shannon's model of communication - where the product meaning is expressed by relying primarily on visual sensing of a product's intrinsic features. At one level this model of communication has overlapping concerns with the 'human centred design' approach discussed by Krippendorff (2006).

This thesis will conclude by analyzing the degree of success of the 6 product characters, and reason upon the advantages of applying an objective product semantics process to solve an inherently subjective domain of Eco-efficient design, and attempt to tame what has been compared to Horst Rittel's concept of a wicked problem (Erlhoff & Marshall, 2008, p-108; Syarief & Hibino, 2003).

Human Centered Approach to Product semantics

Krippendorff and Butter who first applied the science of Semantics to product design (Boess & Heimrich, 2008; Vihma, 2007) are largely credited with having first used the term 'Product Semantics' in 1984 (Krippendorff & Butter, 2008; Demirbilek & Sener, 2003) and ideas discussing

this upcoming field were first presented in the IDSA (Industrial Designers Society of America) journal called *Innovation* in 1984. Krippendorff defined Product Semantics as "a study of the symbolic qualities of man-made forms in the cognitive and social contexts of their use and the application of the knowledge gained to objects of industrial design". Blaich defined product semantics as "an area of inquiry or discipline concerned with the meaning of objects, their symbolic qualities, and the psychological, social, and cultural contexts of their use". Athavankar (2009) cited product semantics as having 2 core goals, 1) Improving user-product interaction. 2) Demystifying complex technologies.

Semantics as a discipline has traditionally been applied to study spoken language and study of meanings in languages, but its application into product design has been pioneered by Krippendorff and Butter (1989). The intention of semantics as a design theory was to apply linguistic theories into a design process to develop 'readable' or 'self- evident' products through easy to apply methods (Brown, 2006). The early design theorists of semantics namely Butter (1989), Krippendorff (1989,2006, 2007, 2008) strove to develop it as a new approach to design (Brown 2006; Boess 2008) through what they called the Human Centered view of design, a break from Luis Sullivan's "Form follows function" doctrine & instead proposed "Form follows Meaning".

The human centered approach to product semantics is based on the attribution of 'characters' in products to express a meaning. The uniqueness of the human centred approach is to acquire a second order understanding or an 'understanding of the users' understanding' (Krippendorff, 2006, 2008) when designing meanings into artifacts. Design theorists have pointed out that companies which are able to communicate a certain meaning (i.e. Eco-efficiency) through their appearance can achieve a competitive advantage and increase their chances of success (Blijlevens et al, 2009). Product characters are adjectival constructs or visual metaphors (Gorno & Colombo, 2011; Krippendorff, 2006). Attributing characters makes it easier for users to anticipate the functioning of the object and also explain its behavioral patterns to the user. It thus follows that users tend to make a connection between certain appearances and the characters they attach to them i.e. transparent surfaces appear more futuristic, and organic forms appear more feminine. Based on these insights it can be said certain characters can potentially form stable relations with certain appearances and this interdependency between the 2 can be an opportunity for designers.

Why home appliances?

Within the Europe home appliances account for the largest share of domestic energy consumption. With refrigerators and freezers accounting for 15% of residential consumption followed by washing machines accounting for 4%, and dishwashers, ovens, and clothes dryers accounting for around 2% of total residential end use (Mills & Schleich, 2009). This makes them an important contributor to the agenda of energy efficiency.

On its part the EU has set an efficiency guideline to increase appliance efficiency by 20% at the end of 2020. Most appliances under development at the moment are meeting the 20% consumption reduction target in the A+ energy labeling category. The ultimate goal of the appliances manufacturers is to reduce over-all consumption by upto 80% (Whirlpool Europe internal directive).

Appliances companies are large corporations with shareholders, who demand constant 'value generation'. Leadership which is unable to deliver these goals is swiftly replaced. Eco-efficiency for these corporations is a risk. A 'risk' is defined as a future event which has not yet realized itself and could have a positive or a negative impact. Appliance manufacturers are unsure of the benefits of

investing in an Eco-efficient platform, whose returns on investment are very ‘risky’. A typical platform takes couple of years to develop and can entail several million euros of investment, thus increasing the marketing performance of an Eco-efficient appliance will encourage higher investment in this industry segment where consumer awareness is already low mainly due to the poor and overly complex product communication strategies for Eco-efficiency (Mills & Schleich, 2009). Typically Eco-efficiency is largely looked upon as a debatable investment by important functionaries such as marketing and finance within companies (Cramer, 1997).

Product semantics can help to make this communication easier and more intuitive to the end user thus helping to increase the competitive advantage of Eco-efficient appliances in the marketplace and thereby reducing the perception of risk taking by manufacturers.

Methodology adopted

The methodology followed in this research is that of action research using the “research through design” approach described by Rampino & Colombo (2011) utilizing various methods of literature review, design activity, applied research, and design workshops in different phases of progression. Finally the research ends by applying the product semantic approach to a design process adapted from Butter’s (1989) ‘*character attribution process’* which he introduced to design product forms with predetermined meanings. He developed his process as a set of sequential steps, through the medium of design workshops which were readapted as a design process aimed to apply the product semantic approach to express Eco-efficiency in washing machines. The process has 7 main steps:

1. Perform a design workshop which is aimed at developing a series of Eco-efficient washing machine design concepts using product design students.
2. Collect suitable adjectives by conducting feedback questionnaire analysis on the design concepts from non-expert users.
3. Extract the most suitable adjectives amongst all the adjectives collected. These adjectives will be ranked and grouped using a group voting methodology (KJ method) and organized as product characters.
4. Product characters will be visually attributed using mood boards and used as input for a second designed workshop. In all 6 characters were finalized.
5. Second workshop performed using product design students aimed at designing a washing machine expressing the given characters.
6. The effectiveness of the characters will be tested in communicating Eco-efficiency by using a second feedback questionnaire from non-expert users.
7. Product characters are verified as successful design guidelines for appliance designers.

Contribution to the field

Though product semantics had noble intentions of applying linguistic theories into a process to design readable products, in the end this entire construct remained largely theoretical and therefore an academic exercise unable to offer professional design community a ready to apply methodology which was sufficiently robust to result in successful product developments, thus leading to the eventual decline of the semantic theory in the design community by the late 80’s and early 90’s (Brown,2006). This research seeks to revive the application of product semantics to address a socially relevant challenge such as Eco-efficiency and derives a set of design guidelines in the form of 6 product characters (*Futuristic, Feminine, Unconventional, Practical, Simple, Smart*) which designers can easily apply to increase the competitive advantage and communicative value of their designs for

Eco-efficient home appliances. As confirmed by Blijlevens, Creusen, and Schoormans (2009) two of the characters ie: Modern and Simple are highly stable characters which consumers can easily understand and can be attributed across most product categories beyond home appliances.

Implications for theory and practice

Examples of professional designers having applied the product semantic theory into successful product development are few and far between, such as a Philips 'Roller Radio' (Blaich, 1989). Early proponents of product semantics such as Krippendorff blamed an 'untheoretical design profession' (Capitello, 1991) for this eventual rejection. The fact is that professional design practitioners and theoretical academicians regard semantics in fundamentally different ways. Designers tend to depend more on intuition & experience with little or no qualitative tools when dealing with conveying a meaning through form giving (Lawson & Storer,2008; Boess,2008). In fact designers hardly ever refer to any theory or methodology to give meaning to product form and rely solely on intuition (Boess, 2008). Brown (2006) confirms this view by saying "designers don't value academic theories as particularly useful in their everyday design practice". Thus this thesis attempts to throw some light into this issue by extracting 6 product characters using the product semantic theory and try to introduce an element of objectivity to communicate Eco-efficiency in home appliance appearances. Although the product characters derived here are based on a Human Centred design approach based on feedback captured from users, they need to be tested across a wider variety of consumer product categories in order to prove their robustness. The research outcome therefore should be taken as a possible roadmap for future development and has attempted to enable better communication of Eco-efficiency in home appliances.

Finally application of Product Semantics in the home appliances industry can help to bridge the gap between what marketing communicates through mass media and the designers intend through product aesthetics, while working on the development of the same appliance platform thereby improving the market identity of a manufacturer.

Introduction

The European appliance industry in the recent years has identified Eco-efficiency as one of the most important issues to be addressed both in terms of customer demand and technology capability. It is both a very big challenge and an opportunity for manufacturing companies in this sector. Eco-efficiency is the production of goods and services which meet human needs while reducing environmental impacts (Schmidheiny, 1992)[1]. In a much broader context 'sustainability' has pervaded quite deeply into the design and manufacturing worlds, but in the context of home appliances, the guiding principles of sustainability *i.e.: environmental stewardship, social equity, & development- rather than growth*, have not quite penetrated. On top of that a growing number of corporations today are voluntarily reporting upon their environmental performance (Fiksel, McDaniel, & Spitzley, 1998; Blumberg, 1997), further highlighting the direction this issue is taking, as improving the environmental performance of their products is recognised both as creating value for the shareholder and meeting the corporate social obligations.

The '4 steps model' (Charter & Chick, 1997) cites 10 fold increase in the resource and energy reduction which needs to be achieved in order to exist in a perfectly sustainable world (Figure 1). This means in accordance with the 4 step steps cited within this model manufacturers have to move from 'Re-Pair' to fundamentally 'Re-Think' the way products are manufactured. This model also cites that the situation today has reached the 'Re-Design' phase. This shift has implications which the appliance manufacturers have to face up to regarding how they conceptualise and build their platforms. Although on the face of it designing with environmental considerations seem as a source of cost escalation for manufacturers (Matthews & Chambers, 1998), but there are marketing benefits and other competitive advantages to be gained with respect to the brand image. According to this model Eco-efficiency is the second 'step' concerned with refining existing products. Home appliance industry is today embracing this step and this research will attempt to throw some light into how appliances can be *re-designed* in order to achieve the next step according to this model.

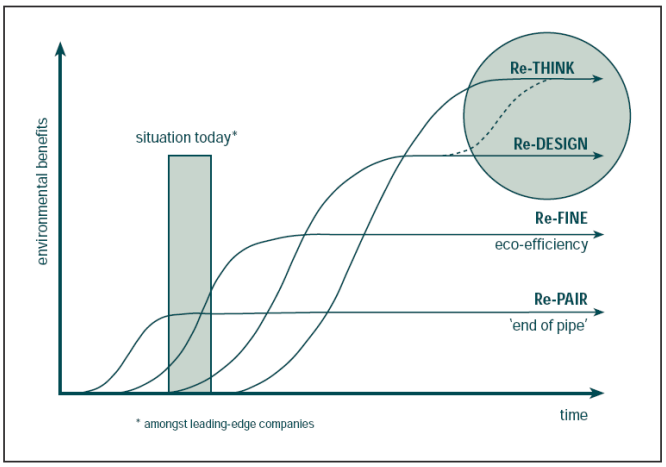


Figure 1: The 4 steps model

Source: JSPD 1 (1997) pp-5

1. [1] Cooper, T. (1999). Creating an economic infrastructure for sustainable product design. *The journal of sustainable product design*, (8), 7-17.

Eco-efficiency has been cited as a technical issue in appliance manufacturing (Brezet, Cramer & Stevels, 1995) not concerned with design. Technology push has been proposed as a relevant driver for environmental innovations in the context of home appliances (Rennings, 2000; Kammerer, 2009). Appliance companies have been cited in literature as using environmental improvements to differentiate their products and gain a competitive advantage (Reinhardt, 1998). However Kammerer (2009) warns that consumers are unwilling to pay premium prices or compromise in product qualities only for 'green' attributes (Peattie, 2001). Although according to Kammerer, consumers prioritize Eco-efficiency, they seldom back this with purchasing behavior in appliances (Wong et al,1996; Kuckartz,1998; Prakash, 2002). Kammerer argues that all discussion on environmental innovation focuses on social benefits, whereas more focus on personal benefit is required in terms of home appliances and should as a result focus on product improvements. Reinhart (1998) says more focus on personal benefits rather than social benefits will increase the market share of Eco-efficient appliances. In terms of marketing the appliance industry is already pushing Eco-efficiency precisely as consumer benefits (i.e. Energy Labeling is also displaying cost to consumer), but the ground reality in terms of product design is not reflecting this.

Luttropp (1998) notes the platform knowledge to the designer in the beginning of the Product Development Process (PDP) is quite limited, thus a designer of such complex products are not always at liberty to make the choices regarding material choices without the consent of the marketing and finance departments within a company. Although an 'intellectual break-even point' (Figure 2) is cited where the designer has enough knowledge along the product development process to make the correct choices for designing for disassembly while keeping cite of the manufacturing and cost implications of the project at hand. This is especially true for home appliances product category, whereas the platform progresses along the PDP, the designer is infused with more knowledge with respect to the final outcome of the project, which simultaneously curtails his creative freedom whilst at the same time endowing him with realistic scenarios and solutions which he can impose upon the design process of the appliance. This break-even point though is very ambiguous as is evident from the author's personal experience and insights within Whirlpool Europe.

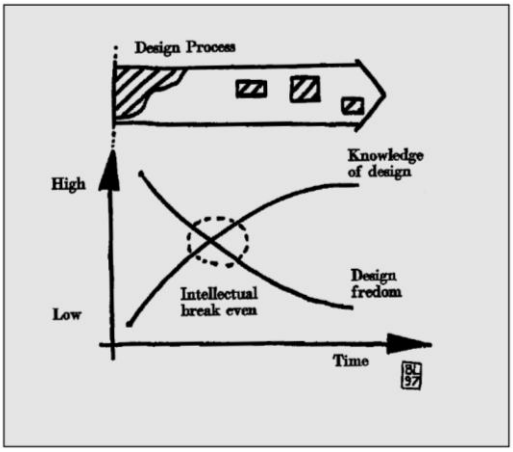


Figure2: The intellectual breakeven point

Source: JSPD 6 (1998) pp-31

In another insight Matthews & Chambers (1998) contend that increasing the end of life value of technological products is intrinsically less beneficial to company in question, as it increases the product

development costs, complicates supplier relationships, and could force the end user to pay a higher price in terms of monetary meaning due to structural changes which might have to be enforced within the product. That aside, environmental health and safety regulations are forcing most manufacturers across product categories to consider product take back programs, recycle and disassemble the platforms which they have sold. This view is somehow reinforced by Marin Charter (1998) when he says the current Eco-efficient design tools available such as LCA (Life Cycle Assessment) severely limit the efficiency of the designer and are accused of being complex and time consuming in addition to the fact designers are unskilled in using such tools in the first place. In essence these strategies imply that manufacturers have to develop a reverse logistical supply chain, so that such products can be captured after the end user discards them. As is evident such strategies are potential supply chain nightmares which no manufacturer willingly wants to embrace unless regulations force them to, given the low numbers of Eco-efficient products currently marketed in terms of market share and production volume. To complicate matters further the legislations can be sometimes contradictory such as the *UK Trade Descriptions Act* which stipulates that new products must contain new components, thus severely restricting manufacturers from utilising the captured assets from being extracted and put back into new assemblies. As a result the situation in the appliance industry is that of not taking back the products which they manufacture at the end of their life, but rather, to improve the performance of the ones which are being shipped to the store shelves to begin with.

So the situation could be improved if the numbers of Eco-efficient products moving off the assembly lines could be improved in other words if more consumers could be convinced that the Eco-efficient offerings are somehow a unique and meaning added proposition over other mainstream alternatives. This benefit to the consumer has to be measured and evaluated (Luttropp, 1998), as consumers are only willing to sacrifice up to a certain extent in terms of product performance and only if the environmental benefits are substantial. One way to achieve this product differentiation is through design.

The scenario in the end is somehow a paradoxical one for the appliance industry, seeing as the '4 steps model' cited previously commands that production and consumption be reduced, whereas the basic financial model of all appliance manufacturers rests on the assumption of achieving robust production volume increase year on year. Thus improving the environmental performance and the Eco-efficiency of existing appliance platforms becomes even more crucial.

As of today home appliances have embraced Eco-efficiency using technology as a medium. There are various technological innovations and inventions which are incorporated within all the major appliances typologies today to improve their performance which remain hidden visually to the ordinary user. The role of design in Eco-efficient appliances remains secondary and ambiguous. Indeed this trend is well documented and as has been said "..in markets driven by functionality, products often compete on the basis of their technological sophistication…and designers may strive to use a product's form to emphasise its underlying technology" (Crilly et al, 2008). The physical appearance of appliances today doesn't really communicate the gradual transformation of these machines into 'smart & Eco-efficient' appliances. Crilly, Moultrie and Clarkson (2004) in their article about consumer response to visual domain in product design say that the users' demands to products which are designed can be compared to *Maslow's hierarchy of needs*, suggesting that once the issues of utility, safety, and comfort have been satisfied, then the emphasis may shift towards the decorative, emotional, and symbolic attributes of design. This analogy can be drawn for the developed markets of Europe, where the functional and performance criteria of appliances are taken for granted; hence the focus increasingly shifts towards the visual characteristics.

Home appliances which are constantly striving to achieve product-person relationships are potentially a product typology which can be significantly impacted by the product appearance, a criterion known to greatly effect the commercial success of artifacts. With respect to the above cited argument of Kammerer (2009) and Reinhart (1998) of adding personal benefit and value to Eco-efficiency in appliances, this research proposes that Design can add precisely the often discussed missing dimension to Eco-efficient appliances. Redesigning Eco-efficient appliances to reflect their 'hidden Eco-efficient' qualities visually, can be a source of personal benefit to consumer, as it would offer consumers an opportunity to enrich their personal identity using such artifacts.

This is where the role of 'product semantics' comes into play. At the moment Eco-efficiency needs an identity in terms of product appearance, and nowhere is this truer than in the home appliances industry. Apart from certain extrinsic features such as eco-labeling and energy labeling appliances by and large don't differentiate themselves based on their intrinsic features (geometry, proportions, composition). This research will seek to understand how to ordinary users cognitively associate with Eco-efficiency based on language structures and how to attribute these associations visually as designed features of an appliance. The end result sought here is to seek if appliances can 'speak' their Eco-efficiency non-instrumentally through mere visual sensing by the buyer. Product Semantics in the context of this research is used as a design theory seeking to exploit the cognitive processes and the inherent pattern making (i.e. according gestalt theory) capabilities of the human mind to communicate the pragmatic qualities (Eco-efficiency in this case) of an artifact.

Semantics says certain shapes, patterns, & symbols create specific emotional responses & associations in the beholder (Janlert & Stolterman, 1997).They make reference to the 'Character Theory' which postulates the existence of stable associations between physical appearances of artifacts and the expected characteristics which it is expected to exhibit. This is a psychological process and largely defines how a user expects a product to behave based on the character he has attributed to it. The 'character modeling process' outlined by Janlert & Stolterman elaborates upon this much more and will be looked into in detail in the later stages. In a nutshell it could be stated that when a certain shape is perceived by a user it triggers a cognitive response which includes forming an initial aesthetic impression, followed by a semantic interpretation wherein the user attaches a subjective meaning within his brain and ending with a symbolic association wherein the user tries to visualize what the product would say about its owner and its attached social significance (Moultrie, 2006). Thus it could be said that the physical appearance of the product and the arrangement of its parts (i.e. visual gestalt according to Maeda, 2006) should pass on a meaning or a message to the user. Therefore the gestalt of a product should pass on the intended message as clearly as possible i.e. in this case- Eco-efficiency, and every product has an inherent Gestalt (Maeda, 2006). The product in this case can also be thought of as a text written by the designer and to be read by the consumer (Lawson and Storer, 2008). According to Shannon's mathematical theory of communication adapted by Crilly (Crilly et al, 2004) the product is a transmitter of a message originating from the source which is the designer and to be received by the user.

Users have certain associations in language with respect to Eco-efficiency; these could be broadly the product characteristics which make up a product character. These characters, which are metaphorical constructions, ascribe the demeanor and appearance which users expect an Eco-efficient product to portray. It is the designer's job to plant 'symbols' or visual cues within the design to construct a product character, such that it leads the user to semantically interpret Eco-efficiency within the psychological

space. If appliances embrace and progress towards this approach then platforms could potentially 'talk' their Eco-efficiency to the users thus creating a unique mental association towards such an appliance by the user.

At the moment a product character associated with Eco-efficiency is almost unknown in the current language usage scenario of both ordinary users and design experts, and attributing unknown characters is a notoriously difficult task (Janlert & Stolterman, 1997). This research then looks into how Eco-efficiency can be made explicit in terms of product characters and attributed through design into Eco-efficient home appliances.

Research Area:
Product Semantics to communicate Eco-efficiency

The research map below (Figure 3) highlights the 3 major over lapping areas which are investigated in this research- product design, Eco-efficiency, & home appliances. The core areas of research are Product Semantics and Eco-efficiency and the application context is home appliances. Product Semantics, which is the focus, lies within the broader subject domain of Product Design. The region where product semantics overlaps with Eco-efficiency and home appliances is where the research question lies: *How to design a home appliance which communicates Eco-efficiency?*

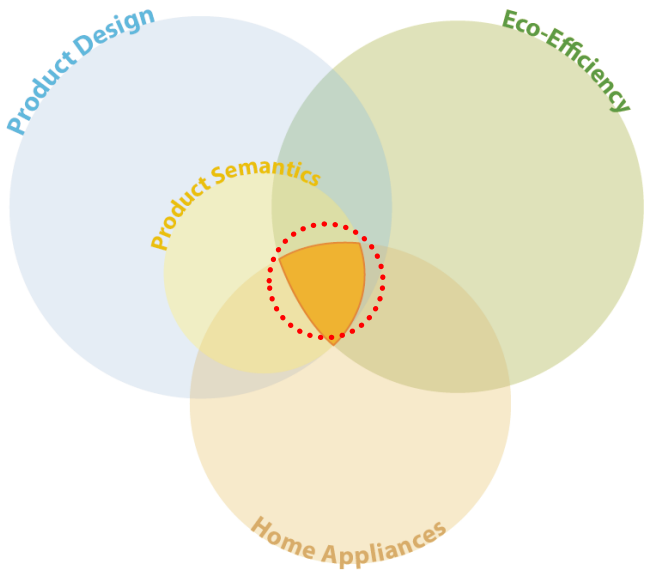


Figure 3: Research Map

This research will individually look into all the 3 areas of Eco-efficiency, Product Semantics, and home appliances in the respective sections and finally conclude with a design process which has been systemized in this research to explore how application of Product Semantics can help in redesigning the product characters of home appliances to improve the communication of Eco-efficiency.

1. Research Objectives

1. Research Objectives
1.1 General Objectives

Eco-efficiency is not a feature it is a meaning which the product expresses. Through literature, publications and industry opinion it is possible to understand that there is an ever growing interest into infusing this meaning into most product categories. The main objective of this research is in essence to understand how this process is being handled currently in the home appliances industry and where does design figure in it all.

Home appliances are complicated platforms with a complex Product Development Process (PDP). This complexity is put into place largely through various aspects of manufacturing within such large multinational corporations. A typical appliance development process spans 2-3 years from initial product concept proposal to final serial production costing several million Euros of investment from the manufacturer and the partner suppliers. Some of the main factors controlling the product development process is management best practices, complex supplier relationships, procurement and cost reduction, safety regulations, robust design restrictions, Opex protocols- *operational excellence* to move from one development milestone to the next, new technology development and advantage, reducing part number counts in global inventory management systems, soft and hard tooling investment scoping and management, to name only a few. Just trying to infuse Eco-efficiency into a new appliance development keeping all these frameworks in place, brings forth the complexity of the whole task. Stevels (1998) acknowledges this complexity within modern manufacturing as also indicates that Eco-design (which he uses as an approach to achieve Eco-efficiency) is a cross-functional activity requiring the cooperation of all the internal organizational divisions. In fact very important company functions such as marketing and finance have been intentionally left out, but, typically Eco-efficiency is largely looked upon as a debatable investment by these very important functionaries (Cramer, 1997). Businesses and manufacturers need to be convinced of the economic benefits of Eco-efficiency in order to invest in it, and this decision becomes more difficult by the poor quality perception surrounding products with a higher environmental performance amongst end users (Earl & Clift, 1998). Even so there have been studies which have proven that business to business consumers are more driven to buy products with a higher recycled or recyclable components content than personal consumers ie: the main target customers of the appliances industry.

In light of all these restrictions and requirements, appliance manufacturers have quite limited shoulder room left to maneuver when they want to increase the environmental performance of their platforms. Presently companies are undertaking several measures which can be enacted within the present scenario and these relate mostly to emission reduction, restricting certain chemicals and effluents from the production process, and generally reducing the content of hazardous substances through complying with guidelines such as RoHS.

Brezet, Cramer & Stevels, (1995) describe Eco-design as a basis of achieving Eco-efficiency. Citing Eco-design as essentially a ‘technical issue’ he proposes a 4 step model as a method of incremental improvement: **Step1**- *improve the existing product* i.e. reduce parts, reduce material, eliminate hazardous substances, reduce weight, reduce packaging etc. **Step2**- *radical redesign* i.e. pre-development level lab research work, pushing limits of physics, chemistry, and electronics, end-of-life durability, cross functional thinking on a strategic managerial level etc. **Step3**- *Propose product alternatives* i.e. re-think the current product model, re-organise supplier base, identify strategic environmental challenges, and

incorporate LCA tools in product planning. Needless to say this current manufacturing has not yet reached this level, and significant financial and operational risks exist in implementing environmental consideration to this level in any manufacturing organization. **Step4**- *Achieve completely sustainable product concepts*.
According to the above model Eco-efficiency in appliance manufacturing can be achieved in both steps 1&2, as has been validated with the author's experience within Whirlpool Europe. The Ixelium flat cooktop reinvented the current gas burner architecture and pushed energy reduction by upto 20% which was projected by the manufacturer as a strategic advantage of this product over the competitors. This research concentrates on the implementation of Eco-efficiency within appliance manufacturing at step 2 level according to this model as going beyond this step requires stakeholder involvement and crosses into the realms of social innovation which is beyond the scope of this thesis and also the current manufacturing model.

The role of design in this complex process therefore has been largely overshadowed or reduced in significance & Stevels (1998) confirms this by citing Eco-design as a technical issue. In the end delivering a platform which meets its cost targets, meets marketing requirements, and fulfills all environmental obligations is such a daunting task in itself that to achieve product differentiation through a unique product appearance which communicates all the effort gone behind in making a platform Eco-efficient is deemed, well, secondary.

This is unfortunate, as is apparent just by looking at the physical architecture of home appliances which basically hasn't changed in the last 40 years since the 1960's more or less (Figure 4).

Figure 4: Product displays in a department store (Burdek, 2005).

Surely design can make a more positive impact if given a chance or if companies can realize that investing in developing a product appearance which communicates the Eco-efficient technical features incorporated inside all appliances can be a fair competitive advantage.

At present though this is not the case, but has the potential to change.

1.2 Specific Objectives

This research has 3 specific objectives which outline the end goals it aims to achieve.

The **first objective** is highlighting the exact usage context for Eco-efficient design. There are lots conflicting definitions currently being used in the scientific and industrial context. It is important that everybody speaks the same language in order to be able to address the same issues in most effective manner. The problem is essentially a semantic one. Green design, eco design, sustainable product design (SPD), environmental product design (EPD) are some of the many terms being used by designers and educators alike to address a general direction in product design and development with consideration for the environment factored into the process.

As a starting point The Journal of Sustainable Product Design defines Eco-efficiency as "reducing resource conservation, whilst adding meaning and reducing costs".

The **second objective** seeks to define a product semantic identity for Eco-efficiency. Just as in language Eco-efficiency also lacks a clear expression in terms of design. This research identifies product characters which best communicate Eco-efficiency in an appliance through 'non-instrumental interaction' i.e.: to understand how Eco-efficient appliances can "speak" their environment friendly character to the potential buyer before s/he operates the appliance, nor becomes influenced by its usability.

At present an emerging issue surrounding Eco-efficient design is lack of application of Product Semantics which communicate this quality within a product. Design has been defined as "making sense of things (to others)" in the essay "*Design Research, an Oxymoron*", p-69 (Krippendorff, 2006). This sense making activity becomes increasingly difficult in the context of home appliances, seeing as there is absolutely no product differentiation with respect to their physical appearance. Design in the current appliance companies is a 'styling' function, and styling has to do with forms not meanings (Krippendorff, 2006). There is a total lack of semantics here as well. Semantics can also be called 'shape-coding' which passes on a symbolic message to user i.e.: product progresses beyond form follows function to incorporate meaning into itself (Blaich, 1989). Product semantics can be said to combine the physical, ergonomic and aesthetic functions with symbolic qualities. Ultimately the application of semantics is a (new) design tool for achieving (product) differentiation (Blaich, 1989), and product differentiation is what appliance manufacturers seek to achieve in order to capture market share.

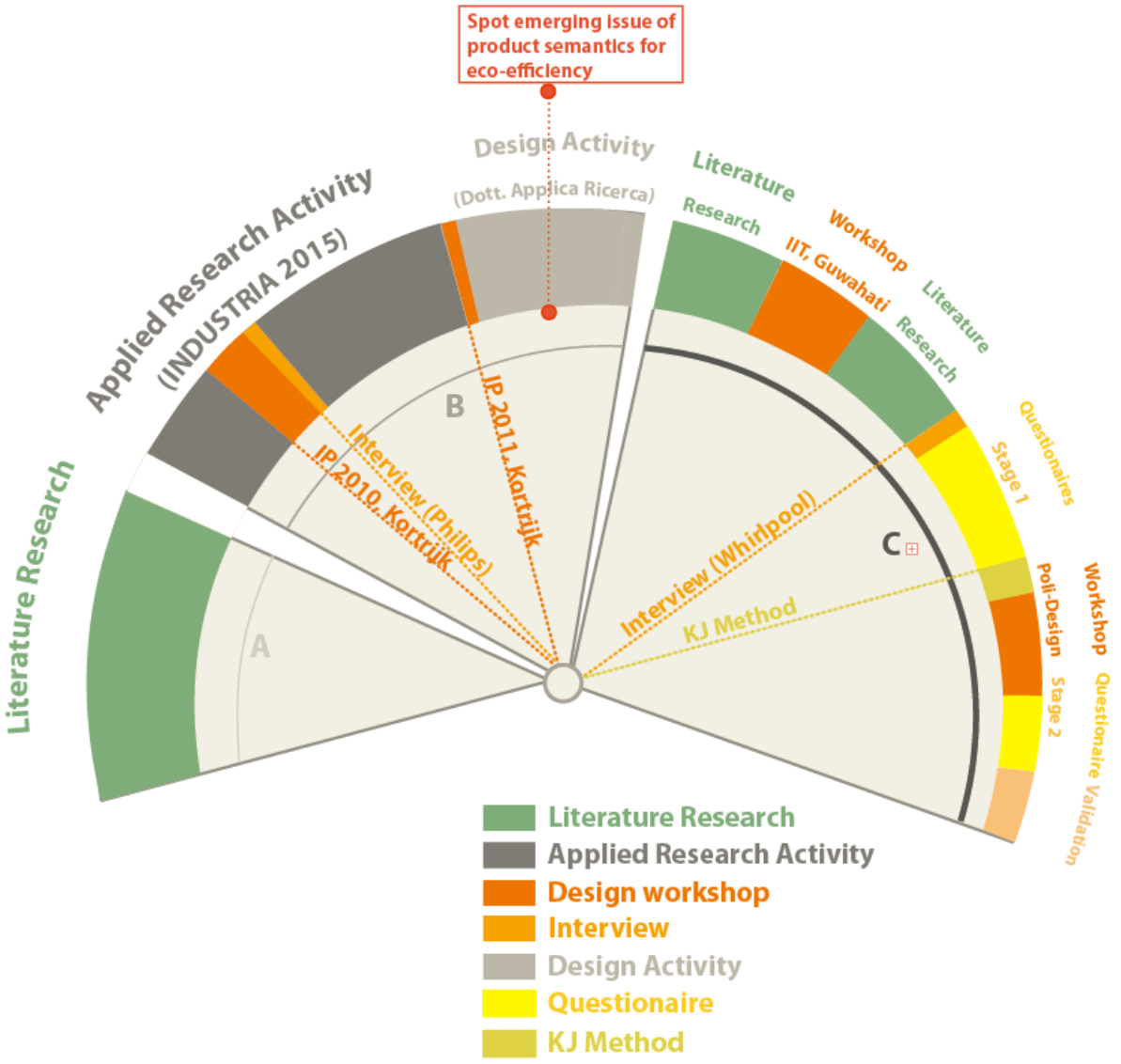
The understanding of this objective has been achieved through various design activities during the course of this research. The participation of the author within Whirlpool Europe in the Global Product Development - Cooking appliances division as a design engineer gave deep insights into how Eco-efficiency is currently expressed within cooking appliances and its relevance in the over-all Product Development Process. In addition 2 design workshops were organized to design washing machines which communicate Eco-efficiency in Indian Institute of Technology (IIT, Guwahati) and PoliDesign (Milan). The first workshop was sort of a test bed to understand how designers are currently addressing Eco-efficiency, and the second one was a validation tool where design guidelines were given to the students based on the results of studies performed on the outcome of the workshop in IIT. These specific research tools will be elaborated upon at a later stage.

The **third and last objective** is to achieve a set of design guidelines based on the outcome of the design workshop in PoliDesign. These design guidelines are in the form of product characters which communicate Eco-efficiency. A character can be defined as a unity of all characteristics within a product (Janlert & Stolterman, 1997). Furthermore a character is not just a simple collection, but with all related characteristics integrated into a coherent whole. A certain character pervades through all aspects of a product and can put across 'soft' or subtle expectations to the user. The expectation in this case would be that of 'Eco-efficiency'.

These design guidelines would be useful as tool for designers within appliance companies where they could be put to test to develop Eco-efficient platforms in the near future. Of course the true success of these guidelines would only be demonstrated if such appliances would achieve a marketing success in terms of revenue to the company so that such companies would be willing to invest further in developing more Eco-efficient platforms to drive their volumes and not just limit Eco-efficiency to the high end premium flagship appliances, as is the case now.

These guidelines could also be a basis for further research & development, to delve into other product categories such as digital televisions- an obvious candidate category.

2. Methodology



2.Methodology

2.1 Research Process

The research methodology followed in this research is of action research. This methodological approach consisted of various methods used to execute the entire process. These constituent methods inturn used several tools within them to enrich their progress.

The action research process visualised here is a semi-circular path utilising certain recurrent methods. Action research has been described as "research through design" by Rampino and Colombo (2011). They go on to say that it is a process of creating research through a design project. Indeed in this research the nature of the problem itself became clearer through the implementation of several design projects. Saikley has been cited by Rampino & Colombo as quoting that this is the methodology of dealing with " fuzzy research problems", which was exactly the nature of the research question here of defining product characters which best communicate Eco-efficiency.

Figure 5: Action Research: Research process and methods

This research process is divided into 3 major phases (Figure 5): Phase 'A' relates to the starting point using literature research as the major method in order to help form the initial research question.

Phase 'B' is the applied research and design activity which was majorly centered around the collaboration developed with Whirlpool Europe during the course of this research. This phase above all served to give insights into the limits and opportunities of the appliance PDP.
Phase 'C' uses the product semantic approach in a design process to see how Eco-efficiency can be communicated in an appliance platform by re-designing its product characters, in this case a washing machine. Why a washing machine? This choice was made keeping in the mind the product categorisation across different appliance platforms in different parts of the world. A washing machine was deemed to be an appliance category which is more or less constant across the different parts of the world, thus universally recognised. This reduces the impact of the cultrual differences which designers and users might feel when looking at the same washing machine concept.
The starting point of this product semantic process is designing the *meaning* that is Eco-efficiency into an appliance through design concepts developed in the design workshop in IIT, Guwahati. The final objective was to be able to extract adjectives which could be designated as product characters and could then be used as a starting point for the PoliDesign workshop of re-designing the product characters of a washing machine. This methodology was adapted from 'TheSemantic Turn', p-232-240 (Klaus Krippendorf, 2006). It was based on the assumption adopted from the same reference that product characters can be described using adjectives.
At this point it is important to make explicit some assumptions about the research process. According to Liz Sanders'(Interactions, vol-XV.6, pp-14) research map discussed in "An Evolving Map of Design Practice and Design Research" there are 4 principle quadrants along which a research area could be placed according to figure 6 below:

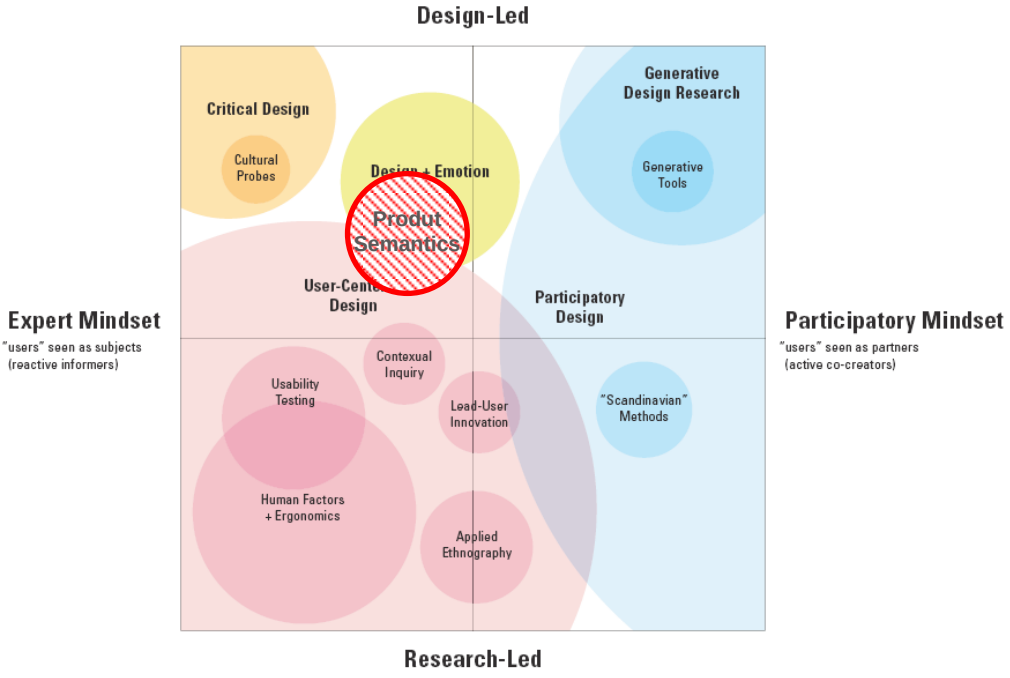


Figure 6: Map of design research—research types

According to this map there are 2 kinds of cultural mindsets in research: a participatory mindset and an expert mindset. On the left is Designer as the expert where the designer is the only one principally involved with the process of creation consulting people only for feedback and treating users as "consumers and subjects". This culture is the opposite of participatory cultural mindset on the right which

believes in co-creation. Liz Sanders further makes it very clear that it is very difficult for people to move from one side of this map to the other as it entails a significant cultural change.
The area of this research falls firmly in the domain of Design led & Expert mindset and is marked by the 'Product Semantics' paradigm. In this case there is a overlap between the 'Design + Emotion' and 'User Centered Design' paradigm. This research treats Eco-efficiency as a 'meaning' and not a 'product feature' as it is an attribute which influences each and every aspect of an appliance platform. Eco-efficiency is not just a matter of increasing the performance of certain feature within a product ie: the rotation speed of a washing machine, and for this reason it is difficult to be communicated.
The overlap with the 'Design+Emotion' & 'User Centered Design' is justified due to various methodological similarities and the 3 major starting assumptions grounding this research:

1. **Eco-efficiency is based as a meaning.** ie: a message to be communicated.
2. **The product characters can be 're-designed' to communicate a certain 'meaning'.** (Adapted from **Klaus Krippendorff**, *The semantic turn, p232-240, 2006,* itself an adaptation of the process suggested by **Reinhart Butter** , *Putting Theory into Practice: An Application of Product Semantics to Transportation Design*, 1989.)
3. **Product characters are described by adjectives (or visual metaphors)**. (Gorno & Colombo, *Attributing intended character to products through their formal features*, 2011) & Klaus Krippendorff, *The semantic turn*, p157, 2006

'Characters' in this case are defined as conceptual devices that reduce the mental effort involved in dealing with artifacts (Krippendorf, 2006).
Gorno (2010) in her PhD thesis " Designing emotions through industrial products features" cites that a product appearance by virtue of semantic interpretation elicits an emotional response in the user because of the visual stimuli captured through the highly developed sense of sight in human beings.
Due to the similarities in the background of Gorno's thesis, which was in the design+emotion field and this research, plus there are definitely strong points of overlapping in the entire research development process.
In addition according to the research map in figure 5, section'C' is a design process aimed at extracting and redesigning product characters which successfully communicate Eco-efficiency in washing machines
The final outocme of this design process is to develop a design guideline in the form of product characters for Eco-efficient home appliances, using specific methods and tools such as questionaire analyses, focus groups, and mood boards which is close to the definition of the 'user centered design' approach by Liz Sanders i.e. "People use research-led approaches with an expert mindset to collect, analyze, and interpret data in order to develop specifications or principles to guide or inform the design development of products (and services)".

2.2 Research Methods

Literature review:

The starting point of this research was ofcourse literature research. In this phase the position of Eco-efficiency was investigated through reading papers, journals, and publications. This process was repeated several times during the entire process of research, whenever a certain scientific underpinning or

grounding was required in order to proceed to a following step along the research process. The objectives fulfilled through this method were:

1. Make semantic clarification about Eco-efficient Design.
2. Reduce some of the confusion associated with Eco-efficient design by identifying exact usage context.
3. Understand how semantics addresses attributing product characters.
4. Research methods & tools to benchmark and classify product semantics for Eco-efficiency.

Applied research activiy:

The initial literature research phase was immediately followed by the applied research activity of working within the ***Industria 2015*** research project as part of a consortium comprising Whirlpool Europe, Cefriel, UdR:IDEA. In this phase the nature of activities varied from working as a researcher to benchmark Eco-efficient features in appliance categories, understand the evolution and future trends of appliance design and technologies, plus in addition also participate as a designer to work on the GreenKitchen 2.0 project with Whirlpool Europe to help design the Graphic User Interface (GUI) of the smart appliance platform which in turn also gave scientific insights into using 'Eco-visualization' as a tool to improve machine-user communication.

Design activity:

This was a method used where the nature of activities was to entirely work as full time gas technology design engineer within Whirlpool Europe in the food preparation division. This activity above all else gave insights into the actual appliance Product Development Process (PDP) through working on the innovation development project called the 'Flat Cooktop'. Furthermore it was during the design activity that the emerging issue of product semantics for Eco-efficiency became quite clear (Figure 4), due in part to the direct confirmations received through the observation of the Flat Cooktop appliance PDP.

These initial steps helped to frame and clarify the original research question.

Design Workshops:

The final phase 'C' of the research process was redesigning the product characters of a washing machine to communicate Eco-efficiency. 2 workshops were planned to fulfill this phase of research. An initial workshop was done to understand how designers approach Eco-efficiency by designing an appliance platform as a project. The results of this workshop were analyzed and used as an input for the second workshop which would serve to achieve the final result of defining which product characters emerge most successful in communicating the intended product meaning of Eco-efficiency.

1. Workshop on designing Eco-efficient washing machines in Indian Institute of Technology
2. Workshop on re-designing product character of washing machines to express Eco-efficiency in PoliDesign.

During the course of this research were also conducted several multi-disciplinary design workshops called Intensive Programs (IP) inter-spaced between phases 'A' & 'B' in the research process map, on designing 'green products through a multi-coloured approach'. These were multi-disciplinary design workshops were quite international and multi-cultural in nature and conducted in the University of West Flaanders, Kortrijk, Belgium in 2010 and again in 2011. Though these workshops didn't really have any direct bearing on the research process and outcome, they did serve to give insights into how the manufacturing industry in other product categories is approaching Eco-efficiency. A direct benefit of this insight was to strengthen the research question further.

3. Erasmus funded Intensive Program –IP, 2010- 2011, 15 day workshop on green products through a multi coloured approach, HOWEST, Kortrijk, BE.

Interviews:

Interviews served as great insights and also validation of the original research assumption during key phases of the entire research process. These interviews were carried out in principally in Philips Consumer Lifestyle, where meeting with global innovation manager Dirk De Boe gave strong affirmations to the validity of the original research question, which even Philips as a consumer electronics company felt was valid in the LCD tv's market. This insight gave an early indication that perhaps the issue of addressing product semantics for Eco-efficient products may have application beyond the appliance industry.

The second great input was from meeting with Head of advanced concepts development and Head of usability within the Global Consumer Design division of Whirlpool Europe, who served to give an industry expert level affirmation of the research question and helped to tune and refine the research assumptions which would be more aligned with the reality of the appliance industry.

Questionnaires:

A questionnaire analysis was used in 2 stages of 3rd phase of the research map shown in figure 5. In the first instance it was used to understand how the infused meaning of Eco-efficiency within washing machine concepts was perceived by end users in terms of product characters. These product characters were defined through adjectives and a group of adjectives defined to project a similar or synonymous set of meanings were clustered together using a thesaurus, and defined by one representative adjective henceforth termed as a 'character'. In the second instance an online questionnaire was performed to measure the rate of success of the product characters used to design the washing machine concepts in the final workshop to ordinary users (scientifically naïve, non-engineering trained- Krippendorff,1989) and non-designers.

The first questionnaire analysis helped to undertake a quantitative analysis into what the users think when they look at a particular product concept represented by a list of adjectives captured from numerous ordinary persons and non-designers. The second questionnaire simply ranked the success rate of the product characters attributed within washing machine design concepts.

KJ Method:

KJ method is a group ranking and voting process which will be discussed in section 7.6 in more detail. This method was used with 4 design experts performed within the research group of the author. Keeping in mind the insights put forth by Blijlevens et al (2009) that design experts are more skilled in dealing with complex adjectives and basically organise and understand them fundamentally different terms than non-expert designers who have limited cognitive capacity to deal with such activites. Successful application of the KJ method ensured that the adjectives captured from the first questionnaire analysis were organised into characteristic groups and 1 adjective was voted within each group to form a representative character. The ultimate aim of this method was to extract product characters which were to be utilised in the subsequent design workshop. 6 characters in total were extracted using this method.

2.3 Research Tools

Each of the research methods discussed in figure 5 above used several tools. Some of these tools are discussed in more details below.

Classification of Eco-efficiency in product design:

One of the tools used was to try and understand the different approaches which design uses to address Eco-efficiency in products. There are many examples of Eco-efficient products being marketed today, and developing an understanding into what are the different ways in which designers approach this issue was important. The point of this exercise was to help illustrate as a starting point about how product design in general communicates or achieves the meaning of Eco-efficiency seeing as a semantic approach to Eco-efficiency is lacking even in this broader scale. The classification- "This is Green?" (Ferraris & Chakraborty, 2010) was tested on various occasions through design workshops such as the one in HOWEST, Kortrijk and IIT, Guwahati. In both these occasions design students positively reported having benefited through this categorisation as input for the development of their projects.

Case Studies:

Case studies were important to understand the current state of the appliance industry in terms of product categorisations, market positioning of home appliances currently under production.

Teaching Eco-efficiency in a multi-disciplinary environment:

Participating as a tutor in a design workshop served 2 purposes. First it helped to understand how designers today perceive and approach Eco-efficiency, which was aided by the first tool cited here of 'classification of Eco-efficiency'. This also helped to showcase the creative possibilities which the community is exhibiting, and also to warn designers which approaches are not feasible and essentially just 'green washing'. Drawing this distinction as a tutor was an important contribution because as became evident during the course of teaching activities that such a distinction is not easily obvious to product designers.

The second important purpose was to understand how companies in different product segments such as Philips in consumer electronics, and EuroBike in the bicycle manufacturing category are approaching Eco-efficient design. In a way this understanding afforded the possibility to further refine and confirm the original research question.

Benchmarking Eco-efficient features in appliances:

Benchmarking all the Eco-efficient features currently being developed and marketed by different brands of appliance manufacturers gave a strategic overview into the direction this industry is taking with respect to Eco-efficiency. The trade-off between technology and design is one of the important considerations which this benchmarking clarified. If technology is the dominant force driving Eco-efficiency in the current appliance platforms, then the role of design consequently gets progressively side-lined, although this necessarily doesn't need to be. Gaining an understanding into what role the designers are currently playing in introducing Eco-efficiency in appliances was crucial in order to point out how their role could be improved.

Working on GreenKitchen 2.0:

The GreenKitchen project was responsible for turning design research insights from the INDUSTRIA 2015 into a design project. The INDUSTRIA 2015 research was responsible for studying the evolution and future development of home appliances design and the current state of the art of 'smart grid' appliances. Smart grid appliances are networked appliances 'speaking' to the power grid controlled by the utility provider to reduce and optimise their energy consumption during cycle times to prevent power black-outs. The GreenKitchen was one such Eco-efficient project exploring the extent to which the current design situation within Whirlpool can help to realise such a platform. The objective for the author was to design an interactive tablet device which can be used to remotely control such a smart appliance platform in the home scenario of the near future propose new interaction paradigm based on this device.

This project gave a sense of realisation to the author about the limits and constraints which appliance designers face up to when implementing Eco-efficiency from the point of view of Usability, product communication, safety, user experience, and brand identity.

Working on the Whirlpool 'Ixelium' Flat Cooktop:

The Ixelium Flat cooktop was a purely design activity, and served to give first hand insights into how the appliance PDP functions within a real world manufacturing environment. Understanding the PDP is crucial if any change is to be proposed in how current appliances are designed and developed and especially if the role of the designers is to be made more explicit. Finally Eco-efficiency is infused within appliances at some point during the PDP which is generic to most appliance manufacturers thus if the expression of Eco-efficiency is to be changed within current appliances, then again a real world and not just a theoretical understanding of Eco-efficiency is important.

Focus Group:

Focus groups are group discussions organised to explore a specific set of issues such as people's views and experiences (Barker and Rich 1992, Zimmerman et al. 1990). Focus groups differ mainly from interviews in the sense that the participants are allowed to communicate between one another (Kitzinger,

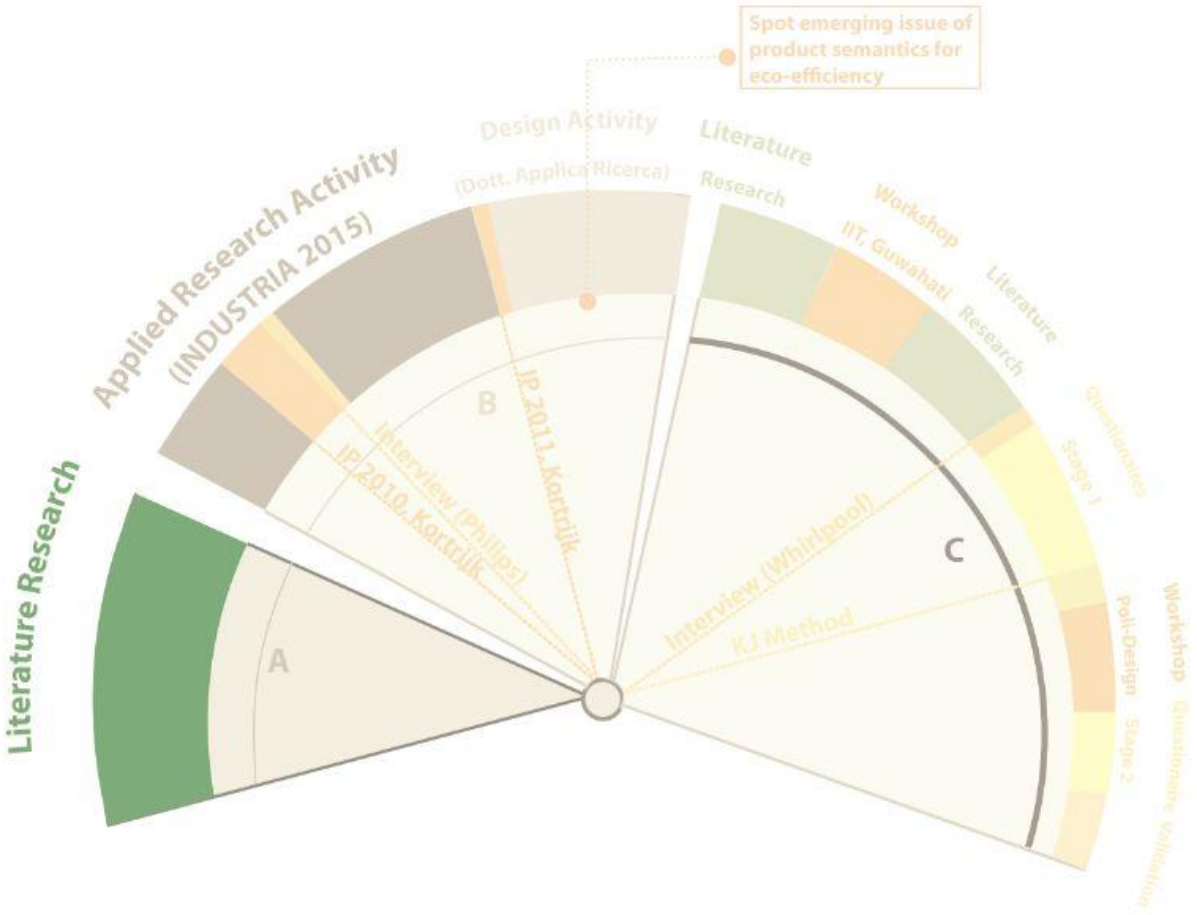
1994). Focus groups are led by a moderator who is mostly the researcher in question and guides the discussion between the participants in order to get the intended result. Unlike questionnaires which only tell the researcher ‘what’ the participants were thinking, a focus group also gives ‘why’ and ‘how’ they thought what they did.
In this research a focus group approach was used in the KJ method in order to rank and classify the adjectives which were captured by the questionnaire analysis previously.

Mood Boards:

Manifestation through images of a particular character is called a mood board (p-233, Krippendorf, 2006). These visual manifestations of characters are carefully selected in order to invoke an intended meaning in a user and avoid unintended ones.

Mood boards were constructed within a mini focus group, consisting of design researchers who are regarded as design experts and most likely to select the correct manifestations for each product character (Butter, 1989).

3. Theoretical Background



3. Theoretical background

3.1 Sustainability and Eco-efficiency in product design

Starting Insights

This section does not aim to discuss all the aspects on the seemingly vast subject of sustainability in product design, but will give a brief over sight about what sustainable product design and how it is distinct from Eco-efficient design, and more importantly this section outlines how Eco-efficiency fits within the over-all agenda of designing domestic appliances in the near future.

This research aims to join to 2 quite new emerging fields: Product Semantics and sustainability. Although there is an interesting emerging 'merging' of these 2 fields, the polarity in their points of view with respect to 'Design' as a discipline can be underlined by how both of them define design to begin with.

Sustainable design defines design as: (The role of) Industrial design can be summarised as activity that connects technologically possible with ecologically necessary. (Vezzoli & Manzini, 2008).

Product Semantics defines design as: Design is making sense of things (to others). (Klaus Krippendorff, *On the Essential Contexts of Artifacts or on the Proposition that Design Is Making Sense (of Things*), 1989).

In the first case design is mostly considered with what technology can deliver to ease the burden on the environment. This definition has a strong cultural background to primarily evaluate the ecological and sociological dimensions of design. How design can help reduce the footprint of mankind on the planet Earth. Here design is an ethical activity first and foremost.

In the second case, design is mostly concerned with the Human Centred approach to products. How do products communicate with the end user, what is the cognitive activity which a user experiences when she first sets eyes upon a product and what is the ensuing emotional reaction to this sight within the user's mental space. Here design seeks to demystify the shape encoding which designers do when they design a product and the subsequent de-coding which the users perform when they attempt to experience the designed product. Product semantics seeks to make this process more intentional and less random. Here design is a professional activity first and foremost.

Focus on Product Design

Stuart Walker sums it well when he says: *"Sustainable product design (SPD)is being approached in many ways but often, it seems, there is more attention given to related but peripheral aspects, such as technological innovations or analysis methodologies, rather than to 'designing' itself."*

This is not surprising considering that the theory of product semantics says that "*The fate of all artifacts is decided in language*" (Krippendorff, 2006) and from a point of view of language the term 'sustainable development' (and by its derivation 'sustainable design') is a semantically empty term. (Vezzoli & Manzini, 1989.) This semantic pollution is attributed to the large scale improper usage of the term sustainable development, thus render it and by derivation again, all its related applications, without much

meaning especially in terms of design application. The implications of this in terms of product semantic theory, which relies on visual metaphors to attribute a specific character to an artefact, is that sustainability (and by extension Eco-efficiency) are ambiguous entities. What cannot be clearly defined in language is difficult to translate into design, much less product features which are attributions of product characters.

This resulted in very superficial and unconvincing product solutions in terms of design. The human centred approach to product semantics relies on metaphors, both verbal and visual, to render a new or a novel artefact product category i.e.: sustainable and Eco-efficient product, understandable to the end user. Since metaphors are grounded in language, and in language sustainability has neither clear understanding nor usage, it has confused designers as well in the application of these terminologies in terms of product characters. Thus fate of Eco-efficiency resulted in becoming what Krippendorff sites as the dreaded 'dead metaphor' or cliché, such as is evident if one looks at the examples and applications which the product design community in general has been able to traditionally offer. Sustainable design has traditionally been concerned with craft based and batch produced objects this though is changing, not necessarily in an organised and concerted manner as Walker (1998) points out that an important part of sustainable design is to utilise local craftsmanship and production (Figure 7).

Figure 7: 'Kind of Blue' chair – rear view

The first step thus, is to de-pollute the cross talk which happens regarding the terminologies which are used with respect to sustainability. There is a list of definitions which are illustrated in a later stage within this section which will spell out these terminologies which the author has come across being widely used in the design community.

The journal of Sustainable Product Design defines sustainable product design or SPD as such: "The addition and balancing of social and ethical issues, alongside environmental and economic issues into the product design process." (Chick and Charter, 1997). It refers to sustainable product design as one which balances social and ethical issues alongside those of environmental and economic ones.

The same source defines Eco-efficiency as "Reducing resource consumption, whilst 'adding value' and reducing costs." This 'value addition' is normally in the form of technological innovation, designing for disassembly, recycle and product re-capture friendly architecture, using novel materials, using a-toxic materials to name some of the main approaches.

From a point of view of sustainable product design 4 different levels of intervention are outlined (Vezzoli & Manzini, 1989):

1. Environmental redesign of existing systems. (1st Level)
2. Designing new products and services. (2nd Level)
3. Designing new production-consumption systems. (3rd Level)
4. Creating new scenarios for a sustainable lifestyle. (4th Level)

They go on to say that environmental redesign of existing systems actually entails mainly technological characteristics (non-toxicity, renewability, recyclable etc.) and does not require actually changing the consumer behavior. The social component here isn't very evolved and basically requires them to be ecologically conscious and choose between different Eco-efficient products according to eco-labeling criteria.

According to this definition Eco-efficient design falls firmly within the 1st level of intervention. This in a way reinforces its immediate nature and the over-all feasibility in addressing it. Perfecting and increasing the acceptability of this first level of intervention can increase the chances of subsequent successes in the following stages. Design plays a pivotal role in increasing the user acceptability and consequently market penetration of the Eco-efficient products.

Focus on Eco-efficiency

Citing the 4-steps model which was shown in Figure 1, we know that today we are in the 're-design' phase. The role of designers thus become even stronger as it they who have to contribute the most in this aspect, since it relates to their core competence. Successfully re-designing products based on even new and novel technologies which communicate effectively to the end users, can increase their market share, thus potentially also creating a 'bandwagon' effect described by (Wade 1995) which says that other companies can also embrace an emerging technology if it has a significant market share, thus strengthening its position. The 10 fold increase which we seek in order to reach a perfectly sustainable society will be borne on the back of technological Eco-efficiency (Vezzoli & Manzini, 1989). In the end though no one really knows what a sustainable society will look like, so far it is a target with constantly shifting goalposts. One way is to adopt the incremental improvement path and keep developing more and more Eco-efficient products and hope to increase their acceptance levels, though consumers will only do so expecting a superior performance criterion, although they might be willing to accept a slight performance comprise but only on the promise of radical environmental benefits. (Luttropp, 1998)

Since this research is concentrated towards Eco-efficiency that's where the focus will lie. The figure (Tischner, 2006) below differentiates the graduation from product design to eco-design to sustainable product design (Figure 8). This figure cites that in order to move from 'Product design' to 'eco design' one has to add the consideration of environment to the 3 basic considerations of product design which are : economic, functional, & aesthetic. In order to move from eco design to sustainable (product) design one has to add the ethical and social issues.

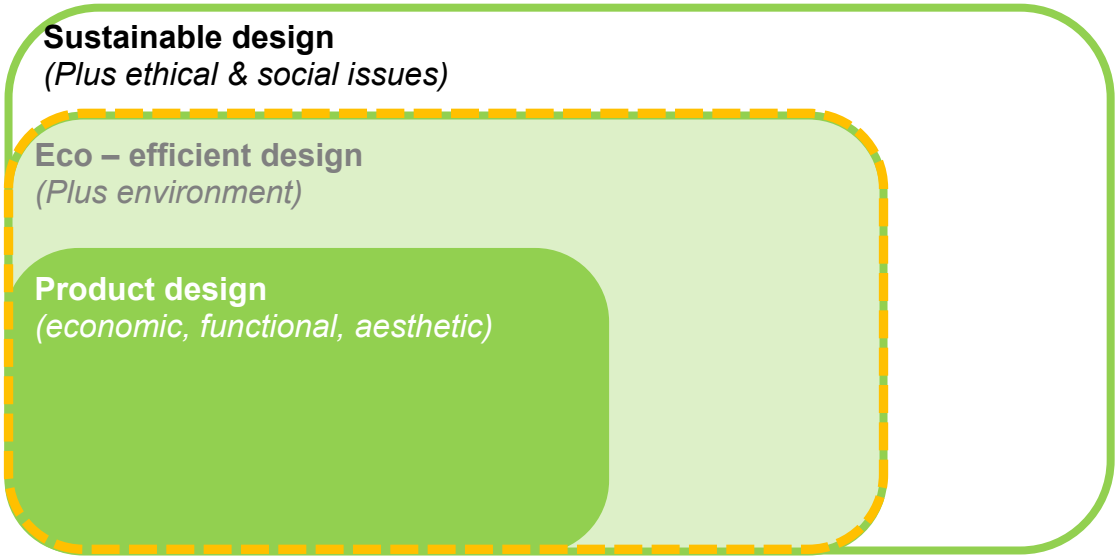


Figure 8: From Eco-efficient design to sustainable design
Source: Tischner- Econcept, (2006)

There are various lists of *design practices* which are readily touted as a means for addressing Eco-efficiency in product design. These practices basically look to improve the environmental performance of products without substantially changing the consumption pattern of the user (in accordance with 1st level of intervention proposed by Vezzoli and Manzini). Listed out and discussed below, these practices would include:

1. Design for disassembly
2. Design for recyclability
3. Using non-toxic materials
4. Life extension or appropriate lifespan
5. Design for remanufacture
6. Design for repairs

(Fiskel, Jozeph, 1996)

(Vezzoli,C.,Manzini,E., 1989)

Design for disassembly: as discussed before, products which have to be dissembled after their useful life is expired, have to have a mechanism which facilitates the taking apart of these products either by the manufacturer, or contracted through an installed supplier base. This is a paradoxical practice, as has been

pointed out by Mathews and Chambers, 1998, increasing the end of life value of a product decreases the benefit to the manufacturer. If a product is to be dissembled by a contractor, the disassembled components have to have an economic value, in order to make this operation viable. The manufacturer has to develop a reverse supply chain in order to be able to capture and analyze the products which have to be disassembled. These then would have to be sorted, graded, and classified according to the assembly architecture of the product. As is obvious this is a very expensive process because it is labor intensive. From the author's experience in the appliances industry, it is possible to say that this process could be potentially as complicated as the manufacturing process itself. Plus there could be other complications such as trade secrets, and proprietary technology which a manufacturer wouldn't want to expose to an external supplier to whom is outsourced the task of disassembly.

Design for recyclability: Closely related to design for disassembly, in the sense that if a product has to be recyclable it has to have aspects such as modularity, easily identifiable parts and materials, in addition to using screws instead of fasteners such that disassembly could happen in a non-destructive manner. Mostly it is the same contractors who would undertake the operation of disassembly and recycling the as recycling would logically follow the disassembly process. Although both these parameters are widely cited and recognized nowadays in order to address Eco-efficient design, the fact is these features are not easy for a designer to tackle. Typically such properties of a product have to be built into the PDP at a very early stage, when the designer has very limited knowledge about the details of the project and the enabling technologies which are going to be used. This is especially valid in a complex manufacturing environment such as home appliances. By the time the designer has gained enough knowledge about the project the technological and manufacturing limitations are too rigid to make any changes of significance to the over-all product. (Luttropp, 1999) If a product or assembly is successfully reduced to its recyclable state then, the constituent parts have to be converted to raw materials to be recycled and be reduced to their lowest virgin state such that they can be re-used as new input for the new manufacturing cycle. Even then using newly forged parts formed out of recycled raw materials are not without its drawbacks, because this gives a perception of lowered quality to the end user. (Earl & Clift, 1998)

Although there is a WEEE (Waste Electrical and Electronic Equipment) directive Europe which mandates manufacturers of certain categories of electrical or electronic devices to register and comply with this directive, the actual compliance rate across Europe could be quite questionable. In the author's own experience with Philips Consumer Lifestyle, it was discovered that a majority or LCD and cathode ray TV's in Europe as of 2010 were shipped to Africa, where mostly school going children dismantled them, granted though this gave them a source of comfortable lifestyle through the income generated.

For the waste treatment industry, recycling contractors are required to set up approved treatment facilities (ATFs) if they wish to export WEEE for re-use overseas.

Using non-toxic materials: This practice relates to the reduction or complete elimination of toxic materials and chemicals in the product assemblies. In Europe there are policy directives such as RoHS (Reduction of Hazardous Substances) which prohibit the use of certain substances such as lead, and pvc free wiring. In the appliance manufacturing industry the use of cfc free refrigerants have been implemented, and water based painting processes implemented as far as possible, to reduce chemical discharges from the appliances platforms.

Life extension and appropriate lifespan: Bestowing the appropriate lifespan to a product assembly is a core concern which should be carefully addressed. Give a life too short and un-necessary waste is generated, on the other hand giving a unnecessarily long life span to a specific component which is out of sync with the rest of the assembly means waste generation again. Also many materials that improve resistance characteristics tend to create problems during disposal (Vezzoli & Manzini, 1989) due to their over-engineered robustness. In addition manufacturing components with a higher projected lifespan definitely needs more energy for production, and if this added robustness is not required then this added energy consumption is a waste. In the least parts which have a lower lifespan ie: consumable parts, parts subject to wear and tear, should be separable and extractable from the main assembly. The appliance industry has been often accused of engineering 'planned obsolescence' into their platforms; though a proper life span balance needs to be achieved. Beyond a certain number of years it is more Eco-efficient to actually replace an appliance with a new and more efficient one keeping in pace with the technology development, this break-even point is on an average fixed between 7-10 years in different appliance categories.

Design for remanufacture: Remanufacturing is basically renewing products such that they are comparable to a (as if) new product and ready to be used by another end user in most cases. Needless to say the application of practice is very dicey most technological and high complexity product categories. Plus there are legislations in Europe such as the UK Trade Descriptions Act, which stipulates that new product assemblies must contain new components and parts. Legislation aside, there are stringent safety regulations in most manufacturing environments which forbid this kind of a practice.

Citing the example of the home appliance, they fall under product categories which can cause risk of fire, electric shock, resulting in serious injury and even death if any component fails. Seeing as each product assembly typically includes upto a 100 parts and sub-assemblies, the performance and safety of each of them has to be guaranteed. According to the strict safety and quality control regimes such as Six Sigma, unless a remanufactured can be absolutely 100% guaranteed to perform without fail it will not be allowed inside an appliance.

A third level of complication could be that remanufacturing components or sub-assemblies would require supplier coordination since most sub-assemblies are sourced from suppliers directly to save costs, at-least in the appliance industry.

Thus as of now manufacturing industry has a simple protocol: new products have new components, parts and sub-assemblies.

Design for repairs: Most electronic and electric products are being designed for serviceability. Design for repairs means if there is failure of severity 5 and above on a 10 point scale of a mechanical or electrical component then it will need to be replaced (according to DFMEA-Design Failure Mode Effect Analysis subject criteria). Arrangement of internal components is such that the trained serviceman knows exactly how to access a specific area with the minimum of checklist procedures.

In the case of appliances when they are designed they have to be designed according to strict 'modular architecture' engineering specifications, not for Eco-efficiency but for cost reduction and part number count reduction criteria. This means, that appliances across a certain category have common components

such as chassis and mounting points. These details assist greatly in serviceability and ease of access with a minimum of understanding.

More over according industry experts the option between repairing or replacing is a complicated decision to make[1]. Consider the graphic below, if an appliance falls within the 'yellow zone' (between 6-8 years old) then consider repairing it, otherwise if a prior repair has already been performed then it is cheaper and wiser to dispose it off and buy a newer and a more efficient appliance (Figure 8).

The idea of this discussion above was not to fault or discourage these practices but rather to bestow a deepened insight with realistic limitations and challenges which each of these Eco-efficient practices is likely to face in the real world outside the confines of the theoretical world. These are opportunities to really innovate in the design and engineering of Eco-efficient products, especially appliances, right in the beginning of the PDP.

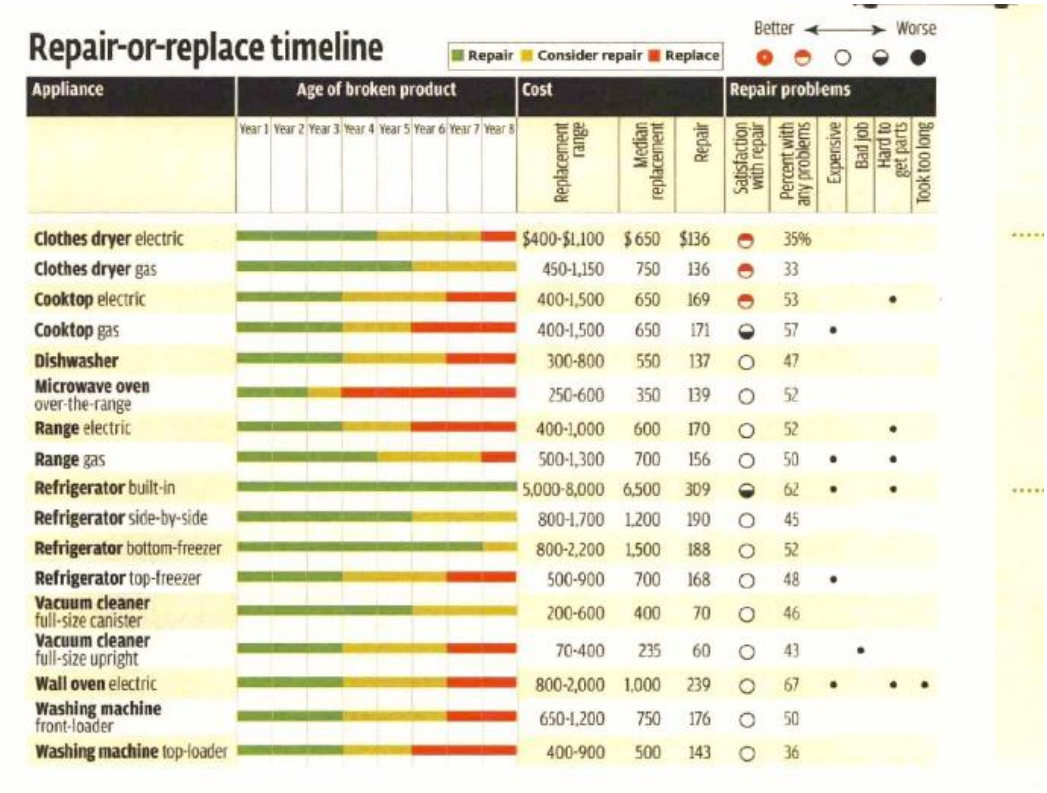


Figure 9: Repair-or-replace timeline (source: Consumer Reports Magazine)

Why Domestic Appliances?

Within the European context home appliances are one of the largest industry segments. By some estimates they account for upto 35 percent of total EU electricity consumption with refrigerators and freezers accounting for 15% of residential electricity followed by washing machines accounting for 4%,

[1] Repair or replace it?. (2011, august 01). consumer reports, 1-7

and dishwashers, ovens, and clothes dryers accounting for around 2% of total residential end use (Mills & Schleich, 2009). This makes them an important contributor to the agenda of energy efficiency.

Either due to changing regulations or changing market demand for Eco-efficient appliances, the appliances industry as a whole is moving in this direction. On its part the EU has set an efficiency guideline to increase appliance efficiency by 20% at the end of 2020. Most appliances under development at the moment are meeting the 20% consumption reduction target in the A+ energy labeling category. The ultimate goal of the appliances manufacturers is to reduce over-all consumption by upto 80% (Whirlpool Europe internal directive).

At the moment energy labeling is the industry standard in classifying Eco-efficient appliances in the European market place. As research has shown there is a mixed level of success of eco-labeling in Europe. Among the appliance categories washing machines have the highest percentage of class-A rated purchases with upto 65% and refrigerators have the lowest at 54%. Consumers with a higher education level and across younger age distribution report to be better aware of the energy label class of their appliances (Mills & Schleich, 2009). All this information points to a significant communication problem which appliances face with regard to their energy efficiency classification. But this is confirmed by the fact that "it is difficult for individuals to make the decision to purchase a particular product based on its environmental impact at the point of sale – it is an invisible factor that requires prior research, unlike price or aesthetic." (Byrnes, 2010).
Perhaps this further reinforces the original research objective being investigated here that product semantics can play a higher and a more significant role in communicating Eco-efficiency to the various users regardless of their age and educational backgrounds.
But in all honesty this will only solve part of the problem. As is affirmed by Byrnes (2010) who goes on to state that sustainability and by its extension Eco-efficiency is too much of an abstract concept. What human beings cannot visualize clearly ie: electricity for instance, they cannot internalize properly, and hence don't see it as an immediate or pressing concern.
Further reinforcing this aspect is the fact the price premium associated with class-A rated appliances is a serious inhibitor of their market adoption (Mills & Schleich, 2009). Eco-efficiency can be best driven higher electricity prices, which will force the consumers to be more aware of energy saving technologies. Nonetheless appliance manufacturers operate in a very challenging business environment. Earl & Clift (1998) cite in their article that manufacturers of electric and electrical products cite higher environmental awareness amongst business to business consumers compared to domestic consumers. Since appliance manufacturers sell almost exclusively to domestic consumers, they have a very steep and an uphill task to convince their target consumers to invest in Eco-efficiency, especially since such appliances always cost more than the normal appliances.
Appliances companies are large corporations with shareholders, who demand constant 'value generation'. Leadership which is unable to deliver these goals is swiftly replaced. Eco-efficiency for these corporations is a risk. A 'risk' is defined as a future event which has not yet realized itself and could have a positive or a negative impact. A risk which has realized itself is known as an 'issue'. Thus appliance manufacturers are unsure of the benefits of investing in an Eco-efficient platform, whose returns on investment are very 'risky'. A typical platform takes couple of years to develop, in the author's own experience, the 'Flat' cooktop cited at a later stage in this research, was driving such low volumes due to its flagship price tag, since the lean and Eco-efficient burner technology incorporated in it was driving up

prices beyond financially sustainable levels. In the end the company decided to push the project only as an innovation showcase, writing it off as a loss making undertaking.

In fact most appliance manufacturers are stuck in this precise dilemma, at some stage of Eco-efficient project development processes. Most design guidelines ask for properties such as robustness built-in, which is actually a carefully calibrated property designed to last a fixed number of years with utmost performance levels. The fact is, if appliances are designed to last indefinite periods of time and consumers don't buy new appliances every few years in a cyclic manner it might lead to economic collapse of these businesses. This will be a highly un-sustainable scenario from a social point of view. An emerging development in this regard is the rise of a product lifetime optimization strategy (Chalkley et al, 2001), where-in the appliance automatically disables some of its critical functions once it has reached a certain point in its lifecycle ensuring appliances are returned under the manufacturer's product take back program in the most predictable condition thus ensuring replacement when it's the most optimum point to do so keeping in view the entire operational lifecycle of the product. Of course this scenario works better in a product service system approach, where the user has just leased the appliances from the manufacturer.

In conclusion, helping to push Eco-efficiency in the appliance sector is projecting the designer's attention where it is needed most. Just to cite the importance of the appliance industry, in November 2011 the United States government cited a jump of 3.8% in appliance sales as an indicator of the national economic health. (http://www.bbc.co.uk/news/business) *captured 25/12/2011*

3.2 Key Definitions

This section just lists out some of the key definitions within the domain of sustainability in an attempt to remove some ambiguity and reduce some of the mismatched usage contexts quite commonly used these days. Green design, sustainable product design, environmental design, ecodesign are construed to be synonyms of each other freely inter-changeable, when in fact they are distinct. In today's scenario designers and even industries freely adapt the terminologies as they see fit. Here below is the brief list:

Environmental Design: Framework that situates the planning, production, & evaluation of objects of every scale, including products, buildings, parks, human settlements, and infrastructure, in a reciprocal relationship with the functioning and resilience of natural systems. (Design Dictionary-perspectives on design terminology, 2008)

Sustainability: A measure of the resilience of a system, the capacity of a system (and all its components) to repair itself when damaged. (Design Dictionary-perspectives on design terminology, 2008)

Sustainable development: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on Environment and Development -*WCED*, 1987)

Sustainable Product Design (SPD): '..the addition and balancing of social and ethical issues, alongside environmental and economic issues into the product design process- to achieve the quadruple bottom-line'. (Charter and Chick, JSPD – 1997 - IS 1, pp-5)

Design for environment (DFE): systematic consideration of environmental performance during the early stages of product development. It also addresses the traditional concerns of health and safety management, to the extent that they are important product or service considerations. In short, DFE is the design of safe and Eco-efficient products and processes.
(Fiksel, 1996)

EcoDesign: Eco-design is design following ecological criteria. Manifested as a compound expression of a vast complex of design activities, it tends to handle ecological questions with an upstream approach, i. e. redesigning the products themselves.
(Vezzoli & Manzini, 1989)
Or
EcoDesign is a concept including human sustainability priorities together with business interrelations. Its main objective in the improvement of product development methods is to reduce environmental loads.
(Karlsson and Luttropp, Journal of Cleaner Production, p-1291, 2006)
Or
Eco-design or 'Design for Environment' is a strategy that aims to incorporate environmental considerations into product development and design, throughout the life cycle of a product or service.
(Charter, Journal of sustainable product design – 1997 – IS2, pp 48)

Eco-effective product design: Eco-effective product design aims to systematically establish and implement goals in product design with the aim of improving environmental performance. Effectiveness can be defined as a measure of goal achievement and efficiency as the amount of resources used to reach the goal. (Frei, 1998)

Eco-efficiency: The production of goods and services which meet human needs while reducing environmental impacts. (Schmidheiny, 1992)

Or
Reducing resource conservation, whilst 'adding value' and reducing costs. (Charter and Chick, JSPD – 1997 - IS 1, pp-5)

Or
Eco-efficiency = Utility (units of service) / Life Cycle Impact (milliPoints) (ALN Stevens, JSPD- 1997 – IS 3,pp- 54)

Or

Eco-efficiency = product or service value / environmental influence (Aoe, Journal of Cleaner Production, p-1406, 2007)

Or

Term introduced at the Rio Earth Summit in 1992. Doing more with less— use of less energy, fewer materials and resources, less disruption to the ecosystem. (Dictionary of Ecodesign- Yeang and Woo, 2010)

3.3 Proposed categorization of Eco-efficiency aspects

The categorization proposed here seeks to narrow down the focus of Eco-efficiency within the vast universe of Sustainability. The graph below (Figure 10) highlights the various *areas of focus* which have emerged between the 2 fields of sustainable product design and Eco-efficient design. The focus here of course will be to explain in brief the various topics highlighted within the Eco-efficient design paradigm.

First consider the layout of the graphic below; it is divided into 4 quadrants. In the horizontal axis is a scale which goes from social objects to socio-technical objects and ending in extreme right on technical objects. An analogy can be drawn with transportation to make this unit of measure easier to understand. Consider the social object as traffic regulations, then socio-technical object would be the public transportation system and the steering wheel of a car would be the technical object.

On the vertical axis is the distinction between social innovation and technological innovation. Looking at this map one can tell that concerns of Eco-efficiency (marked in red circles) are grounded more in technical objects and depend on technological innovation as medium. Sustainability (marked in green) on the other hand is much wider in both its scope and application since it concerns with mainly social innovation as a medium and its application ranges from social objects all the way to technical objects. The top left quadrant of this map represents the social innovation and social object paradigm. Design in this quadrant deals in service and systemic scale represented by domain areas such as consumption models, creative communities, distributed systems and emerging markets. Fair distribution and conservation of resources and natural wealth, reduction of poverty, and upliftment of socially disadvantaged groups is the main focus of sustainability here.

The bottom left quadrant represents social object and technological innovation, thus concentrating on regulations which dictate the industrial model of production and manufacturing. Life Cycle Assessment (LCA), Life Cycle Design (LCD) and systemic level consideration when dealing with product manufacturing take into account the waste stream and product take back programs which are the focus

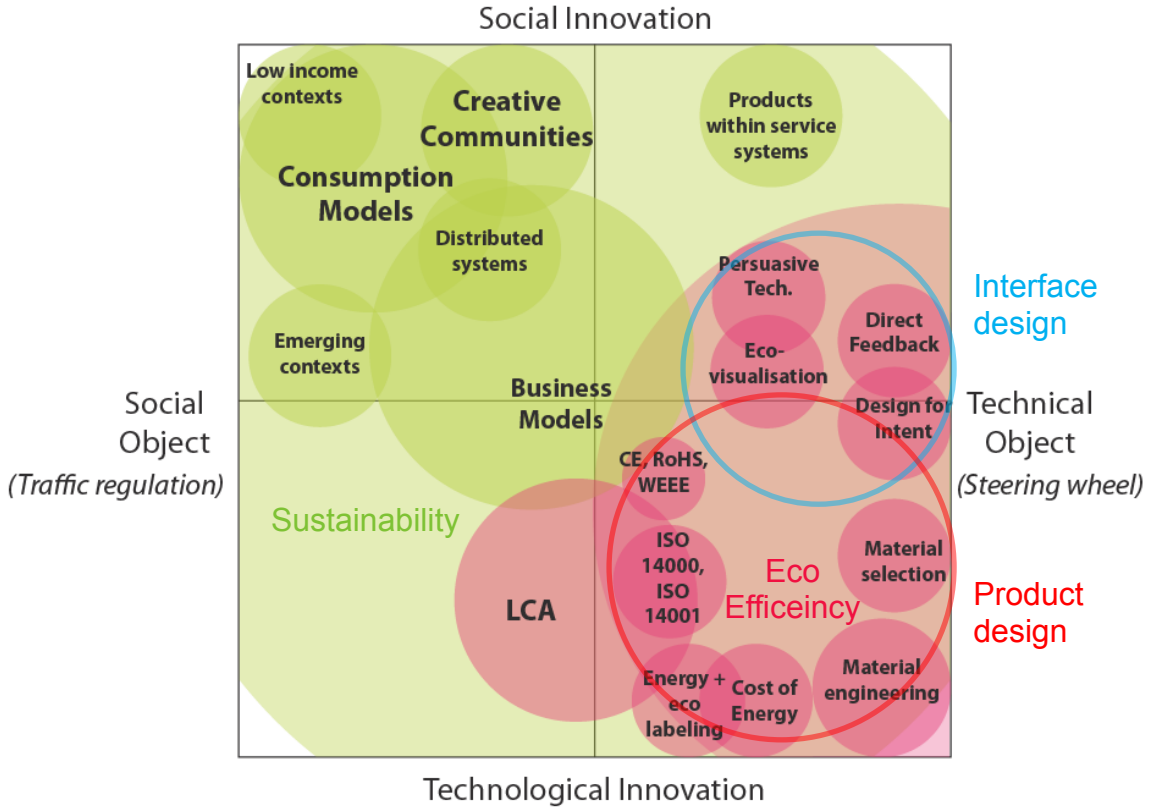


Figure 10: Categorization of Eco-efficiency

of this domain area. The emphasis here is to use systemic level thinking to reduce and ultimately eliminate use of hazardous substances and manage waste production through recycling and design for disassembly approaches.

The top right quadrant is social innovation and technical object. Design in this quadrant concerns with Product Service System Design (PSS). This domain concerns itself with focusing both on the product scale and a systemic level of implementation of a product (or interface) design solution. Closer to social innovation this quadrant deals with car sharing, bike sharing – where the design input is not on designing a new type of car or bike but more on a service which envisages not the consumption of a car but of the service of mobility. Closer to technological innovation this quadrant deals with products concerning with giving feedback to users in order to make them aware of their energy consumption. The idea being if users can somehow visualise the energy which they consume visually they might be persuaded to optimise if not reduce their consumption. Concepts such as a persuasive technology, Eco-visualisation, and direct feedback technology are lying within this domain area.

The bottom right quadrant deals with technological innovation and technical objects thus lying directly within the focus of Eco-efficiency as defined in this thesis. Since this quadrant directly concerns itself with the core focus areas of Eco-efficiency it consists of domain areas looking to increase the environmental performance of products (not concerned with systems) without sacrificing their performance. The focus is on weight reduction, reduction of hazardous substances from the manufacturing channels, material engineering, Eco-labelling, cost of energy, lean manufacturing and all other competencies which can make the manufacturing and operation of products more economical and less demanding on resources. RoHS, WEEE, Eco-labeling, lean manufacturing, Design for Intent are some examples of applications in this domain area.

The main areas of application for Eco-efficient design are described in more details below:

Energy labelling: Agenda 21[2] specifically targets changing of consumption patterns and more efficient use of energy as a policy target (Lorentz and Woersdorfer, 2009). The EU adopted the 'Eco-design Directive' for EUP (Energy Using Products) as a measure to fulfil obligations to the above policy, with specific focus on electric and home appliances. The introduction of labelling schemes is a direct outcome of this directive (Lorentz and Woersdorfer, 2009). The labelling schemes are designed to make the buyers aware of the energy-efficiency of the appliances and the potential cost savings associated with each label class. According to the EU Directive on Energy Labelling of Household Appliances ('Labeling Directive') appliance stores are obliged to provide energy consumption data on certain appliance categories (Mills & Schleich, 2009). The labelling class ranges from class A at the most efficient to class G as the least efficient. The directives implementing this scheme was published by EU in 1994 for refrigerators, freezer, and in 1995 for washing machines, and in 1997 for dishwashers. After September 1999 new refrigerators with classes D and freezers with classes E and G were no longer allowed (Mills & Schleich, 2009). Gas appliances don't have a labelling scheme yet, although the same is under development at the moment.

Although this energy-labelling scheme has helped in improving the market penetration of energy efficient appliances in Europe, but there are certain caveats such as countries with a higher energy cost awareness such as Germany have a higher penetration ratio. Also factors such as age distribution and level education (such as at least secondary schooling) have been cited as effecting the acceptance of these labels (Mills & Schleich, 2009).

Literature published on this subject has proposed that providing energy efficiency information to consumers through introduction of labelling schemes, introduces a solid incentive for appliance manufacturers to introduce cost effective technological innovations (Mills and Schliech, 2009).

Further the design of these labels has been subject to improvement suggestions as well. For example these labels give the absolute energy saving of the appliance, but not the relative amount. For example class A machine is 50% more efficient than class B machine. Different amount of data is displayed on these labels

[2] Agenda 21 is the outcome of 'United Nations Conference on Environment and Development (UNCED) or 'Earth Summit in 1992 Rio de Janerio.

depending on the specific EU nation. Germany for example makes it compulsory to display the energy consumption of all standardised wash cycles of washing machines i.e. cotton at 60° (Lorentz and Woersdorfer, 2009). In addition it has also been cited consumers have a higher tendency to pay extra for an energy efficient refrigerator if the energy consumption is not cited as savings but rather the cost to the consumer (Mills & Schleich, 2009).

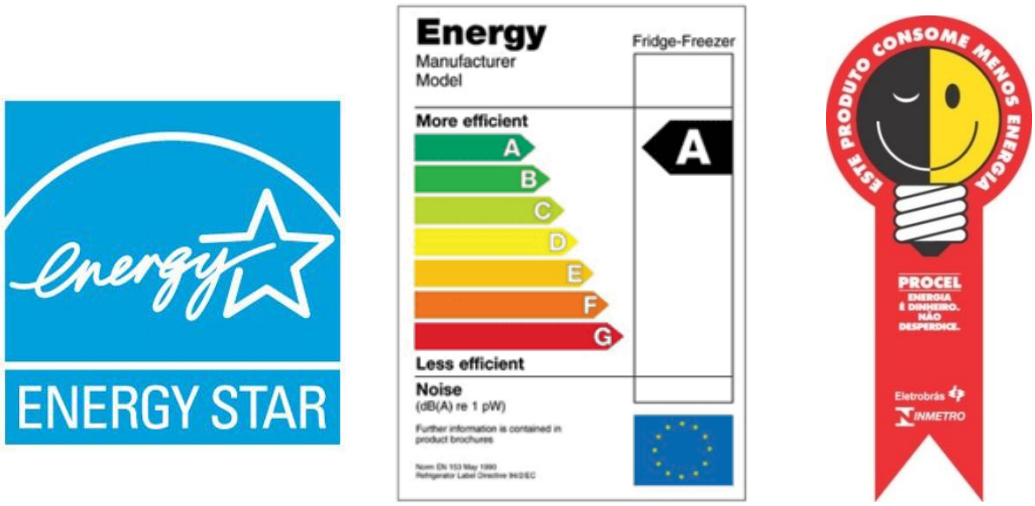


Figure 11: Energy Star (USA), Energy Labelling (EU), Procel (Brazil)

Other energy labelling schemes include Energy Star for electronics and computer equipment in the United States, and Procel for electronic appliances in Brazil.

Eco-labelling: Much of the progress in addressing environmental criteria in home appliances has been achieved through eco-labelling and energy labelling (Datschefski, 1999). An ecolabel is a label which identifies overall environmental preference of a product (i.e. product or service) within a product category based on life cycle considerations. In contrast to a self-styled environmental symbol or claim statement developed by a manufacturer or service provider, an eco-label is awarded by an impartial third party to products that meet established environmental leadership criteria. (Global eco-labelling network, 2004) Basically an eco-label is a communication promising the environmental aspects of a product or service, to stimulate a market demand for them thereby ultimately starting a market driven environmental improvement (Introduction to eco-labelling, 2004).
Unlike energy labelling, eco-labelling is a pass-fail criteria. Although there are different criteria both voluntary and compulsory, the label is only awarded if the product (or service) meets all the standards outlined by the label in question. The International Standards Organization (ISO) has undertaken an attempt to standardize the principles, practices, and key characteristics relating the major labelling types (Introduction to eco-labelling, 2004).
There are 3 types of ecolabels: Type I (voluntary), Type II(self-declarations), Type III (environmental declarations).
There are eco-labelling programs in many industrialised nations (upto 21 groups) and each one of them adhering to a different set of standards.

Figure 12: ecolabels- A) EU B) USA C) Japan D) China-mainland E) Nordic*
(*Nordic Ecolabeling Board = Icelandic, Finnish, Danish, Norwegian, and Swedish.)

At least in Europe the eco-label is used as a qualifying standard for class A and class B home appliances. Studies performed in literature on this subject indicate the significantly differing standards that each of these eco-labels utilize. For example US Green Seal label uses calculations based on volume, rather than mass as used in Europe. This implies that a Green Seal label certifying Class A energy efficiency in a washing machine is 2.5 ft^3/(kWh/cycle), where as a European energy Class A washing machine is 0.23 kWh of electricity per kg of washload at 60 C cotton cycle (Datschefski, 1999). This often means that a machine qualifying as class A Energy efficiency in Europe might not qualify for Class A efficiency in US.

Differing eco-labels also require differing standards of information and compliance from manufacturers. Nordic eco-label have been suggested as more advanced than their counterparts EU and US owing to their more advanced views on toxicity (Datschefski, 1999). Datschefski1 (1999) in his study of western eco-labels cited the differing requirements of Nordic, EU, and US labelling schemes. Eco-labeling can cover a wide range of issues in home appliances starting from appliance recovery (EU and Nordic Blue Angel- *only for diswashers*- labels requiring plastic parts weighing more than 50g to be labelled), packaging (US Green Seals label for refrigerators and washing machines restricts lead, cadmium, and chromium hexavalent content in dyes and pigments, in addition to including atleast 25% recycled content), consumer education (EU label advises on maximum loading of washing machines plus how to vary detergent doses based on water hardness, fabric soiling, and load weight), and even noise standards (Nordic washing machine- 72dB(A) while spinning and 60 at other operations, Nordic refrigerator- 40 dB(A), EU refrigerator- 42 dB(A).

Individually by appliance category for example washing machines there can additional standards such as on detergent- EU eco-label restricts detergent loss to no more than 5%. Appliance manufacturers such as AEG have responded by introducing a lockout valve which shuts the drainage system from the wash tub during the wash cycle (Datschefski, 1999). For refrigerators EU label restricts the use of refrigerants which have zero ozone depleting potential.

Lastly only the Nordic eco-label pays attention to surface coatings restricting lead, cadmium, and chromium content in addition to no more than 5% organic solvents by weight in paints. Exceptions to surface coating have been made for small parts such as screws and hinges.

WEEE (Waste Electrical & Electronic Equipment): The WEEE directive has been enforced in Europe since 2003. This directive which encourages the manufacturers to provide for recycling and safe disposal of their products once the useful lifespan is expended. It is a direct attempt to shift the problem of environmental safety upstream into the design phase, rather than downstream where any intervention is less effective and more expensive (Vezzoli & Sciama, 2003).

ISO 14000 & ISO 14001: This is an important certification important to production processes. The certification implies that the company in question complies with all the environmental laws relating to noise pollution, air pollution, air emissions, and water discharge. Basically this certification ensures that a company is commited to reducing the energy and water wastages across its production facilities with specific environmental initiatives. ISO 14000 series focuses on increasing the concern on environmental issues within manufacturing, however just the adoption of the standard will not guarantee the optimal environmental outcomes. (Cramer,1997)
As stated in ISO standard itself: '*It should be noted that this standard does not establish absolute requirements for environmental performance beyond commitment, in the policy, to compliance with applicable legislation and regulations and to continual improvement. Thus, two organisations carrying out similar activities but having different environmental performance may both comply with its requirements.'*

Design with Intent: This is field of design which is also called behaviour steering design, because there is an intention on the part of the designer to trigger a certain user behaviour. It can be defined as: The idea of using features of a system — a physical product, built environment, computer network, or indeed any system with which a user interacts — to guide, shape or regulate the ways in which interaction occurs has been expressed in many ways in a number of different fields, and might be loosely described as 'Design with Intent' (DwI) thinking (Lockton, 2008). This field of design has very important applications in the Eco-efficient appliance design as it influences the behaviour of the user. Even a very Eco-efficient appliance can be used in an *un*-Eco-efficient way.
Design with intent can be approached on systemic or a product scale, and it concentrates on the affordances which these products or systems put across to the user. The theory of affordances was first outlined by JJ Gibson (1979) and then developed further and applied by Donald Norman into the field of product design (1988). Affordance deals with direct perception of an artefact and can be defined as: the perception of one's ability to do something with what is sensed (Janlert, 1997).
The application of affordances into design for intent has been suggested in the appliances context by reducing the default settings of washing machines, where in the default temperature of the wash cycle is reduced from 40° to 30°, or even simply adopting the most energy efficient mode as the default mode. Suggestions in other product categories have been made such as keeping double sided copying as default setting in photocopying machines.
Norman (1988) has suggested behaviour shaping constraints and forcing functions such as interlocks whereby a set of conditions must be met before a function is enabled (Lockton et al,2008). Further there have been systems developed within manufacturing such as poka-yoke (meaning mistake-proofing) which was invented by Shingo for Toyota manufacturing ensuring 'zero defects' in the assembly process. There are features such as lock-ins, lock-outs, or inter-locks which prevent a worker from proceeding unless a mistake is rectified. These 'zero defects' procedures are also actively used within appliance manufacturing. Within the context of Eco-efficient design the application of such deign with intent approaches could be interesting, such as preventing inefficient operating procedures.

Second category of constraints can be rationing. Unilever has used this in designing detergent tablets, which ensure the user uses only the exact amount of detergent (Lockton et al,2008).
Third category is of physical constraints such as smaller rubbish bins to make the user more aware each time he has to empty it out to separate and compact the waste diligently. Electrolux has designed the 'Smart Sink' in which the sink is a flexible and expandable membrane structure which enlarges to limit the amount of water that can be used plus it has markings and a consumption meter to inform the user constantly about the water usage (Lockton et al,2008).

Figure13: Electrolux Smart Sink

Persuasive Technology: Just as Design with Intent, persuasive technologies focus on the user instead of the product. Design for Intent uses affordances to in a way force the user to adhere to conforming behaviour and usage patterns. Persuasive technology on the other hand is much more subtle and instead seeks to guide the user into reducing his energy footprint by giving him the right information so that the right choice is made. Consider the analogy of a coffee machine: in the case for Design for Intent the size itself of the kettle will be reduced to accommodate a smaller volume of water, whereas in the case of Persuasive Technology, the kettle would be given easier to understand marking metrics such that the user on his own initiative doesn't boil an extra volume of water. This is a discipline which has been developed B.J. Fogg (2003), the application of which in energy efficiency has many possibilities; for example using persuasive technology to give *normative messages* to the user about their energy usage pattern (figure 14), such as comparing it to the median usage of the community(Lockton et al,2008).
The strategies of persuasive technology include tools outlined by Fogg (2003) classifying persuasive strategies include the 'tools' — *reduction* (simplification of a procedure), *tunnelling* (guidance through a procedure, such as a 'wizard'), *tailoring* (individual customisation), *suggestion* (intervention at the most opportune moment, or *kairos*), *self-monitoring* (allowing users to track their own behaviour), *surveillance* (allowing others to track users' behaviour) and *conditioning* (reinforcement). Often these tools can be used in combination with each other.

Figure 14: The 'Positive Energy' bill with neighbourhood comparisons

Feedback is a cornerstone of persuasive technology. The range of feedbacks might include 'indication' of energy usage to the user, 'warning' signals in case of improper usage such as in home electricity smart meters. MIT's HeatSink (figure 15) is a good example of giving the user an indication of the water temperature right at the point of consumption to reduce unnecessary wastage. The Watson home energy meter glows according to the energy consumption level (figure 15).

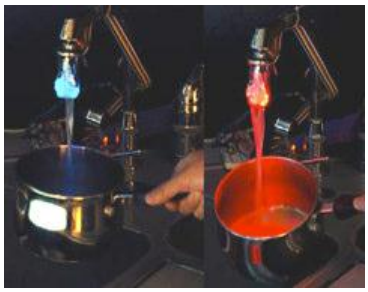


Figure 15: The MIT HeatSink

Watson home energy meter [3]

Persuasive technology and design for intent can draw interesting parallels with product semantics in the area of Eco-efficiency as both of them seek to communicate with the user to embrace Eco-efficiency. While product semantics in this research is trying to interpret the physical appearance through product characters to communicate Eco-efficiency, persuasive technology and design for intent both use digital and interactive tools to make the same communication. The end goal is that all these approaches seek to encourage the user to become 'aware' of Eco-efficiency. While the digital approaches seek to change the user's behaviour in a direct or more indirect way, product semantics just seeks to make the user aware that a certain product is Eco-efficient in nature and as a direct derivation what the product is capable of doing.

Eco-visualisation: It can be a direct subset of persuasive technology. In this case the aim is to visualise through graphic user interfaces all the critical energy consumption information of a product or a system in an 'easy to understand format' which will help the user to change his usage pattern and adopt a more Eco-efficient lifestyle.

[3] Froehlich J. Promoting Energy Efficient Behaviours in the Home through Feedback: The role of Human-Computer Interaction, HCIC workshop, 2009

Eco-visualisation uses several tools which can range from giving energy consumption information on a real time basis, or discouraging the user to cross certain consumption limits through graphical indications such as colours, warning symbols, or even auditory feedback. In addition such interface platforms are normally tied or 'attached' to smart appliances through home automation systems such that they give the user energy consumption patterns of all the appliances tied in a smart grid, such that the user is 'always aware' of the energy footprint he imposes upon the environment. Normally such visualisation platforms also have the capability to 'suggest' to the user the best performance settings to select in the appliances being controlled through this medium, and in the absence of a suitable user input, select the most efficient settings automatically. The 'platform' of eco-visualisation being discussed here could be anything from an internet based service utilising a website to the give the suitable information, or custom made products designed to display such information, or even applications which can be downloaded or installed in computers or smartphones.

3.4 Proposed classification of Eco-efficiency in product design

During development of the theoretical background this classification was developed in order to understand the *different mediums* which designers are adopting to achieve Eco-efficiency in products. This classification was intended to educate designers about the possibilities and opportunities of Eco-efficient design, seeing as many design solutions being generated are influenced by a narrow set of preconceived notions thus resulting in clichéd solutions. A product is a cliché when it has lost its meaning either due to mis-use or dishonest representation by the designers. The author noticed that a large number of products calling themselves '*green*' to ordinary buyers, utilised a standard aesthetic expression of using wooden surfaces, natural materials for external casings and generally misleading the buyer that using a natural material finishing for an industrial product equates to environmental friendliness and Eco-efficiency .

Educating designers about the different possibilities with which they can approach Eco-efficient design also warned them of avoiding the trap of 'green washing'. Green washing has been defined as-
companies that spend more time, effort, and money in promoting their products as "green"
than they actually invest in their production are "Greenwashing" (Environmentalist Jay Westerveld). The classifications were explained in a project wise basis i.e.: if one were to design a product with volume reduction criterion in mind what would a possible outcome look like. Sometimes different classifications can be used in combination to design 1 project.

The classifications developed are listed out as following:

1. Recycled/recyclable
2. Mono/Bio–material
3. Reuse
4. For disassembly
5. Volume Reduction
6. Material Reduction
7. Packaging
8. Service design
9. Technology
10. System Design

11. Eco – Advertising
12. Eco-Awareness
13. Interface design

Recycled/ recyclable: When a product is made of recycled material/ or is recyclable.

Figure 16: Motorola W233 Renew; shell made of 100% recycled plastics
Mono/Bio–material: The product is made of a single or "organic" material.

Figure 17: Dreamball- Unplug design studio- packaging designed for aid drop can be folded and refashioned into a football.

Reuse: The product is made of reutilised materials or parts.

Figure 18: Clockwise from top: Iron refashioned into a table lamp; bicycle wheel refashioned into a stool; shopping cart converted into a couch; old tube lights combined to form a hanging lampshade.
To be noted is the fact such solutions although most widely perceived as Eco-efficient solutions are not the ideal approach. Eco-efficient design doesn't seek to address nor encourage a craft based approach. Most

end users neither desire nor trust the perceived quality of such products. Another issue is that such products cannot be standardized for serial production, since the design solution is not intentional nor planned but rather ‘accidental’ putting together the best combination with what’s available at hand.

For disassembly: The product is made to be easily disassembled.

Figure 19: Viking (Italy): Poltrona Frau

Volume reduction: The volume and the material used are kept to a minimum.

Figure 20: Kada by Danese- Yves Behar

Packaging: The packaging is reduced to a minimum

Figure 21: Paper Water Bottle- Brandimage

Service: The products are shared / reduced / replaced by services.

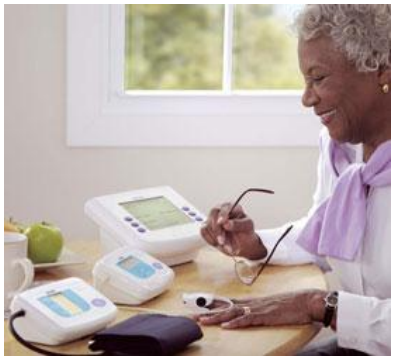


Figure 22: Cardiac Services- Philips (Netherlands)

Technology: Technology improves the efficiency of the product.

Figure 23: ICF-B01- Hand cranked radio/ Sony Corp.

System: The products are made into a system to share components and resources.

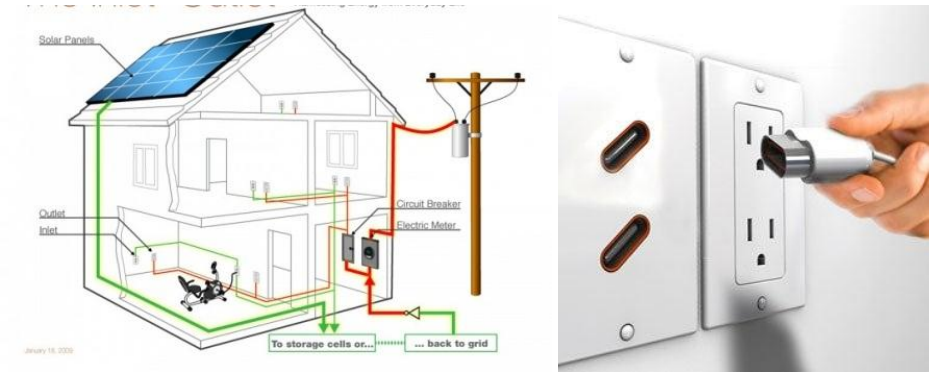


Figure 24: Inlet-Outlet- Power 'inlet' which can capture power and return it to the grid/SmarDesign

Eco-advertising: The Eco-efficient aspect of a product/service/system becomes a quality to be communicated.

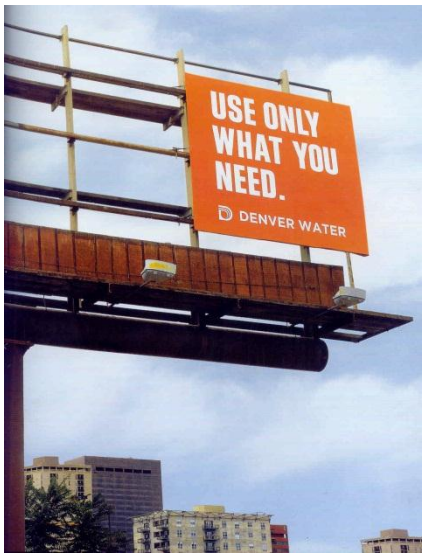


Figure 25: Use Only What You Need- Sukle advertising+Design for Denver Water

Eco-awareness: The products which increase awareness of "Eco-efficiency" to the user.

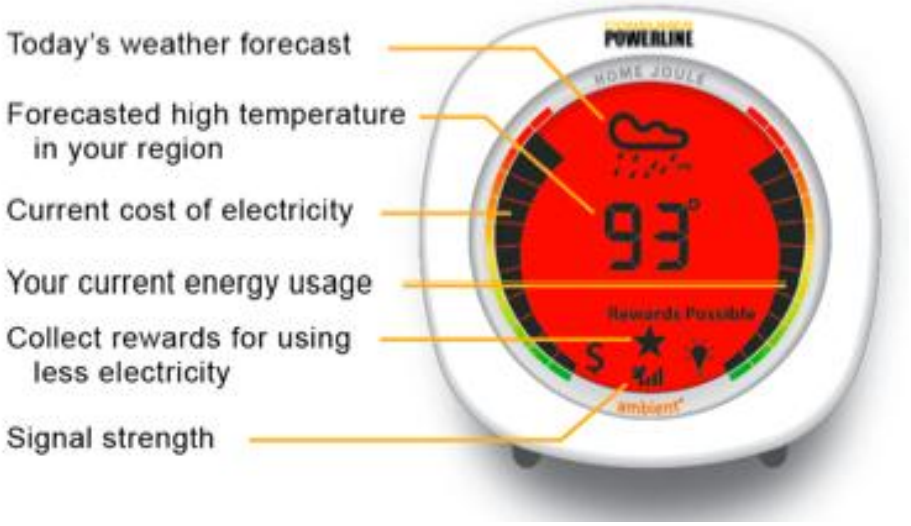


Figure 26: EnergyJoule- Ambient Services USA

Interface: The interface helps to achieve an Eco-efficient behavior in the user.

Figure 27: Footprint Calculator

3.5 Emergence of Semantics in Product Design

Semantics as a discipline has traditionally been applied to study spoken language and study of meanings in languages, but its application into product design has been pioneered by Klaus Krippendorff and Reinhart Butter when they first published an article which defined product semantics as an inquiry into the symbolic qualities of man-made forms in 1984 for the Industrial Designers Society of America (IDSA) journal titled 'Innovation'.

The perception of visual appearances in products has a fairly rich historical precedence. Apart from semantics, other domains which overlap into this subject area are aesthetics, psychology, consumer research, sociology, marketing, semiotics, and ergonomics. (Crilly,2008; Demirbilek & Senar,2003).

Product semantics was an emergent field in the 1980's owing to the demand within the design community of the era to seek out new ways of differentiating their products (Friendlaender,1984) in an increasingly homogenous market and as a means of escaping the modernist methodologies of the time (Boess,2008;Brown,2006). Though the intention of semantics as a design theory was indeed a noble one, the fact remained that it was a concept which sought to apply linguistic theories into a design process to develop 'readable' or 'self- evident' products through easy to apply methods (Brown, 2006). In the end this entire construct remained largely theoretical and therefore an academic exercise unable to offer professional design community a ready to apply methodology which was sufficiently robust to result in successful product developments, thus leading to the eventual decline of the semantic theory in the design community by the late 80's and early 90's (Brown,2006). According to Boess [p.21] in the meantime physical product and computational applications began to merge and "have more shared characteristics and problems. She cites Black and Buur who identified a crisis of usability in 1996 which affected both domains, and they consequently proposed the idea of solid user interfaces (SUIs) which according to them should be concentrated upon to solve the problems of usability. Thus they brought the focus back on meaning in product use and by extension semantics in product design.

Indeed examples of professional designers having applied the product semantic theory into successful product development are few and far between, such as a Philips 'Roller Radio' (Blaich, 1989). Early proponents of product semantics such as Krippendorff blamed an 'untheoretical design profession' (Capitello,1991) for this eventual rejection. The fact is that professional design practitioners and theoretical academicians regard semantics in fundamentally different ways. Designers tend to depend more on intuition & experience with little or no qualitative tools when dealing with conveying a message through form giving (Lawson & Storer,2008; Boess,2008). Brown confirms this view by saying "designers don't value academic theories as particularly useful in their everyday design practice". In fact designers hardly ever refer to any theory or methodology to give meaning to product form and rely solely on intuition (Boess,2008). Butter (1989) says relying on intuition for the success of the product is "at best haphazard and at worst irresponsible". Even the terms used by designers in their work, according to Boess, are different; she cites a designer who equates semantics as "too regid and static", i.e. "white means medical equipment", when asked about the use of the same colour in the iPod. She then concludes by saying most designers have a neutral to negative association with all terms related to the domain product semantics, even though all of them were intuitively considering the application of it in their work.

Companies such as Philips, which have historically shown interest in semantics, specify extensive design guidelines for their internal designers citing terms such a user experience, colour choice, and such like without ever mentioning the term semantics directly (Boess,2008), even though that's precisely their intention. Consider their corporate message which states "sense and simplicity" in light of Krippendorff's definition of design as "primarily a sense making activity". Thus designers are concerned about communicating through their products, but they use a different vocabulary, without clear intentions. Terms such as "communicating; saying; draw attention; foster recognition; generate attraction"(Crilly,2009) are instantly recognizable to them where as scientific glossary such as "meaning; affordance; sense; product character" are lost to them.

It is a well accounted for that designers do consider the aspects of attracting, informing & influencing consumers, during the generation phase of their work (Baxter 1995;Mono,1997;Muller,2001), but to factually document this process is notoriously difficult since designers perceive form generation as an intuitive activity inherent in their skill set (Tovey,1997;Coates,2003).

3.6 Main Concepts of Product Semantics

Although the concept of applying product semantics as a design theory eventually faced reservations from many quarters of the design practitioner community, the early design theorists of semantics namely Butter (1989), Krippendorff (1989,2006, 2007, 2008) strove to develop it as a new approach to design (Brown 2006). There two major application contexts proposing how semantics can benefit the development of products, chief concepts within both the proposals will be discussed below.

Reinhart Butter introduced the concept of designing product forms with predetermined meanings, which he developed into a methodology to as a set of experience based (heuristic) sequential steps, through the medium of design workshops. He along with Krippendorff defined semantics as "*a study of the symbolic qualities of man-made forms in the cognitive and social contexts of their use and the application of the knowledge gained to objects of industrial design*". Their idea of semantics was to go beyond the traditional functional performance of products and include the also the quality of experience (Blaich, 1989). According to Boess they projected this as a human centered approach to design, truly a new methodology to approach product design, a break from Luis Sullivan's "Form follows function" doctrine which was a more technology centered view and moving towards "Form follows meaning" (Krippendorff, 2006). Further Boess says that their interpretation of semantics was directly derived from Semiotics, which is the study of signs, and looked at forms as proponents of language. According to Krippendorff and Butter "The symbolic meanings of form, shapes, and textures, are the most characteristic concern of Product semantics.", in other words simply to think of a product in such a way that it communicates something about itself to the user (Boess,2008). Butter (1989, p.55) elaborates upon the qualitative communication which products must make. He says when generating the list qualities which a product seeks to make to the user one must disregard the "factual attributes" which represent the objective, measurable qualities of "how something actually works" and keep only the "expressive or semantic attributes" which represent the more communicative qualities of a product and the message or meaning which communicate to the user. Thus meaning is the central concept around which interpretation of human centred design as developed by Butter and Krippendorff revolves. Janlert (1997) takes the concept

of symbolic meanings and says products are like vectors of symbolic meanings, which are 'planted' into the object by the designer. For example a car of known make with a very poor safety record but 'looks' built to go fast and feels safe to drive, may jeopardise the life of the user by encouraging him to be reckless. Butter [p.55] warns about such semantic dishonesty in the symbolic communications made to the user which might result in the user rejecting the entire product.

Worth mentioning here is Vimha's (2007)[4] opposition to the view cited by Krippendorff and Boess above, who questions the need to associate visual forms with verbal communication in the first place and separate the concrete functioning of the object with its culturally constructed language based symbolism. This according to her is a trap of the 'design semantics' theory. She questions why form cannot be a carrier of meaning in its own right, and disagrees with Krippendorff's outright rejection of semiotics in studying forms.

The view cited above of course has support from several design theorists. Demirbilek & Sener (2003) cite Wikstrom say that the semantics functions of a product provide the designers a clear platform to communicate a message to the user. The designer therefore should make careful consideration about what the product should and should not communicate. In keeping with the symbolic qualities which a product should exhibit, Demirbilek & Sener says that a product talks not only about itself but also about the person who owns it. Crilly et al classify this as "symbolic association i.e. what the product is seen to symbolize about its user or the socio-cultural context", which is a process residing within a larger psychological interpretation which users make upon sensing a product. All products hold some socially determined symbolic meaning say Crilly et al and as such a culturally agreed meaning allows people to also communicate their identity through the objects they possess or are seen using. Products can also be used as mode of self-expression serving as a platform for users to differentiate themselves from those that surround them and also a platform for selectively expressing their identity such as belonging to clubs or organizations.

Krippendorff further points out that users tend to surround themselves with those objects that make sense to them and which they can identify with. Burdeck (2005) confirms this in the context of the home by saying that "people surround themselves with things that reflect their inner lives". The idea that products can carry symbolic meanings has been discussed long before the term product semantic was coined. In 1966, industrial designer Theodor Ellinger said that a product has the ability to communicate information about itself in the marketplace (Burdek, 2005). The idea that objects can be carriers of information the end user was also postulated by the German design historian Gert Selle (1973) when he said: One can speak of a product language to the extent that the design objects are not only carriers of function, but always carriers of information as well (Burdek,2005). It is important to note that the symbolic meaning of products is a cultural construction as is only read in context of the cultural background within which the user resides. It is the designers' job to decode the values of a culture and attribute them into forms that put across the appropriate symbolic meaning (Crilly et al, 2004).

The second major application context of semantics is to make designed objects more intuitive (Demirbilek & Sener, 2003). Crilly et al say that making forms intuitive also increases their attractiveness

[4] Vihma, S. (2007). Design semiotics- institutional experiences and an initiative for a semiotic theory of form. In R. Michel (Ed.), Design Research Now- Essays and selected projects (pp. 219-232). Basel : Birkhäuser

to the user. According to him designers must "issue subtle instructions for the way that consumers should approach and interact with products" by putting emphasis on the functional components and. The objective of this aspect of product semantic was to increase the self evidency of artifacts to make them spontaneous and intuitive to use. Classifying it as "semantic interpretation or what an object is seen to indicate about itself" of an object, Crilly says a significant portion of the value assigned to products may be attributed to their utility which may comprise of practical aspects such as function, performance, efficiency, and ergonomics. Krippendorff regarded these aspects as 'machine centred approach' opposed to his 'human centred approach' thus his definition of product semantics was more heavily skewed toward the symbolic qualities of objects, perhaps the following definition by Demirbilek and Sener is a bit more balanced reinterpretation of the same "*product semantics is concerned with the relationship between the user and the product on one hand, and the importance that objects assume in an operational and social context on the other hand*."

Norman's book, *The design of everyday things*, talks about how visually presenting product functionality helps the user to understand how the product may be operated. Norman talks about bridging the "gulf of evaluation" and "gulf of execution" between the user and the object (Boess,2008). Norman preferred to talk in terms of "affordance" which according to him are the "perceived and actual properties of a thing, primarily those fundamental properties that determine just how the thing could possibly be used". He also says that affordances "provide strong clues to the operation of things." [p9] According to him if products require stickers, labels, and warnings for proper usage, then clearly the designer has failed. These concepts originally came primarily from the domain of Human Computer Interaction (HCI) community and as a result were not completely assimilated by the product design domain since the application of this concept was not straightforward and perceived as overtly complicated and also partly due to the limited interaction between the 2 communities (Boess, 2008).

Wikstrom (1996) cited by Demirbilek & Sener (2003) reinforces the second aspect about semantics by saying that "the semantic functions should make the product comprehensible. According to him the user should know how the product should be handled just by looking at it, such as a knurled knob should say 'turn me' and glowing red button should say ' press me', a shape which indicates which direction it moves through geometric and surface indications and such like. In short an objects product design should be self-instructing (Demirbilek & Sener, 2003). Actions must be afforded and their consequences foreseeable (Krippendorff, 2006).

According to Evans and Thomas (2011) a designer who understands semantics can "challenge a user's present perception of a product's likely purpose and behaviour" and in doing so help them to conceptualise and interact with new product types. Thus semantics helps to familiarize the users with the unfamiliar as they may be restricted by their own shallow experiences and imagination. Sometimes when the designer's intention is not understood a disruption may result. Designs always perform more efficiently and an easier to use manner when their intended functions match with what they afford. Consequently the designer's intent only becomes visibly when a disruption occurs. Products which work seamlessly from the usability and intended function point of view are more efficient and easier to use (Evans and Sommerville, 2007). This is true not just for physical products but also virtual interfaces. Some disruptions are harmless and plain annoying such as doors which don't function the way one would

expect them to, to more serious disruptions such as safety equipment which didn't function the way the user intended it to thus resulting in life threatening situations.

Norman gives his insight on reducing disruptions by saying that the way people learn how objects are used lies partly in the cognition of the human mind and partly in the appearance of the objects. He provides a 2 step approach to reducing disruptions:

A clear conceptual model: when users interact with any object they form a conceptual model of its functioning. The physical functioning becomes apparent based on the visible structure of the object i.e. a pair of scissors for example; the arrangement of the holes vis-a-vis its linear geometry affords a user to insert his fingers. The reason according to Norman that poor conceptual models are designed for products is because a designer's conceptual model differs when he is designing from the user's mental model he develops through his interaction with the object. The physical structure which has been built is called the system image which includes all the features, functions, labels, and even documentation of the object. When the designer's model doesn't match with that of the user's model of how a system ought to function, due to inconsistent communication which the designer has sent to the user, a disruption results. The user never directly interacts with the designer, but just the system image which the designer has developed (figure 28).

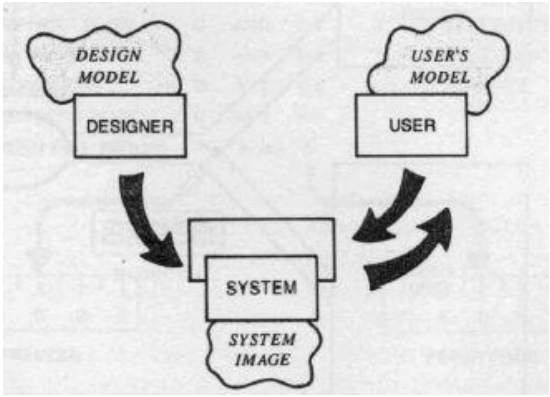


Figure 28: A conceptual model (source: The design of everyday things, D. Norman, 1988)

Make things visible: incorporate visible feedback into the products, incorporate good mappings, natural relationships between the control surfaces and things being controlled, keep single functions per control, all these considerations normally make a product highly visible from a point of view of affordance and usability and minimises disruptions.

From a point of view of a practical application of the facts put forward by design theorists above the case of Philips can be cited. Robert Blaich (1989) the Design director of Philips said practitioners in marketing and advertising have been making use of communication as a tool to 'speak' to the consumers of their products, but for more superficial ends. Designers too can use product semantics to design products which express not just structural and functional components but also communicate their social, cultural and psychological aspects (Blaich 1989). Blaich spoke of designing self-evident products as those which "speak for themselves" eloquently to the potential user and communicate their purpose and correct

operation. Having realised the use of semantics in visual communication of artifacts, Philips explored using this tool as a means to achieve market differentiation and increasing their competitive advantage. He cites the example of the Roller Radio and a coffee maker both of which were using the 2 different aspects of semantics discussed above. Citing the example of a radio (figure 29) which achieved commercial success he says the integration of the small red ball on the top of the antenna reminded the user of a sports car thus making a youthful connection and making a symbolic association with the rock'n'roll culture of the times. Secondly he discusses the use of 'shape coding' to achieve a design for a coffee machine (figure 30) which made operation more ergonomic and easier due to increased self evidency thus using semantics to increase the functional quality and the user interface.

Figure 29: Semantic Drum Radio
(Source: Design Issues, Vol. 5, No. 2, 1989, pp. 1-8)

Figure 30: Coffee machine

As is evident design practitioners are able to use both the aspects of the product semantic theory discussed above, although most of the time they don't explicitly differentiate between the aspect of semantics which they are utilising to achieve a product outcome. Blaich said [p.5] new products were expected to showcase not just structural and functional expressiveness but also communicate the social, psychological, and cultural aspects of the object. His own idea of semantics makes this obvious "Every product should "speak" eloquently to its potential buyer or user and communicate its purpose and correct operation (i.e *semantic interpretation*). The product must contribute meaningful value to our lives. The product should also communicate something about its owners (i.e. *symbolic association*). Further, products should ideally "speak for themselves" -the term given for this phenomenon is "self-evidency." He defines semantics as follows: "*..an area of inquiry or discipline concerned with the meaning of objects, their symbolic qualities, and the psychological, social, and cultural contexts of use*." This is even apparent in some theoretical work within the product semantic domain, where the distinction between using semantics to achieve self-evident products or to construct a symbolic association between the user, the product, the social context is not differentiated explicitly as two different approaches to product semantics.

Both the above principle aspects of product semantics have been questioned by Brown [p.99] when he says that many aspects of the 1980's theory of semantics was heavily criticised for being too unrealistic.

While there was a general acceptance of the principle of making product more self-evident as ease of use was always an achievable design goal also by the design practitioner's community, but the whole notion of imbibing products with a symbolic association reliant on a message or a meaning which the product communicates to the user is where a lot less consensus was met. The fact is meaning is contextual and not only depends upon the environment within which it is perceived but also the personal experiences of the interpreter (Brown,2008; Crilly,2009; Krippendorff,1989; Demirbilek & Sener, 2003). Not only experience but even people's backgrounds, social class, education etc. affects the meaning they bring to the product. This is the reason that Krippendorff (1989) argued that since companies can never be sure sure that the meaning which the designer has objectified is the same that the customer derives, hence necessitating the huge expenditure on advertising, to help the user to derive the intended meaning which the designer objectified in the appearance (Krippendorff,1989).

Regardless of the historic context of discussion on semantics, presently it has been agreed at least more than once that semantics as a design theory is facing even a greater challenge with the onset of 'black box' high technology devices (Boess,2006). "The digital revolution is progressively turning the objects with which we interact into smaller and more intelligent black boxes, making it difficult to understand the mechanism or the working method (Bolz, 2000). Blaich (1989) cites McCoy who said that "as the black box becomes a dominant part of our lives, more visual clue are needed to what the products mean". Technology has resulted in a dematerialisation of objects, the focus of design has shifted from the physical product to the digital content within the physical body, usability and ease of use has given way to 'user experience'. This phenomenon is a modern day challenge to the product semantic theory and has the potential to renew its relevance in the modern design culture if properly applied to the design and communication of digital technologic products.

3.6.1 Communication in Product Design

This thesis rests on 2 important design theories in order to encode the intended meaning of 'Eco-efficiency' into home appliances. The 'product communication' model as discussed by Crilly, Moultrie & Clarkson (2008) and the 'human centred' approach to Product Semantics as discussed by Krippendorff (2006) have many overlapping concerns, and at the same time contain several unique insights into how to make products more expressive of their intended meaning.

The theory of product communication is based on Shannon's basic model of communication as described in his paper 'A mathematical theory of communication' (figure 31) has been used by Crilly, Moultrie & Clarkson to explain how user experience the designer's intension through product forms.

Figure 31: Shannon's model of communication
Source: Design Studies 25 (2004) 547–577

Crilly et al say that all products are transmitters of messages to the user. The designer is the source, the author of the design which seeks to communicate a meaning to the user. The product is the transmitter of this message through its intrinsic and extrinsic product features. The environment within which the product is sensed and the meaning attached is the channel, and the sensing user is the receiver of the original communication, where in the sense of sight is of primary importance. The destination is the psychological response of the user who has sensed the product, and refers to the judgements which the user makes based on the information received by the senses. "These judgements refer to evaluation of the perceived qualities of the products being sensed" (Crilly et al, 2004). The 'user or consumer' can be defined as someone who undertakes the visual consumption of a product, whereas a 'product' can be defined as the output of industrial design activities. (Crilly et al, 2003)

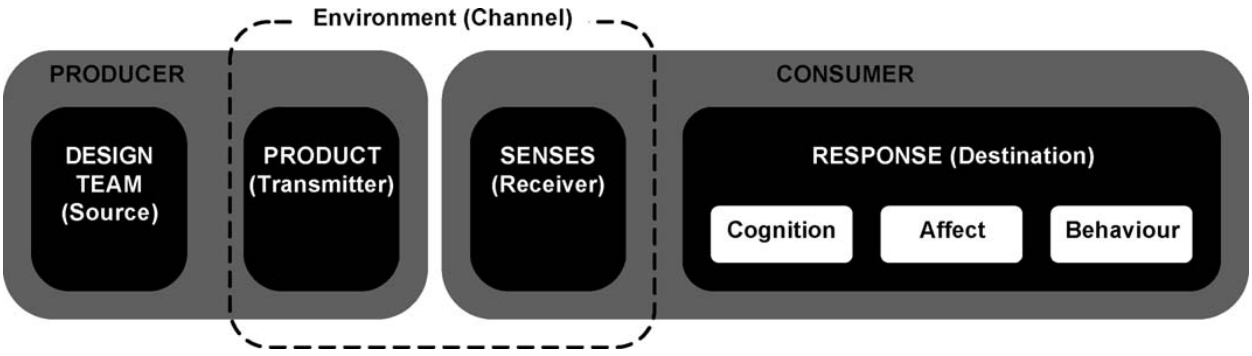


Figure 32: the basic framework of design as a process of communication

Source: Design Studies 25 (2004) 547–577

Figure 32 above outlines Crilly, Moultrie, & Clarkson's (2008) framework of product communication. Crilly (2011) elaborates that designers have to communicate what a product is for, how it should be used, who is it intended for, what qualities it possess and so on. This communication model is in a way reinforced by Demirbilek & Sener (2003) who say that "messages are being constantly sent through products via language structures that deal with meanings". He goes on to warn that designers as agents of communication have to satisfy other stakeholders in the product manufacturing process such as manufacturers, marketers, retailers and also contend with process limitations such as cost, production capabilities, and distribution limitations, and yet reach their 'target consumer' with the product being able to express the meaning originally intended by the designer (Crilly, 2011; Crilly, Moultrie, & Clarkson, 2004). A lot of the original intended meaning of the products is lost due to the disruptions in the process of seeing a product to fruition. According to Crilly the designer's intentions shape the product form and those forms shape the users' experience. He goes on to say that how users' experiences designed into products have very important implications for design as a domain and in theoretical literature this is what is referred to as product semantics. Crilly Maier, & Clarkson however do warn not to cast the consumer as a passive participant according to Shannon's model of communication, since all product interpretation takes place within the motivation, personal experiences, and expectations of the user. Thus the same product will be interpreted by different users in different ways and different contexts, though a designer can attempt to influence those interpretations through the design definition. For example revealing screws and fasteners can be informative and convey to the user how to disassemble the product, or conversely depending upon their prominence on the overall design solution they can also convey a message of

robustness (figure 33), durability, and quality manufacturing (Crilly, 2011). "Designer's intentions shape the artefact, and the artefact shapes the interpretation, but the interpretation takes place independently of the original intentions" (Crilly, Maier, & Clarkson, 2008) and this statement is reinforced by observations made in literature which point out that designers often face difficulty when asked to assign an intended meaning to a product (Blijlevens, Creusen, & Shoormans, 2009).

Figure 33: Panasonic Toughbook

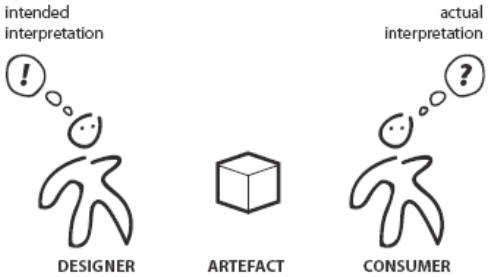


Figure 34: Basic structure of a communication based model of design (Crilly, Maier, & Clarkson)

Elaborating on design as a process of communication model of Crilly, Moultrie, & Clarkson, they expand further the psychological response of the receiver, earlier mentioned as the destination according to Shannon's model of communication as consisting of cognition, affect and behaviour.

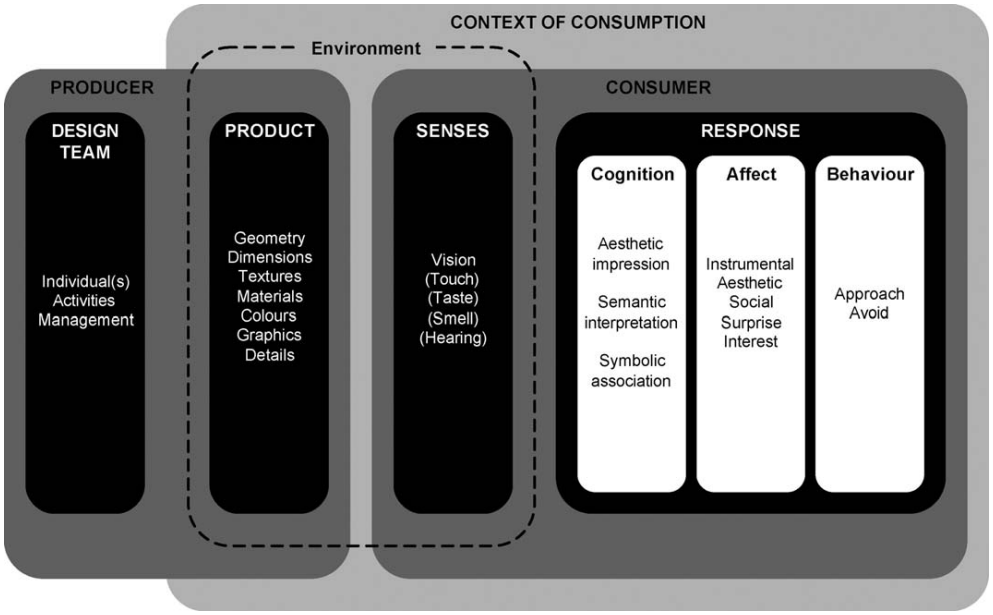


Figure 35: Elaborating the design as a process of communication model of Crilly, Moultrie, & Clarkson. Source: Design Studies 25 (2004) 547–577

The process of cognition consists of:

Aesthetic impression: the sensation of attractiveness and unattractiveness in products. Norman associated this with the visceral level in design.

Semantic interpretation: what a product is seen to say about its function, mode of use and qualities. Norman associated this with the behavioural level in design.

Symbolic association: the perception of what the product says about its user. Norman associated this with the reflective level in design.

This initial cognitive assessment by the user triggers an emotional response in user where the word 'affect' is used as an umbrella term. Affect is defined as the psychological response of the consumer to semiotic content of a product (Crilly et al 2004).

Overall the emotions associated with a product appraisal (the culmination of all the 3 cognitive processes) are given 5 categories as proposed by Desmet:

Instrumental emotions: they help a user to understand if a product will help the user in achieving their objective. These emotions are more ground in the usability of the product (satisfaction, disappointment).

Aesthetic emotions: potential of the product to 'satisfy or offend the senses' (disgust, attraction).

Social emotions: Result of the judgement of the result to which a product is seen to satisfy the social norms and standards (admiration, pride).

Surprise emotions: They are driven by the perception of novelty in a design (amazement).

Interest emotions: the perception of 'challenge combined with promise' (boredom, fascination).

According to this model of the design process the cognitive process and the affective process work in a very interdependent manner to each other where "cognition leads to affect and affect influencing cognition". Crilly et al cite Norman when they say that both these processes are infact information processing systems where "*the cognitive system makes sense of the world and the affective system is judgemental*".

Following the psychological response (comprising cognition & affect) results in a behavioural response represented by either 'Approach' or 'Avoid' corresponding to an expression of interest or disinterest (Crilly et al, 2004). An approach behaviour will result in a further investigation of the product and perhaps product purchase leading to product use. Crilly says that an avoid response can result in product ignorance, or even product abuse, and hiding the product, perhaps this reaction can be cited as a symbolic dis-association by the user.

3.6.2 Human Centred Design

The early design theorists of Product Semantics namely Butter (1989), Krippendorff (1989,2006, 2007, 2008) strove to develop it as a new approach to design (Brown 2006; Boess 2008) what they called the Human Centred view of design, a break from Luis Sullivan's "Form follows function" doctrine. Krippendorff expressed his aversion to the functionalist approach to design which confirms and reinforces

'part-whole' relations derived from biological structures. A malfunction similarly renders the whole useless, since its unable to fulfil its intended function. Human centred design then was an alternative to this 'normative submission', or as Krippendorff proposed 'form follows meaning' almost as an intuitive approach to Luis Sullivan's theorem. The functionalist approach excluded and somewhat disregarded human intellect, designers could only get away with a certain aesthetic if they could justify that it was a perfect fit for a certain functionalist requirement of the artefact thus giving rise to a whole era of 'functional aesthetics'. (Krippendorff, 2008) Krippendorff cites the historic context of product design as a profession born out of the need to endow aesthetics to industrially produced products. Products of this era were meant to be operated according to their functional capacities and such products which made this operation difficult such as typewriters and washing machines were assigned training courses by manufacturers.

Meaning is the central concept of human-centred design, and meaning is not grounded in forms but rather in the users who interpret these forms according to Krippendorff. And since meaning changes with the user's culture, background, personal experience, and context of interpretation, it implies different users and attach a different to the same artefact i.e. a pair of letter opener can have a very different meaning on a study desk than in the hands of an aggressive person in a dark alley.

Boess (2008) discusses the Suchman's (1987) study on people's use of copying machines as directly contributing to the emergence of human (user) centred design. Suchman observed that users acted in unexpected ways with copier machines, many times not in the way designers had foreseen.

Vimha (2007) has cast doubts on the success of human centred design in addressing design questions. In its quest to involve to user, Vimha argues that for human centred design product form is merely a practical and functional concern, only a point of view to understand the users' ability to 'function with the final design outcome.' According to her, interest in human centeredness increased in companies and consumer insight specialists due to the increase of technology in everyday products and the resulting difficulties which consumers faced decoding such products. Human centeredness laid the precursor to product semantics, which in itself was nothing but a response to solve the gap in communication between the designer's intentions and the user's apparent interpretation.

Klaus Krippendorff discusses Human Centred Design in his discourse 'The semantic turn' as a new design methodology to design semantically expressive artefacts. In this case he distinguishes the human centred view from the technology centred view on the basis of their approaches. Technology centred view "improves the world on the designers' terms" where-as human centred design derives itself from "a community of users" in whose world the designed artefacts would have to co-exist – thus focussing upon the user. Technology centred design lends itself from more hierarchical organisations such as militaries and assembly lines where specialist equipment has to be used according to the strict instructions imparted by those in charge to a trained manpower. Such an approach doesn't work so well in scenarios where the users acquire the artefacts on their own terms. The fact that users willingly undergo a degree of inconvenience to drive the car of their dreams or to wear the shoes they really would like to be seen wearing suggests that there are criteria other than technical ones which dominate everyday usage of artefacts (Krippendorff 1989).

Further human centred view challenges the technology centred view on 2 counts:

1. Instead of a universal and culture free interpretation of design, it acknowledges a role for language in its interpretation.
2. Instead of enforcing usage patterns in users through special training, letting the users learn the use on their own terms (Krippendorff, 2006).

The differences in the point of view of these two approaches can be better highlighted from their definition of design. "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (Hebert Simon,1969). Krippendorff says giving such qualifications to the users shifts the focus to a more human centred view. He instead defines design as "making sense of things". Design in the realms of semantics in his perception focuses not on designing technology for humans but rather the interface of technology with humans and how they use it and acquire it into their daily social and cultural context.

The cornerstones of human centred design are meaning, affordance and language. Affordance is based on James Gibson's 1979 'ecological theory of perception' which talked about affordance and direct perception. "Affordance is the perception of one's ability to do something with what is sensed", a chair therefore affords sitting, a pen affords grasping, a doorknob affords turning." For Gibson meanings are perceived affordances" (Krippendorff, 2006). Direct perception on the other hand deals with objects which don't require any reflecting on the user's part in order to start using them automatically. In semantics such objects are called self-evident or intuitive. Krippendorff cites the recent penetration of the human centred concepts of Gibson's work in interface design which was traditionally always dominated by technology centred concepts such as ergonomics (Flach et al, 1995). Though it must be said that Krippendorff underplays the role of building affordances in artefacts to increase their self-evidency and intuitiveness (Athavankar, 2009) in favour assigning them 'symbolic qualities' thus exposing a bias in his approach to human centeredness.

Gibson never talks about the role of language in his theory however. Benjamin Lee Whorf is cited as the pioneer of the contribution of language in the human centred view of design by Krippendorff. Whorf and Edward Sapir said that how speakers of a language think and act in this world is dependent on the grammar and vocabulary of the language. Berlin and Kay (1969) went on to give insights onto the role of language on perception of colour, by demonstrating a link between the colours present in a certain language the colours which the speakers of that language could recall and conceptually handle. Language is important because it gives the context through which meaning is attached. Ludwig Wittgenstein said "the meaning of a word is its use in language". Therefore language effects how users sense objects and attach meanings to them. Krippendorff says "Conceptions provided in language are indispensable part of how objects are perceived". This is also why manufacturers spend such huge amounts of resources on advertising, as an attempt to dictate the perception and meaning of the product to the target user. In fact he cites the example of the Braun SK4 radio-record player designed by Hans Gugelot which acquired the name of 'snow white's coffin' due to the use of transparent materials, thus springing a surprise to the designers. Artefacts tend to acquire new meanings not foreseen by the designer. This correlation between affordance, language, and meaning is the foundation for human centred design and its application to Product Semantics.

3.6.3 Sense

Sense is the tacit, taken for granted and largely unconscious monitoring of what is (Krippendorff, 2006). Gibson (1979) in accordance with his theory of ecology called it "direct perception". Sense is unique to each person, it is personal, and has the ability to spot patterns. Ultimately sense is the background against which 'meaning' is formed.

When users place what is sensed into a context a meaningful whole is formed, much like a coherent image. Krippendorff likens the process of sensing into a 3 stage phenomenon:

A. The user initially forms a "fuzzy image" of that which is sensed.

B. Placing the object into context starts forming arbitrary distinctions within the user.

C. A sufficiently coherent understanding develops when the user has placed what is sensed into all possible contexts and attached resulting meanings.

All these steps culminate into a moment of realisation for the user when he reaches a final understanding thus terminating a sense making activity. Although the sense making is continuous circular process where the user's experience and past memories can constantly contribute to refine and redefine that which he has initially sensed.

Weick (1995) & Pirolli (2007) point out sense making as how people see meaning in the data they capture from around them. "People are explanation machines looking for meaning in what they experience" (Bruner, 1990). Woods & Roesler (2008) discuss sense making using the concept of 'framing' and 'reframing'. They cite Klien et al (2006) by proposing that sense making is based on how people *frame* their world around them referring to frame as the perspective or context within which data from this world is interpreted. This means that changing the context according to Woods & Roesler (2008) can change the way a person would interpret the very same data or event. As a person acquires new information from the surrounding environment, the current frame is questioned and remodelled i.e.: *reframed* based on the new captured information. Sense making is concerned with how people synthesise the information from the world around them moving from 'information gathering' to synthesising, assessment and re-assessment to finally developing 'explanations'.

John Maeda in his publication "Laws of simplicity" contends sense making method to a "designer approach" to easing the user's process of understanding, as against the engineer approach which is to read the manual and acquire the proper knowledge before operation (A suitable parallel can be drawn here between Krippendorff's technology centred view and human centred view). He says good design instils a "sense of familiarity" thus giving rise to a "hey I've seen this before!" reaction from the users. One has to leverage the mind's ability to relate objects with contexts and experiences in addition to its disposition to form patterns based on Gestalt psychology. Human beings, he says, tend to relate, organise, and categorise what they see.

Crilly (2008) talks about generating 'recognition' as an important designers' objective, which can also be compared to sense making. He says that designers intend to make forms which users can recognise as belonging to a particular category or source (i.e. brand). He makes a particular reference to a designer's

interview and points out that if the customer doesn't understand the product within a few seconds on the shop floor, the product is immediately rejected as irrelevant. Thus there is a strategic opportunity on the designer's part to design products which are easily recognisable by the users.

According to Krippendorff's (1989) argument the basis of product semantics is the sense which artifacts make to the user. This is why users surround themselves with artifacts which make sense to them. Since sense is the background against which meaning is constructed by users, Krippendorff suggests that sense making is a continuous circular cognitive process starting with the user sensing an artefact and constructing a meaning around what has been sensed, and repeating this process until sufficient clarity and a coherent understanding has been achieved by the user regarding the identity, functionality, and what it can do. Successful conclusion of this sense making process leads to a 'aha!' moment in the user. Athavankar (2009) also relates to this by saying the ultimate objective of product semantics is to reduce the time period between these 'aha' moments which users experience upon seeing a new product. Product semantics does this by introducing an objective process and reduce the reliance on designerly intuition, a point on which both Athavankar and Krippendorff agree. Krippendorff concludes by saying "*something must have form to be seen but must make sense in order to be understood and used.*"

3.6.4 Meaning

A meaning is always someone's meaning (Krippendorff, 2006). Artifacts acquire meaning through use, and watching how users use an artifact can give insights into the attributed meaning. Thomas (2006) points out that "meaning of form is a human production, as it is both malleable & undefined. Meaning is born in perception, thus it is essentially a human construct, and is only limited by people's capability to imagine (Thomas, 2006). It thus follows that any form by itself has no meaning, but is rather "a window to opportunity" according to Thomas. Hekkert & Schifferstein (2008) say that it is only through interaction with people that objects acquire a meaning. According to Krippendorff's human centred approach objects are open to interpretation, and language structures provide for how artifacts are perceived. Since forms trigger meanings, therefore forms can also subvert meanings (Thomas, 2006). The same form can trigger multiple meanings, based on the scenario in which it is present. A knife in a kitchen means entirely different than in the hands of a man in a dark alley. Thomas points out that context influences the interpretation of a form, thus shaping the message it communicates. Thus it follows that meaning is contextual, the same object assume a different social role based on the contextual meaning it generates from the users.

Since meaning is born out of human perception that indicates that meaning is influenced by personal experience of the user being a psychological construction. Thomas points out that meaning is formed from the past. Past experiences and encounters influence meaning attribution. Krippendorff (2006) points out that meaning is not constant and is invoked by 'sense' and so in this way related to 'perceived affordance' according to Gibson's (1979) theory of ecology.

Crilly (2004) points out that meanings attached to products are determined by factors external to artifact's appearance since meanings have a more symbolic dimension. Materials can have a bearing on the communication of meaning. Handcrafted wood denotes craftsmanship; metal surface is associated with precision, and plastic with cheap products.

New product categories are always a test of how far users are willing to stretch the meaning of an accepted product typology. Krippendorff cites the example of concept cars and the SUV which was invented as a new automobile category with no previous existence in language.

(a) (b)

Figure 36 (a) Meaningless shapes (b) A juicer appliance with use context explained
Source: The semantic turn (2006) 62

Meaning mainly concerns itself with how people use objects. Meaning is a cornerstone of human centred design because it challenges the notion that how products are designed is the exclusive domain of professionals (Boess, 2008). Boess also discusses the importance of integrating meaning in product use into the design process. Boess says that product semantics and affordance are theories directly related to and informed by meaning in product use. Studies performed by kanis (1998) have shown that although designers try to anticipate on product meaning, the intended communication rarely succeeds. Meanings thus often go unrecognised by users. Boess (1998, 2008) discusses the concept of 'usecues' as a pragmatic tool to describe meaning in product use. Usecues are meanings which users draw on the functionality which a product offers and the possibilities of 'activating' these functionalities. As a pragmatic tool a usecue can be seen as an opportunity for interaction by the user i.e. a ribbed round knob can 'talk' the functionality of turning to the user. Boess (2008) also points out that usecues are the voice of a product. Some usecues are successful, other not based on level of cognitive effort, ability of skill based actions, past habituations, fixation due to previous experiences are cited as some reasons of failure. Usecuess would be the equivalent of what Krippendorff called affordings according to Boess.

Krippendorff (2006) discusses meaning in terms of difference between perception and reality i.e. difference between what is sensed and what is really happening. Using the famous duck-rabbit flip figure Krippendorff states that meaning is grounded in perception. Meaning are not fixed, meaning emerges from language in the sense that products derive their meaning based on their position in language i.e. a safe car spoken about as such by its intended community of users will eventually acquire this positive association.

In addition it has been pointed out in literature that materials attribution has effects on the intended meaning of an artefact. Hekkert and Karana (2010) in their study of lighters with similar geometries and differing materials demonstrated that products having similar intrinsic features, such as shape, geometry and function, when attributed with different materials such as metal and plastic can make quite a

difference in the perceived meaning. For example rounded geometry in plastic appears more futuristic than sharp shaped geometry, whereas sharp edged geometry in metal appears futuristic. Their study also demonstrated that familiarity (tied to circumstances, events, and past experiences) effected meaning decoding by the users. What doesn't exist in a user's language structure and psychological space cannot be associated to as a meaning by the user.

Figure 37: Study on meaning transmission through materials lighters (metal and plastic)
Source: International journal of design (2010), 4(3), pp-46

3.6.5 Affordance

Around the same time that the product semantic theory was coming to light in the product design community, the HCI (human computer interaction) community also started to discuss product meaning (Boess & Kanis, 2008). The concept of affordance was introduced to product design by the pioneer of cognitive psychology Donald Norman in his work 'The psychology of everyday things' in 1988. There are several competing definitions and points of view on the subject of affordance, and this discussion will highlight the original concept of J.J. Gibson and the differing aspects its shares with the points of view of the cognitive engineering plus HCI and product semantics.

The confusion which the design community introduced by adopting an ambiguous interpretation of definition of affordance has been richly debated in literature (You & Chen, 2003, 2007; Boess & Kanis, 2008; Norman, 1999) and is generally regarded as a misunderstood term the application of which in design has yet not been demonstrated.

Gibson (1977), a perceptual psychologist, in an early version of his theory of direct perception also known as Ecological Approach, first defined affordance as "the affordance of anything is a specific combination of the properties of its substance and its surfaces taken with reference to an animal." According to his definition affordance is an objective property which relates to the action possibilities an environment offers to an observer. You and Chen (2007) point out that Gibson also proposed that "the invariant combination of properties is meaningful whereas any single property is not" which explains why a flat, rigid, level and extended surface which is knee height affords sitting-on to an observer instead of the individual properties of such a surface.

Thus Gibson's notion of affordance proposed that the properties of an environment are expressed in relation to the observer which inhabits within it. In this way Gibson's concept of affordance is dependent on the 'human target characteristics' in terms of the capability of the observer (Boess & Kanis, 2008;

Michaels & Carello, 1980). Only an observer who has sufficient height would perceive a surface as capable of sitting-on. Gibson had subsequently modified his definition to state "the affordances of the environments are what it offers the animal, what it provides or furnishes, *either for good or ill*" further stating affordances "have to be measured relative to the animal." Thus Gibson's definition was also concerned with the polarity of affordances in the way of positive affordances which are benefitial to the user and negative affordances which are potentially harmful to the user (Maier & Fadel, 2008). With this observation in mind, You and Chen (2003) define affordance as "the perceivable potentiality of human-scaled object that supports the intended action without requiring memory, inference, or interpretation.

Affordance in the context of design is thus a 3-way relation between user, object, and action (You & Chen, 2007). Gibson's original theoretical framework is called direct perception because it considers affordance as the potentiality of products to support user action without requiring users' memory, inference, and interpretation (You & Chen, 2007). According to Gibson affordance does not depend on the subjective needs and experiences of the observer but is an environment-organism system that effects the behavior of the animal. This point of ecological psychology departs from the cognitive psychology view to which Norman prescribed. Other ecological psychologists have contributed to refining Gibson theory of affordance, such as Turvey (1992) who said that affordances were animal-relative properties of the environment that had significance to the animal's action (You & Chen, 2007). Chemero (2003) said that affordances were not properties of the environment but rather relations between animals and the features of the environment.

Gibson's concept of affordance is attractive to the design community because it shifts the focus from the user's mind to the users' actions, thus suggesting new possibilities for design practice and research (You & Chen, 2003, 2007).

Boess and Kanis (2008) challenge Gibson's concept of action possibilities latent in an environment regardless of observer's subjective status as over optimistic. They cite the example of Gibson's postbox illustration where Gibson suggested that any user beyond the age of 6 would know that the narrow slit on a postbox of a certain height would afford "insertion of a flat object, to the extended object clutching hand" (Gibson, 1979, p.133). Invalidating this argument they discuss Palmer's (1999) comparison of trash bin with a similar opening as the postbox, thus the two objects being perceptually similar (figure 38). Palmer countered that it is only due to associative meanings, due to associations stored in memory of posting letters, post being removed, and post offices, that the affordance of mailing is perceived by the observer.

Gibson claimed that designers often modified the properties and surface layouts of artifacts to achieve a needed affordance without requisite theoretical framework. He said products are 'not a patchwork of surfaces' to users but possibilities of actions (You & Chen, 2007). You and Chen also support the idea that Gibson intended to lay a foundation for a new theoretical basis of design based on the theory of affordance.

Figure 38: A postbox (left) and a trash bin (right)
Source: Product experience (2008), pp-312

Norman's (1988) definition of affordance is the popularised concept within the human centred design community – "the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used." He also said that "affordances provide strong clues to the operation of things." As a cognitive scientist, where Norman's view differed from the Gibsonian one was in the belief that affordance is formed from users' mental interpretation of artifacts based on previous experience and knowledge. According to this concept affordance was a clue to the usability of an artefact, recessed knobs afford rotating, textured dials afford turning, and strings afford pulling (figure 39). Norman famously declares that "when simple things need pictures, labels, or instruction, the design has failed".

What the original concept of affordance stresses is that affordances are not for communication or conveying information, but just a groundwork to initiate the necessary behaviour to achieve the artifact's function (You and Chen, 2007). Thus the question arises that- out of the seemingly infinite affordances offered by an artefact, which one is perceived? Why is one action afforded and others excluded? Although these questions might be important to the design community, but Gibson's concept doesn't address them. Norman's concept of affordance is based on usage of objects no matter if the real affordance exists or not. Norman calls this perceived affordance and says "it's very important to distinguish real from perceived affordances. Design is about both, but the perceived affordances are what determine usability."

With respect to Norman's concept Gibson's concept also doesn't address the degree or *how well* a certain affords a certain use or behaviour in terms of *quality* (Maier & Fadel, 2008). Within an organism-environment system unlike Norman, Gibsonian affordance is independent of the observer's needs, experiences and goals. A chair affords both sitting and carrying, however generally chairs afford sitting much better than carrying, unlike a briefcase which is the opposite although it too affords both the actions.

Where Norman's concept lacks is that it blurs the differentiation between affordance itself and the information revealing the affordance, as Norman (1999) himself has several times complained about the use of this term by interaction designers in the context of designing icons and symbols. Norman argued that designers had confused perceptual possibilities with cultural conventions (Boess & Kanis, 2008). Designers were designing onscreen buttons with 'protrusions' and shadowing to depict pushing, Gaver

(1991) has discussed affordance in this context. Gaver said "affordances per se are independent of perception" and "affordances exist whether or not they are perceived, but it is because they are inherently about important properties that they need to be perceived."

Norman in his discussion within POET (Psychology Of Everyday Things) proposes that affordance in the context of psychology of artifacts. He even discusses the psychology of materials by presenting the idea that separate materials such as glass afford breaking, seeing through and wood affords opacity, support and carving (Norman, 1988, pp-9).

Figure 39: Knob for temperature control Dial for lighting control

Affordances according to Norman contribute in forming the visible structure of artifacts which provides the clue of how things work. Acting on the affordance allows the user to see the see the feedback on well-designed artifacts which help in forming a clear conceptual model of functioning. Complex systems such as air-conditioning where there is no mechanical feedback need only to furnish a simple conceptual image of functioning with direct feedback. The knob on figure 39 illustrates rotating left towards increasing blue to lower the temperature and right towards increasing red to elevate the temperature. Krippendorff (2006) calls this positive correlation. Well-designed conceptual models allow the user to predict the results of one's actions or *feedforward*, when artifacts don't behave as furnished by their conceptual models a disruption occurs.

The third important concept of affordance has been proposed from the product semantics perspective. Krippendorff (1989) equates affordance as a semantic dimension in his theoretical framework. Keeping with this point of view affordance was defined by Krippendorff as "all possible behaviour behaviours (form) that confirmed what a user expected the object to do (meaning)." Product Semantics is mainly concerned with the communication of meaning and how the end user decodes the intended meaning and makes sense of the product based on one's own interpretation. Krippendorff (1990) also claimed that "product semantics aims at the design of things whose affordances cover at least the range of meanings users have in mind." Thus product semantics was mainly concerned with relationship between the users cognitive model and the intrinsic features of the product, thereby focusing on higher order cognitive processing foregoing motor level interaction (You & Chen, 2007). The focus in this concept is not on how users would manipulate the artefact but on how one would interpret the artefact. Unlike the Gibsonian version where action is key, affordance is not concerned with conveying information for communication purpose, but in product semantics meaning is key. "The outward appearance of a product appears as signs capable of arousing user's cognitive response to the product, such as aesthetic preference, functional

preference, and symbolic association" (Crilly et al., 2004). You and Chen (2007) cite Butter (1990) who said that most semantic approaches consist of three common steps, namely, determination of an intended character for the product, selecting relevant attributes, and exploring visual expressions of the selected attributes.

Thus designers using the product semantic approach rely on visual metaphors to transmit meaning onto product forms, and borrow shapes and intrinsic features from other categories to relate products to an intended character for purposes of meaning transmission. Krippendorff (2006) interprets the original Gibsonian concept as a human centred one, "The lesson of Gibson's work is that one does not perceive objects but usability: the sit-ability of a chair, the carry-ability of a box", he goes on to say "To be graspable, an object has to have two opposing surfaces separated by a distance less than the span of the hand, not smaller than what two fingers can pick up". Krippendorff's emphasis was to point out that perception of objects was tied down to what humans can do with their bodies, he said in order to be perceived as useful with accordance to the Gibsonian theory, objects had to be designed keeping in mind their users' abilities, i.e. in human centred terms.

Krippendorff further presents the view that Gibsonian affordances i.e. the perception of possible uses, the awareness of usabilities, equal the meaning in an artifact's use. Perceptions he said are anticipatory of bringing about changes caused by an actions. Actions which bring about the anticipated consequences end up becoming reliable. According to him, in the natural world there are many such motor-sensory coordinations which acquire such a fit with each other that they end up becoming reliable without causing disruptions. Citing the example of a baseball bat, one can immediately understand which end to hold the object with both hands and use it for swinging, smashing or other such actions, even if one has never heard of baseball or used a bat. Thus Krippendorff says that such direct perception exist because such sensory-motor coordinations are afforded by nature or artifacts which are made that way, and not because affordances exist without a perceiver. Designers thus need to pay attention how users' senses, meanings, and actions follow, and find ways to materially support such affordances to achieve intuitiveness in artifacts.

Boess & Kanis (2008) cite the experiment of Djajadiningrat et al. (2004) of designing a power switch for a video recorder, trying to only use affordances to convey meaning in product use intentionally excluding any semantic content. Using the direct perception approach Djajadiningrat et al. (2004) designed contours into the switch surface, upon rotation the 'flow' of contours was broken, symbolising break in electrical flow (figure 40).

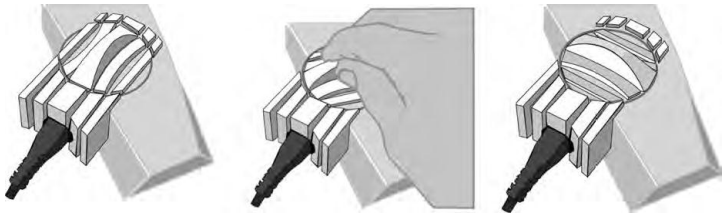


Figure 40: The power switch, symbolising flow
Source: Product experience (2008), pp-315

For someone who had never used a power switch the concept of 'flow' of electricity might never work, although one could live in a society operating power switches based on learned conventions by rote without ever associating switching or electricity with flow. Therefore Djajadiningrat et al. (2004) concluded that symbolic meaning and semantic content cannot be separated from meaning in use, artifacts need to provide some feedforward giving an indication to users the consequences of their actions, if they are to achieve reliability. Indeed Boess and Kanis (2008) point out that Gibson never intended the affordance concept as an aid to designing human-product interaction only as an aid to understand potential for action.

Similarly the empirical study of Oshlyansky, Thimbleby, and Cairns (2004) on the effects of cultural convention on the affordance of light switches arrived at a similar conclusion. Due to changing conventions in UK and USA of switches, users unfamiliar with the system could not guess the correct functioning. In the UK switches point downward when switched on and it is the opposite in the USA. Thus Oshlyansky, Thimbleby, and Cairns (2004) concluded that switches have no affordance per se since it has been learned in a cultural context and more attention needs to be paid to the effect of cultural conventions, rather than purely affordances, to understand meaning in product use.

3.6.6 Aesthetics

Hekkert (2008) defined aesthetics as the "*pleasure attained from sensory perception*". He is careful to point out further that aesthetics is related to "sensory pleasantness in general" thus effecting all domains of senses – touch, smell, listen, and taste. Hummels and Overbeeke (2010) propose that 'aesthetics always refers to culture, to what people in a specific culture find valuable.' Therefore aesthetics refers to ethics. Aesthetics is regarded as a non-instrumental product quality, forming an important aspect of overall appeal and experience of a product (Hassenzahl & Tractinsky, 2006). Though this has been disputed in literature, Hummels and Overbeeke (2010) cite Dewey's pragmatic perspective, which proposes aesthetic experience as a sense making and a meaning making process, such as when experienced by a blind user.

Aesthetics has relevance in the overall context of this research because in accordance to the product communication model elaborated in section 3.6 aesthetic impression directly influences to semantic interpretation of artifacts. Although aesthetics is not an emotion it is driven by emotion (Hekkert & Leder, 2008; Hassenzahl, 2008). The rewarding effect of visually sensing a beautiful object leads to positive emotions resulting in a positive mood within the user. Thus there is interplay between aesthetic sensing, which is a cognitive process, and the emotional process of generating moods. Though Hekkert & Leder (2008) do point out that according to (Kant, 1952; Scherer, Schorr, & Johnstone, 2001) aesthetic interpretation is independent of other concerns beyond perception of an object and the pleasure that derives, which is unlike an emotional reaction which is always directly related to some expectation or goal either getting violated or fulfilled to trigger a positive or negative reaction.

There has been debate in literature that it is quite difficult quantify aesthetics or to believe in universal laws of aesthetics (Crozier), although reference to Gestalt laws (i.e. *balance, proportion, symmetry*) are made as a basis upon which to elaborate recent research into this area (Crilly, 2004; Hekkert & Leder, 2008). Studies performed by Locher, Overbeeke and Stappers (2005) and Nodine, Locher and Krupinski

(1993) have even studied scanpaths of eyes of people looking at altered versions of paintings lacking the balance of original versions, which proved that people made more effort in the form of eye movements to find the missing 'balance' and composition hence demonstrating a sensitivity of people towards the above cited Gestalt principles. According to another study performed between 311 participants by Jacobsen et al (2004) on the words associated with aesthetics , showed 92% used 'beautiful' and 41% used 'ugly' as the most associative of aesthetics beating words such as 'attractive, enjoyable, and cool' each scoring only 5%. Thus beauty is an important part of the aesthetic experience of an artefact. Additionally The HCI community too, from a psychological perspective 'analyses aesthetics through the objective and scientific account of how people perceive it- i.e. through which mechanisms people perceive *beauty*' (Stolterman, Jung and Donaldson, 2007).

Hassenzahl (2008) therefore discusses aesthetics in terms of beauty. Beauty according to him is a hedonic quality as opposed to 'usability' which is a pragmatic quality of an artefact. The correlation between the 2 is inconclusive although Hassenzahl does cite a study on correlation between attribution of beauty and goodness by users for mp3 skins. Although the perception of goodness changes significantly in the participants before and after experiencing usage of the artefact but the perception of beauty remained unaltered, suggesting that beauty is not related to usability. This correlation between beauty and usability has been subject to some debate as Norman (2004) had famously stated that "attractive things work better". Hassenzahl further points out that judgements on beauty are remarkably stable for artifacts. Users do not change their judgement on the beauty of an artefact which can be formed in as short a time as 50 ms and this judgement doesn't change even after being exposed to the usability of an artefact. Thus unlike usability, beauty or attractiveness, can be immediately assessed and formed based on just the visual properties of an artefact i.e. its visual gestalt.

Hassenzahl (2008) also makes interesting reference to the study performed by Bloch et al (2003) to portray that buyers of toasters (a test consumer product category) attach '*value*' to beauty. In fact Bloch et al (2003) put the value at about $13.15, on an average which a test sample of buyers was willing to pay extra for a more beautiful appliance in relation to a less attractive alternative containing similar technical features.

Using the same approach as his argument for product characters (section 3.7) he classifies beauty as a hedonic quality of products diverse from a pragmatic quality such as usability or efficiency. He proposes that like product characters (Hassenzahl, 2004), the appeal of beauty is also contextual (hassenzahl, 2008). Citing a study of text input software performed by Meyer and Tractinsky (2006), users were willing to pay more for high usability than beauty, unlike the previous study on toasters. Thus task and efficiency oriented contexts reduced the importance attached to beauty than a social context where beauty is of paramount importance (Hassenzahl, 2008).

Beauty and attractiveness being hedonic aspects of a product do result in an 'endowment effect' in buyers and consumers (Kahneman, Knetsch and Thaler, 1990; Hassenzahl, 2008). In a study of wristwatches having 2 distinct product characters i.e. hedonic (exclusive, sporty, fashionable, beautiful, valuable, dynamic) and pragmatic (useful, effective, accurate, reliable, robust), the buyers were willing to pay more for the pragmatic version than the hedonic, but once acquired the buyers were willing to sell the hedonic

watch for more than the pragmatic one. Thus although users are less willing to pay extra for a beautiful object, but once owning it they get attached to it and are less willing to give it up (Hassenzahl, 2008).

Norman (1988) addresses aesthetics by saying "if everyday design were ruled by aesthetics, life may be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier." He urges designers not be 'selective' in their attention when dealing with usability and aesthetics but address both in equal measures, but cautions that aesthetics blinds the designer to the issues of usability.

Indeed the discussion between beauty and usability is quite extensively debated in literature. It is also interesting to note that opposite to Hassenzahl, who regarded beauty and usability as unrelated to each other, Tractinsky (2000) through experiments had found that beautiful artifacts are perceived as more usable (Stolterman, Jung and Donaldson, 2007)

According to Berlyne there is an optimum level of arousal associated with each artefact which is perceived as attractive (Crilly, 2004;Hekkert& Leder,2008). Too low arousal and the artefact is perceived as indifferent and too high a level of arousal will be over-the-top and consequently appear unpleasant. Berlyne (1970) also said that the complexity of a product form directly influences arousal or pleasure. Regarding the aesthetic model of Berlyne and Baxter (1995), Chang (2008) says that the key to visual attractiveness is not the 'intrinsic complexity' but the '*perceived* complexity' to an observer. Thus a visually complex product may be perceived as simple and thus appear attractive only because the user is familiar with it due to past experiences. With repeated uses as a complex product becomes familiar its attractiveness increases to the user (Chang, 2008). Visual familiarity breeds a sense of easiness, whereas the unfamiliar and the new demand attention and cognitive resources.

Coates suggests that a theoretical model on perception of attractiveness, which according to him consists of 'information' and 'concinnity' (Crilly, 2004). Information consists of *novelty* and *contrast* whereas concinnity consists of *sense* and *novelty*. Information and concinnity are not just results of objective qualities of objects but also subjective experiences of their users. Objective information in a design represents the contrast (i.e. colour) it possesses with respect to its surroundings. Subjective information consists of the novelty value of a design. Objective concinnity is the perceived order in a design thus corresponding to the gestalt principles and subjective concinnity denotes the extent of sense the design makes to the user. In the end this theory proposes an equation with a balanced valence: when information outweighs concinnity then the object appears meaningless and ugly. When concinnity outweighs information the object will appear dull and boring. Similarly Berlyne Coates suggested that information and concinnity in an object have to be balanced in order to be appreciated as attractive and pleasant.

Aesthetics as a theory has met with some disregard since it has historically not taken into account the subjectivity of human perception and judgement. Crozier cited by Crilly (2004) also says that difference in judgements between people make it difficult to form universal aesthetic principles. Krippendorff (2006) mentions the historical epistemological mistake of aesthetic theory of proposing universal concepts of aesthetics and disregarding human judgement, changing tastes, and cultural differences. Hardonk (1999) though demonstrated that universal aesthetical principles do exist by studying decorative band patterns from 20 historic cultures. Band patterns are 2D frames which demonstrated some universal conventions such as vertical symmetry, simplicity, order, mirror symmetry, unity, variety, etc. (figure 41)

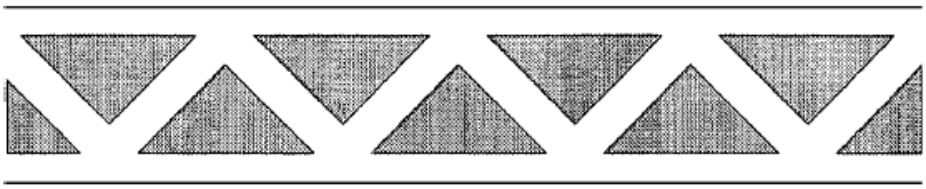


Figure 41: Universally accepted band with universal concepts of symmetry, simple shapes, parallelism. Source: Product Experience, (2008) pp-273

The study of performed by Zajonc (1968) proves that past experience does have a bearing on aesthetic appreciation of artifacts by users and influences their aesthetic impression by citing the fimiliarity principle: '*fimiliarity breeds liking*' (Hekkert & Leder, 2008; Crilly, 2004, Chang, 2008). In it Zajonc proves that mere exposure to a stimulus increases its appreciation by the users. Hekkert and Leder city evolutionary forces which are at play for this phenomenon citing that fimiliarity leads to safer choices. As an alternative theory exposure to artifacts also reduces the cognitive effort required to read them 'fluently' (Reber et al, 2004). Reber et al (2004) also say that one tends to perceive oneself when evaluating objects, and thus appreciating objects more which are easier to process. This validates the literature from product semantics which says that users tend to sorround themselves with objects which make sense to them and they can identify with.
Figure 42 below shows the 2009 Volvo C30 which had the unique truncated hood design. Though largely regarded as appealing to the past and odd at the time, after 5 years on the road the latest models of 2013 have all accepted its design appeal as original and very novel.

Figure 42: Volvo C30(2009) Mercedes A class (2013) Ford Mondeo (2013)

This presents an obvious problem for design, which tends to push for innovation and novelty. Leder and Carbon (2005) demonstrated that users can easily reject new and innovative design solutions in favour of more traditional ones although with proper evaluation and experience innovative features will be appreciated more by users. The MAYA (Most Advanced, Yet Acceptable) principle introduced by Raymond Loewy (1951) suggested that designers need to find a balanced approach between novelty and tradion. On studies performed by Snelders and van Wieringen (2003) for designs of products such as telephones and teakettles, they concluded that novelty and prototypicality highly corelated the effects of which were almost equally strong.Thus designers need to adress this contradiction by finding a balance between novelty and typicality in order to maximise the attractiveness of their designs.

Hekkert and Leder (2008) further argue the role of human evolution through their 'by product' hypothysis according to which the aesthetic sense of humans is a by product of the evolution of their sensory system. The human sensory system has evolved pleasant and unpleasant feelings towards factors which are either harmful or benefitial to gene propogation. Selection of symmetry is one such factor, as symmetric faces are appreciated as more fertile and disease free thus more attractive.
Human beings have a tendency to group, organise, and categorise visual information, thus processing information becomes more cognitively less demanding. Detecting such structures is emotionally rewarding (Hekkert and Leder, 2008), which is not just restricted to physical forms but also semantic qualities of an object i.e. the attribution of metaphors for transmission of meaning in products. Successful interpretation of meaning in product appearances can trigger pleasurable emotional responses.

The fact that human senses want to economise their functioning (Gorno, 2010) effects aesthetic preference is described by the conjuctive ambiguity principle (Hekkert and Leder,2008; Boselie and Leeuwenberg, 1985). This principle presents the view that when a certain pattern can be interpreted in more ways than one then "conjuntive ambiguity concerns the case where the separate interpretations are compatible and jointly effective" (Hekkert and Leder 2008). The opposite of this case is covered by disjuntive ambiguity where the separate interpretations are mutually exclusive and as such result in beauty reduction such as in the famous duck-rabbit figure. The conjuctive ambiguity principle has been discussed as a special case of the 'maximum effect for minimum means principle' which enfurthers the economy driven argument to ideas, formulas, and solutions. Generally humans prefer ideas and solutions which encompass the minimum number of constituent parts and elements while solving a range of problems (Boselie and Leeuwenberg, 1985). Hekkert and Leder propose that for the same reason one prefers bridges, components, products as aethetic engineering solutions simply because they solved the problem at hand with the minimum number of constituent components. Similarly designers have been known to prefer simplistic and sometimes minimalistic solutions such as the ipod shuffle (white box, with 4 playback buttons, and no screen).

3.7 Product character, characteristics and attributes

Both in product semantics and character theory it is a basic assumption that artefacts can be bearers of a message through the characters which they express. A character pervades all levels of a certain artefact, once it has been attributed to a product. A character can be indicative of the external appearance, internal functioning, or behaviour of the artefact. There are several points of view of product character, characteristics, and attributes which have been systematically discussed in this section to give a general idea of the discussions currently spanning this subject area in literature.

Demirbilek & Sener (2003) make it very clear when they say that all manufactured products make a statement through shape, form, texture, & colour. Further they go on to discuss that regardless of how designers use colour, shape, form, & texture in designing a product, a message is being sent out through the product using language structures. Thus designers and ergonomists should know exactly what kind of message they wish to transmit to the user and be aware of the symbolisation and attribution structure of

the language in question. A product also achieves a symbolic significance and transmits messages through language structures not only about itself but also about its user.

Crilly et al (2009) project that designers intend consumers to attribute specific ‘characteristics’ to a product. Crilly has further equated characteristics as ‘technical qualities’ (such as reliability) or an abstract quality (friendliness) which a product exhibits. According to him designers have the power to manipulate the attribution of these ‘qualities’ and as a result control the value which these products communicate and the manner in which consumers might relate to them.

From a point of view of user experience Crilly (2011) further deals with the subject area of product characters by saying that designer’s intentions and product forms influence the inferences which users form towards the designer’s intentions. Product’s form influences if it appears clean, safe, durable, or aggressive and according to Crilly this is the subject area concerning Product Characters. Crilly deals with the subject area of product characters from a point of view of persuasive design and relegates it as a rhetorical area of inquiry. According to him revealing details , such as fasteners (figure 62), which inform the user of a product’s construction and overly emphasising them through numbers or visual prominence might give the impression of ‘robustness’ while other details such as introduction of horizontal strips along a narrow geometry might give the impression of ‘slimness’. Such tactics have been demarcated as ‘persuasive intentions’ by Crilly although the same subject area is strongly related to and widely discussed as product characters in literature.

Crilly makes an important observation when he demarcates products as ‘persuasion attempts’, designers as ‘agents’ and users as ‘targets’ similar to Crilly, Moultrie, & Clarkson’s framework of product communication (figure 61). He says the targets have the most difficulty discerning the rhetorical claims of physical products based on their appearances. He wisely distinguishes between ‘physical products’ and more verbal mediums of expression such as advertising which could rely on both a verbal sales pitch and a semiotic association through text and branding. Eventually Crilly does concede that even non-physical visual media such as print advertising can exhibit character through its persuasive attempts of selecting a font, typography & layout to make a symbolic representation about a product’s qualities. Crilly confirms that in this regard even a physical product’s outer form is an advertisement seeing as it ‘speaks’ about its qualities and attributes (ie. I’m Eco-efficient).

Janlert and Stolterman (1997) have made a clear hierarchal distinction between a product character, characteristic, and attributes. According to them character attribution reduces the mental effort to deal with artifacts. In fact the ‘character ascription process’ is a natural phenomenon active in all human beings and constantly at work. One ascribes characters to even people based on just their physical appearances, to geometry (suggesting rounded forms and warm colours have a friendly character etc.), and children are more accepting of character ascription and readily assign characters to even simple objects.

“A character is a unity of characteristics i.e. not a simple collection, but with related characteristics integrated into a coherent whole” (Janlert, 1997). This means all the characteristics united to send a common message to the user of the artefact.

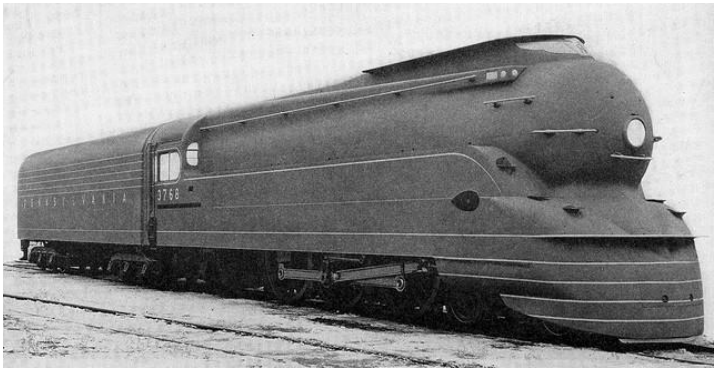
"A characteristic is interpreted as a qualifier of attributes. A characteristic is a kind of a higher order attribute, a meta attribute that applies to all attributes within a character or individual." Knowing a few of the characteristics constituting a character enables one to guess the remaining ones.

An attribute is "understood in a very wide sense as including all kinds of specifications of an object". These attributes can be ordinary in nature, such as colour and weight, or they could even highlight a tendency such as collapsibility, or flammability etc. On a human level they could even highlight ability such ability to speak Italian, or ability to drive etc.

A sum of attributes which are qualified by a certain characteristic go into forming 1 characteristic, and a group of similarly constructed characteristics intending the same meaning combine to form 1 character. The hierarchy is thus pyramidal in structure.

Seeing as a characteristic is a higher order attribute, it can be also a 'complete' if it applies to all the attributes within an artefact without exception (Janlert & Stolterman, 1997). Thus a complete characteristic is cognitively very powerful and thus requiring lesser mental effort to decode, but has limited applicability in terms of contexts. A 'partial' attribute on the other hand has wider applicability but lacks in cognitive power. Finally a characteristic has the capacity to link the physical appearance of an artefact with its technical functioning.

Figure 43: Alienware PC



Steam locomotive by Raymond Loewy (source: Locomotive Encyclopaedia of American Practice, Tenth Edition - 1938.

A wrongly attributed characteristic can thus cause disruptions and generally prove to be a nuisance though with time users will eventually detect a mismatch between the appearance of an artefact and its technical performance and due to the continuous character ascription process in the users' minds re-associate the appearance with some other quality. A good example of this is the steam locomotive designs by Raymond Loewy (figure 43), which looked really streamlined as if ready to go really fast but in reality went no faster than an average locomotive. Eventually the streamlined became associated as a symbol of progress, modernity and scientific advancement.

Modern day computer artifacts also sometimes use the same tactics as is apparent from the Alienware PC above which uses a streamlined and aggressive appearance in order to indicate fast operation even though in reality it might not be faster than other PC brands.

Butter (1989) also warns of this tendency through the use of 'factual attributes' and 'semantically expressive' attributes. Factual attributes he says represent measurable qualities such as speed, while semantically expressive attributes measure communicative aspects of a product's quality. A mismatch between the 2 can lead to rejection of the entire product due to its fake character i.e. 1950's cars with exaggerated tailfins suggested speed which they didn't really possess. But on the other hand John Maeda (Laws of Simplicity- 2006) points out that even though such a practice can be misleading but it still would be desirable from a customer's point of view, even if only as a source of mental comfort that time might be saved while using such products.

Janlert and Stolterman (1997) further indicate that a character can be ascribed with so much as a casual glance. The idea being that users substitute characters as a convenient conceptual construction to decode the internal workings of an artefact based on its external appearance. It thus follows that users tend to make a connection between certain appearances and the characters they attach to them i.e. transparent surfaces appear more futuristic, and organic forms appear more playful. This relationship also points out that if an object behaves in an unpredictable manner then the character attributed to it could be modified or even the object redesigned. Based on these insights it can be said certain characters can potentially form stable relations with certain appearances and this interdependency between the 2 can be an opportunity for designers.

Characters have to be 'planted' into a product with great care. A complex product such as a car or an appliance is made up of several characters and even 1 character wrongly attributed can be misleading and detract from the carefully cultivated message which the product is trying to communicate. Thus designers have to be doubly careful with the details and feature they utilise to attribute a certain character. Selecting felt where a hard plastic surface could have been more coherent or adding transparency where and opaque surface would better pass on the intended message would be distracting to a consumer and can ultimately leave him in doubt about the message which the artefact seeks to pass on. Certain characters are easily recognised by users, and are thus more easily attributed, but characters which are not very well recognised are quite challenging to attribute. Furthermore some characters have a tendency to be coupled together such as 'big and heavy' or 'short and fat', thus resulting in stereotypes. Ultimately properly attributed characters reduce the mental effort required on the part of the user to interpret a product and attach a meaning to.

The investigation of this research is limited to visual appearances of artifacts. Although Stolterman pointed out that appearances are not just visual, but also acoustic such as the sound of a car motor, and also encompass olfactory (smell of upholstery) and haptic senses (feedback from switches). The sense of sight is merely the most powerful and developed one "collecting up to 80% of all the perceptual stimuli and therefore the most influential sense" (Gorno, 2010).

Reinhart Butter (1989) pointed out that characters can be designed into artifacts to give rise to intended meanings amongst users. Krippendorff (2006) gives an interesting insight when he discusses product characters in terms of linguistic attributions. He refers to characters as adjectival constructions and points

out to the importance of adjectival constructions in language to distinguish, among other things, between object properties, personalities of people, and qualities which objects possess or not. According to him an artifact's character is already being formed when people discuss about it and assign it adjectives in discussion such as user-friendly, or difficult to handle, safe or dangerous, futuristic or old fashioned etc. Thus artifacts are created or destroyed in *language.* In a way this implies that regardless of the designer's intentions, an artifact's fate is already sealed once a negative association is made against it in conversation thus resulting in attribution of 'unfavourable characters'. This is reason why companies spend such large amounts on advertising i.e. to influence public perception about an artefact and endow it with positive associations.

He defines a character as 'all the adjectival constructions that a community of stakeholders in that artefact deems suitable to that artefact. Each individual adjectival construction is a character trait.' A character trait is a stable attribution of a *quality* by means of a particular adjectival construction. An interesting Based on Athavankar's work (1987)[5], Krippendorff (1989) further discusses characters as qualities which are basically a cognitively constructed stereotype which users utilise to differentiate between prototypical artifacts. Attribution of these qualities creates sub-categories between artefacts. An example would be '*baby* shoes' or '*sport* shirt' or a '*5-star* hotel, clearly these qualities are *nouns*. Thus a sport shirt would have to be *sporty* (adjective) in character. He proposes that as characters qualify objects, adjectives qualify nouns.

This thesis rests on the fact that communication of 'Eco-efficiency' (noun) as a higher order meaning in an appliance can be done through successful attribution of characters in such a fashion and set apart an Eco-efficient (adjective) washing machine from a washing machine. Figure 44 shows the hierarchy between the three elements.

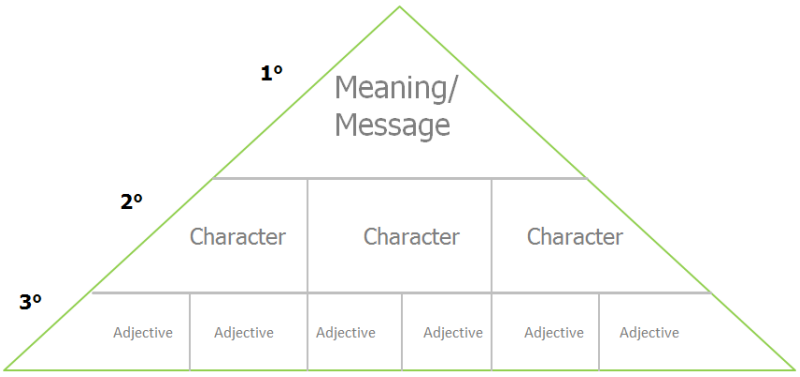


Figure 44: Hierarchy of meaning, character, and adjectives

Vimha's (2007) opposition to Krippendorff's language based approach to designing product has been already discussed. According to her '*when a product, a practical tool, has been designed with an emphasis on something other than its practical functioning, it is said to have acquired language-like properties. The theoretical idea is that, when a concrete product is looked at from a non-practical or non-technical point of view, it becomes language like.*' She poses the question that how can a concrete product

[5] Uday A. Athavankar "Web of Images Within." ARTHAYA, *Proceedings of a Conference on Visual Semantics* (Bombay: Indian Institute of Technology, Industrial Design Center, January 20-22, 1987).

be suddenly transformed to a word like system? An analogy which according to her is sure to cause confusion and unnecessarily mislead.

Be that as it may, Krippendorff calls his approach to character attribution as a human centred construct. Product characters are not objective product properties such as ergonomics which measures human perspective objectively based on physiological measurements thus lying in the domain of 'machine centred conception'. By contrast human centred concepts are based on human senses and experiences and not on how a 'mechanical device is designed to respond'. As an example of heaviness human centeredness relies on defining heavy only in terms of what is light in the user's experience and not objectively in kilograms and pounds which bypasses the human perception and judgement. Therefore Krippendorff concludes that product characters which are of interest to designers can rarely be measured objectively. To clarify, consider the next image:

Figure 45: Apple Magic Mouse (elegant, feminine, fashionable)

Logitech G600 gaming mouse (high tech, masculine, high performance)

Krippendorff has proposed 5 distinct categorisations of adjectival construction based on the English language structure, this categorisation has been also used to realise the outcome of this research (to discussed in greater detail in section 7.5):

1. Objective adjectives which measure quantitative properties: size, speed, noisiness, fragility, brightness etc.
2. Evaluative adjectives which measure aesthetic aspects: beautiful, balanced, harmonious, elegant etc.
3. Adjectives of social values: high class, expensive, outstanding (vs common), etc.
4. Adjectives of emotions: exciting, appealing, inspiring, joyful etc.
5. Adjectives of interface quality: reliable (vs unreliable), clear, easy to use, efficient

Finally since designers are primarily concerned with what users are sensing through seeing, touching, feeling, and discussing therefore they are concerned with measuring perceptions, feelings, and emotions, none of which can be readily measured. Thus designing product characters means designing sensory experiences according to Krippendorff.

Demirbilek & Sener (2003) suggest that users intuitively understand the expressive language of human bodies (such as facial expressions) and using them as a 'semantic resource'. As an example the character of 'cuteness' in artifacts results from variations in proportions and inducing roundness in forms much like a baby's physiology. Consider figure 46, it shows calibrated changes in the car's upper and lower proportions in the context human physiological changes from a baby to an adult.

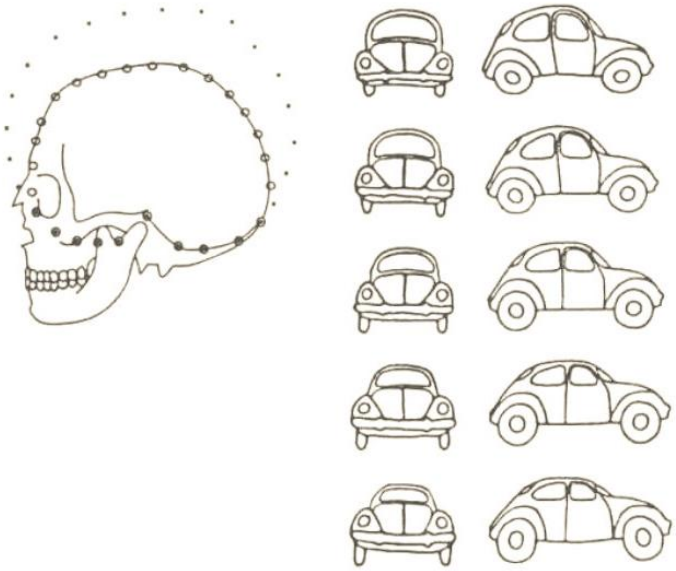


Figure 46: In context of human physiology how changes in proportions can age a car (Papanek 1995).

Distinct from Krippendorff's language based approach, Janlert and Stolterman (1997) propose a 'character modelling process' to describe how users ascribe characters to artifacts. At first the user acquires a target artefact with specific 'interaction goals'. He goes into this interaction with various expectations which can be described as expected outcomes to his actions. Lacking suitable complete about the artifact's functioning, the user ascribes characters based on the initial appearances and the expectations he carries regarding the consequent behaviour. As the interaction progresses, new situations and scenarios arise following which the user modifies his understanding of the artifact's behaviour. The user then continuously ascribes new and more suitable characteristics to the artefact which will ultimately build 1 unified character and conclude the character modelling process. They point out that it is not quite clear that at which point precisely the user begins this character modelling process, does it begin as soon as the user visually acquires the target artefact, or does it begin when the user initiates an instrumental interaction at a later stage?

According to this process artefact already assigned with a character can be re-ascribed with a new character in due course if the user's experience with the artefact doesn't quite meet with his/her expectations. Clearly the character modelling process is based in context and therefore a human centred one, and like sense making it is a continuous and one could say self-feeding process. Joining the character modelling process with Krippendorff's language based product semantic approach can suggest that attaching certain characters in a product's appearance communicates a certain meanings to the user.

Hassenzahl (2004) proposed an *intended* product character which the designer attributes. The user comes in contact with the artefact and constructs a personal interpretation of the product character which is the *apparent* product character. The apparent character leads to 'consequences' ie. Judgements about the product's appeal, thus leading to an emotional reaction (pleasure, or repulsion) and finally resulting in a behavioural consequence through approaching the product and spending additional time with it. This

character attribution model is similar in structure to the product communication model proposed previously by Crilly, Moultrie, and Clarkson (2004). It is important to point out that the consequences of the same product characters are context and situation based, change of context can have change the outcome (emotional + behavioural) of the same product character.

According to Hassenzahl (2004) a designer fabricates a character through combining several product features (i.e content, style, functionality, & interaction) but this character is only intended by the designer and so there is no guarantee that the user will actually perceive it as such and appreciate the product in the same way as a result. People construct an apparent product character according to a personal standard. A personal standard consists of other product which a user can compare this particular product to which explains why differing individuals attach different characters to the same product.

As also pointed out by Janlert & Stolterman (1997), Hassenzahl (2004) argues that an apparent character is also not the final interpretation, as it changes over time within the same person with experiencing the product over time. An unusable product can over time become familiar and the user can learn to appreciate it as easy to handle.

Hassenzahl also warns that since product characters are a cognitive construction, there relevance to user changes according to the scenario. He cleverly cites the example of an automatic teller machine (ATM) which has been deliberately endowed with a character of 'easy to use'. A first time user of such a machine will appreciate this character of following one step at time operation, and thus experience satisfaction. Though if another user is in a tearing hurry, and the series of small steps of operations slow down the transaction he is unlikely to find to find the character of 'ease of use' of much relevance at this moment thus not likely deriving any satisfaction from the experience and rather ending up frustrated.

Thus Hassenzahl argues that characters have relevance according to context, depending on the situation a user may or may not desire a certain character.

Hassenzahl drives 2 main categorisations of product characters as *hedonic* and *pragmatic*. Pragmatic characters assist in manipulation of the environment and are thus primarily instrumental. Pragmatic characters fulfil internally generated or externally motivated behavorial goals. Pragmatic characters can be represented by "clear, efficient, usable, and controllable". Hedonic attributes on the other hand emphasise 'an individual's psychological well-being'. Hassenzahl bases his definition of hedonic as "*of, relating to, or marked by pleasure*" and typically are represented by attributes as "outstanding, impressive, and exciting". Finally hedonic characters provide simulation, communicate identity of a user, and provoke symbolic memories. A tool to drive a nail such as an average hammer possesses a pragmatic character whereas a power tool with a hammering functionality and a recognisable professional branding possesses a hedonic character.

In terms of product functionality, product functionality which are used and work well will be perceived as pragmatic and those functionalities which lie unused but appear interesting to the user are hedonic.

Consider the matrix proposed by Hassenzahl to construct 4 categories of products based on his basic categorisation of hedonic and pragmatic characters:

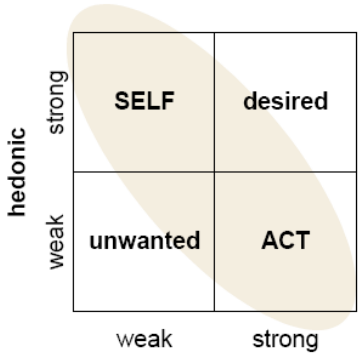


Figure 47: product characters emerging from a combination matrix of hedonic and pragmatic (source: Funology: From usability to enjoyment, 1-12)

Thus on the lower left corner, on a combination of weak hedonic and weak pragmatic will result unwanted character. On the opposite extreme a combination of strong pragmatic and strong hedonic attributes is a desired character which all products should ideally have. A product with a strong pragmatic attributes and weak hedonic are called ACT products and vice versa are called SELF products by Hassenzahl. An ACT product is linked to the user's behavioural goals, whereas a SELF product is linked to the user's self (i.e. memories, relationships, and ideals). It goes without saying therefore that SELF products are much easier to appreciate by a user than an ACT product. Hassenzahl concludes that only products which have at least some relation to the self of a user will be stably appreciated by the user.

Karjalainen (2003) discusses the importance of using product characters to develop a strategic brand identity of company products. Based on his doctoral research Karjalainen proposes that the brand identity of a company is transmitted as a meaning to the user through character attribution in their products. A brand identity can either be constructed artificially through marketing and advertising efforts (albeit as a result bear an element of dishonesty in its projected image) or it may result naturally through no direct intervention based on the identity of its products in user language.
Companies thus ideally should thrive to build up a 'design bank' in the form of attributable product characters which set them apart. As stylistic elements these product characters are discussed as rhetorical components of a product communication paradigm to be communicated as a meaning by the manufacturers. Using the example of Volvo, Karjalainen cites the emphasis on safety which is attributed as a character in all their vehicles using design elements such as thick body panels, over-riding shoulders (figure 48). Designers must enable a strategic connection to the brand *identity* by providing relevant codes within their branded products. He states further that a "brand name functions as a sign, connoting specific meanings by activating a network of association, both intended and unpredictable".

This aspect is very important to the outcome of this research, as the author here seeks to ultimately investigate what kinds to visual cues enable a successful transmission of Eco-efficiency as a meaning in home appliances. But in order to successfully apply this research for future product development, the aspect of transmitting and adhering to a brand identity will be a very important issue. Although it can be safely said that unlike Volvo, which is an iconic brand (as it continuously reinforces the attribution of the same product character of muscularity in all its vehicles) appliance manufacturers have yet not achieved that quality of communication. Rather they choose to rely on brand peculiarities which can be identified,

for example - by a target group familiar with Whirlpool's refrigeration appliances. But beyond this small target sample appliance brands are hardly ever recognised and are largely unknown to average users.

Figure 48: Visual design elements which endow a product character of safety to Volvo cars (source: Karjalainen, T.M., proceedings 10th International Product Development Management Conference, Brussels, 2003)

The target group here can be regarded as buyers and consumers having a high level of involvement thus they recognise easily with the brand identity which is reinforced by marketing elements such as branding, pricing, etc.

Krippendorff (2006) makes an interesting connection between character and identity by proposing that products exhibiting characters come to be directly related to their users by supporting identities. Identities project a social meaning. According to him people surround themselves with artifacts which they identify with in an attempt to project a certain image. Thus identities are enacted in public and artifacts hidden from public view cannot participate in reinforcing an identity. This is why manufacturer badges are so important and prominently displayed in automobiles and are a frequently stolen item commanding a very high resale value (e.g. *free replacements for stolen Skoda badges published by Autocar.com – May, 2012*[6]). Krippendorff also suggests that identities can be mode of social inclusion or exclusion through possession of certain artifacts (Apple's popular iPhone comes to mind). Companies reinforce their corporate identities through the way in which consumers utilise their products (i.e. one doesn't own a smartphone but an i-Phone). Thus it follows that artifacts which are easily accessible by virtue of availability or even price cannot contribute to forming identities.

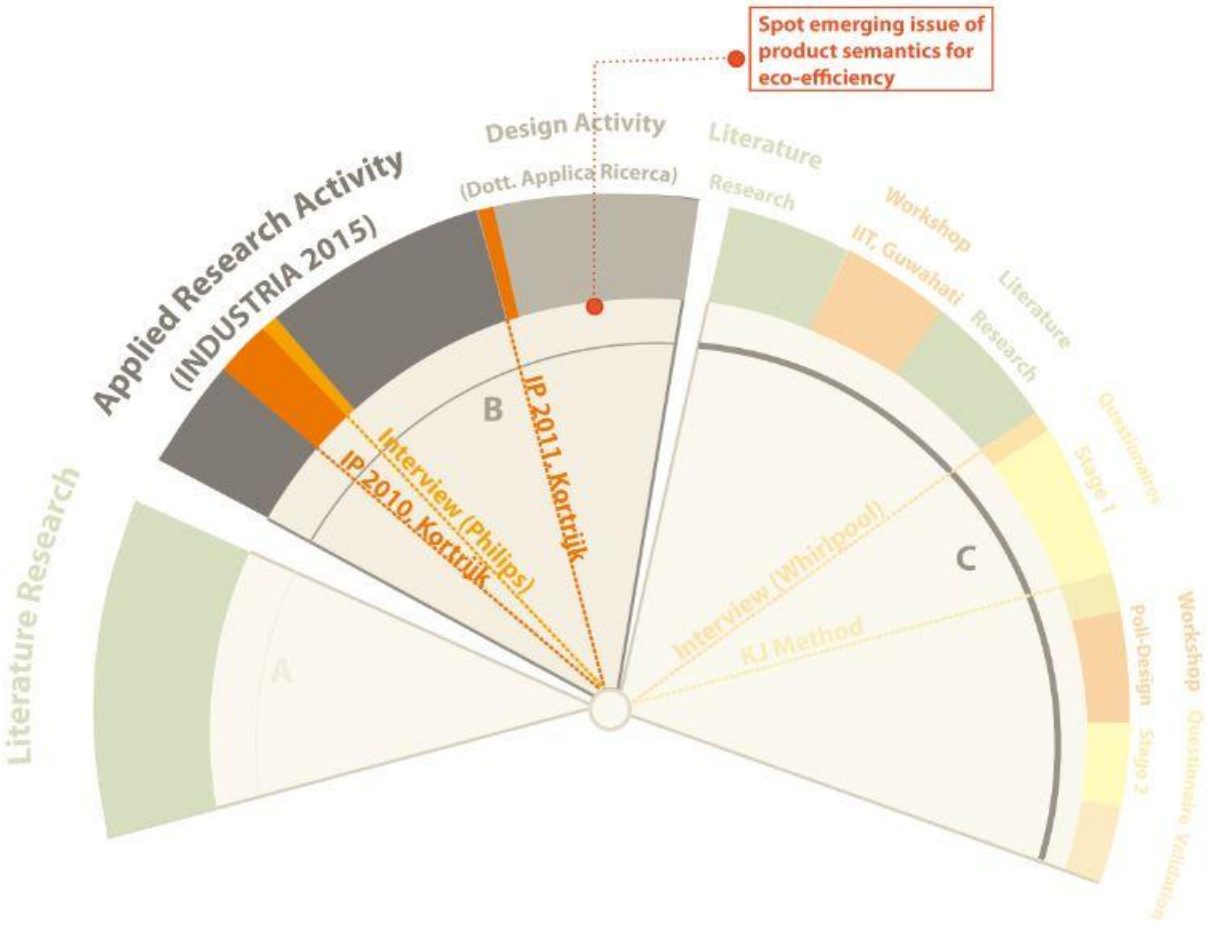
Krippendorff also suggests that identities can change, thus suggesting they are not stable aspects. When a company deems that another is stealing its identity (product or corporate), it normally results in a lawsuit as is apparent on the chronic court battles fought between major smartphone manufacturers accusing each other of stealing patently unique product identifying aspects (eg. *Apple vs Samsung published by Wired magazine– August, 2012*[7]). Under such circumstances companies normally reinvent their corporate identity or invent newer technology. On an individual level if a user spots others using objects serving his/her identity then such objects are changed or replaced to forge a new identity.

[6] www.autocar.co.uk/carnews - captured 13/8/2012

[7] www.wired.com/gadgetlab - captured 13/8/2012

Since Eco-efficient appliances are an upcoming category in the European market, at least developing a consistent and coherent product character for all Eco-efficient appliances can be a starting point for an appliance manufacturer to begin improving the currently weak and inconsistent identity of Eco-efficiency which users can associate with.

4. Applied Research + Design Activity with Whirlpool Europe



4. Applied Research activity & Design activity with Whirlpool Europe

4.1 Industria 2015- Introduction and background

The Industria 2015 was a research project which was conducted within a consortium of participants including major organizations such as Cefriel (Non-profit ICT innovation organisation), Politecnico Di Milano, and Whirlpool Europe. The ultimate aim of Industria 2015 was to facilitate development and manufacturing of 'smart grid' appliance in EU by 2015.This was a large multi-dimensional research undertaking, but the research group: IDEA to which the author belongs to, undertook a phase of this project which will be discussed here.

The major objectives of the research undertaken within Industria 2015 being discussed here are:

1. Evolution of the living spaces since the 1950's and its impact on appliance usage patterns and scenarios.
2. Social and technological evolution of home appliances since 1950.
3. Current state of the art of Eco-efficient features being developed within appliances
4. Exploring integration of different appliance categories for possible energy saving opportunities.

4.1.1 Evolution of living spaces and impacts on appliance usage

Home appliances are designed according to the usage scenario which the living spaces inside the house demand. Living spaces are subject to change according the social evolution, which is a constant never ending phenomenon. Domestic appliances are not just technological platforms which make daily rituals and functions more convenient but perhaps more like permanent features of the domestic landscape. The domestic landscape itself is constantly evolving according to the social and family dynamics.

Take a look at the kitchen for example, which is the most important living space because the majority of the appliances are placed there (figure 49). Basically 50 years from now the kitchen, dining room, and living room were 3 different spaces. With increasing importance or the role of women in the domestic scenario, and the central importance that the food preparation ritual started acquiring in family, the size of the kitchen started expanding and becoming more centralised from an earlier more peripheral role. From the earlier scenario, where those who consumed the meals didn't want to see where and how their meals are prepared, increasingly started accepting meal preparation as an important activity and a precursor to enjoying a good dinner with the family together. As the importance of cooking and rather consuming food increased, the dining areas and the cooking area completely merged together entirely, right up to the role of the social kitchen toward the end of the 20th century when the kitchen and dining spaces merged completely with the living space. Cooking had now become a social activity, a ritual which brought friends and loved ones together. Dining was now no more distinct from cooking and socialising or entertaining family and friends. Another important impact on this evolutionary flow was that cooking was

no more the role of just women but increasingly also men, although women would predominantly continue to be main target audience of appliance designs.

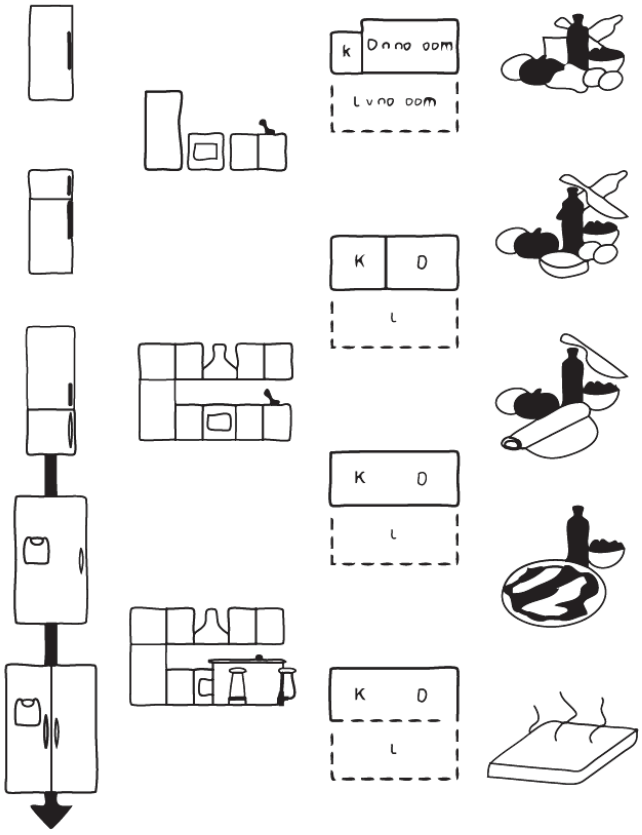


Figure49: The evolution of living spaces and its corresponding impact on appliance design and nature of food preparation.

Appliances did gradually increase in size and functions. Looking at the above figure 26, it becomes clear that appliances are no longer designed as isolated islands of function, but rather increasingly designed to complement and integrate their functioning with other appliances operating in the same area. For example, consider food preparation, no longer do we have cooktops and ovens as separate entities but rather cooking and ovens have been merged since quite some time as 1 product category. Even though these appliances might be manufactured separately they are always installed together for usage, and show a lot of consideration for each other during the design phase. Looking further washing machines are no longer designed in isolation but rather conceived as a pair along with the dryer as ‘duets’. Even though their mechanical functioning might be independent of each other still, but aesthetically and functionally they are being merged as far as possible, i.e. mostly washer dryer duets are sold as stackable units along with the laundry basket integrated, therefore an entire laundry management centre rather than islands of functions.

4.1.2 Social and technological evolution of home appliances

Along with prominence of the living spaces, the prominence of the major home appliances also increased. Not only did they become bigger and more prominent in their capabilities, they embraced technology and

from ‘difficult to use’ novelty equipment they became lifestyle complimenting necessities. Appliances were always seen as the springboard into realizing the lifestyle of the future. There has consequently always been a healthy fascination with conceptualising the appliance landscapes of the future. The ‘Monsato House of the Future’ on display in DisneyLand from 1957-67 forecast ultrasonic dishwashers for plastic dishes (Lorenz, 2009). Even computers tried to enter the cooking space in the form of the $10,000 HoneyWell kitchen computer in 1969, which could store all the recipes, in addition to cooking suggestions according to the ingredients available (Figure 50).

Figure 50: HoneyWell Kitchen Computer (source: www.old-computers.com)

Closer home to reality however, appliances started incorporating features such as ‘fuzzy logic’ which allowed appliances such as washing machines to incorporate more complex wash cycles. Fuzzy logic allows an electronic product to go beyond the yes and no binary language to make ‘what if’ decisions. One of the results of this innovation was to provide more complicated wash cycles in washing machines, if the user selects ‘cotton wash’ then the machine automatically sets the water temperature to 40° for example.

It is possible to say that with the advent of the internet era in the 90’s appliances were always seen as prime candidates to adopt this technology into their operation. The first step was to add computers to home appliances. Initially it was visible that as more technology was being incorporated into home appliances their complexity increased. Companies like LG released refrigerators with touchscreens built inside them. There was a rush to add computers to all appliance categories so that they could join the worldwide web.

“A decade ago, we tried to install a computer in every appliance. Not anymore. Now all the information you need is on the internet.” (Alessandro Finetto, Design Council Magazine,2009). The next trend in appliances design is to simplify the entire experience of using them with the minimum of user intervention required. Nowadays appliances are moving away from Usability and into User experience. According to Doug Beaudet, global director of User Experience and Interaction Design, Whirlpool “Usability is a term that appeared in the 1990s, at that time, appliances were too complex and hard to use.

We had to make them more usable for consumers. Today, it's about creating an engaging consumer experience that you see so much in consumer electronics. We want to create an experience with users that they can hold on to for years to come." (Source: Whirlpool internal publication). Alessandro Finetto, Head Global Consumer Design, confirms this by saying that the first step is to kill off complications such as user manuals, with manufacturers sending instructions to smartphones through apps or webpage based information (Design Council Magazine, 2009).

As an example the figure below discusses the evolution of washing machines since the last 50 years. The most obvious change has been in the evolution of user interface (Figure 51).

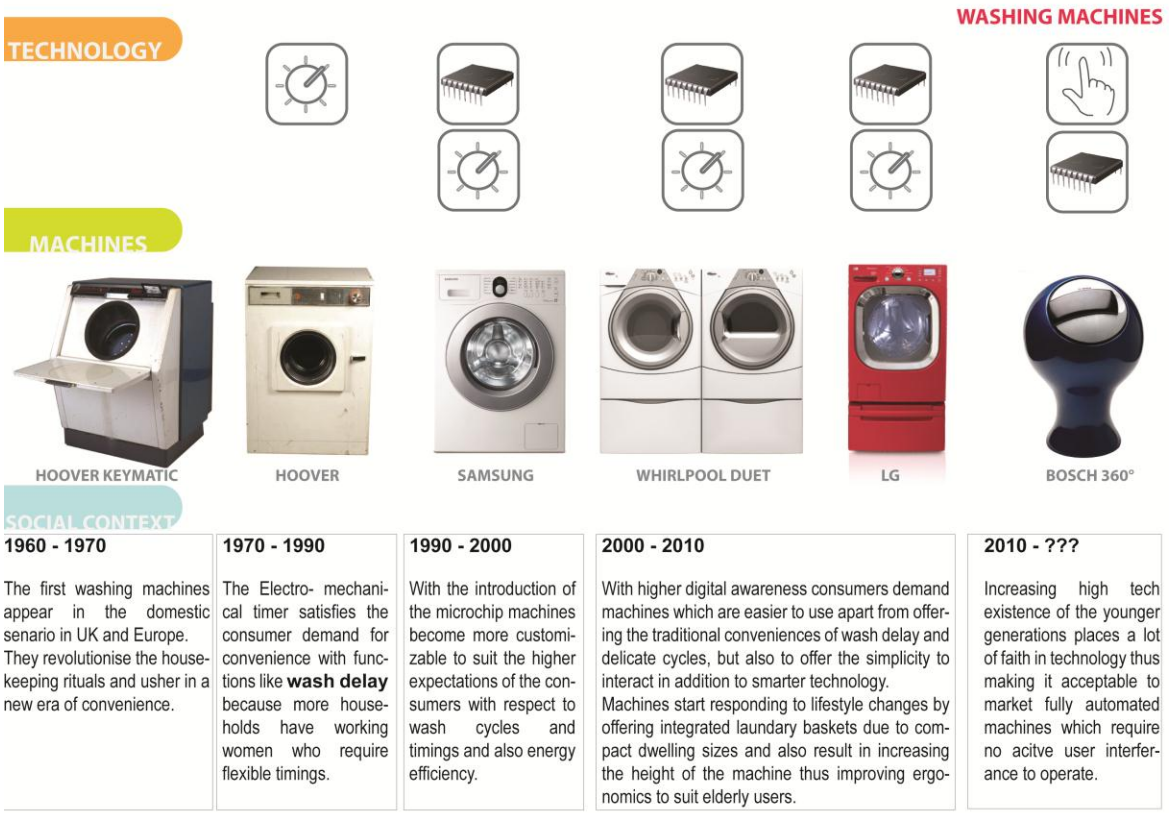


Figure 51: Evolution timeline of the washing machine

The Hoover Keymatic used programming cards, which were basically punch cards with preprogrammed commands built-in. Thus inserting a particular card allowed the washing machine to perform a specific wash program.

The next innovation came with the introduction of the mechanical knobs with wash programs calibrated according to their rotation. This allowed for significant additions to the number of wash cycles and convenience of not having to organize and keep all the punch cards. With the introduction of the microprocessors and thereafter printed circuit boards, washing machines were introduced to electronics. The merging of mechanical interface elements such as knobs with electronic wash selection programs

gave a new level of sophistication to the appliance. Now literally dozens of wash cycle were possible and even the possibility to customize and memorize these custom cycles. Eventually the concept of touchscreens was introduced to washing machines, and the traditional input method was completely changed. No longer does the user have to select 'cotton' or 'wollen', now it's more a dialog box which opens and allows the user to interact with the machine in the same way as one might with a smartphone. The appliance had become a gadget in keeping with the technology savvy consumers of the 21st century. Whirlpool recently released the 'Vantage' machine which comes loaded with the Google Android operating system and 5" touch screen (Figure 52).

Figure 52: Touchscreen of the Whirlpool Vantage

Now the washing machine is capable of giving much more information, even taking most of the decisions for the user in the absence of the user's input in case one doesn't have the knowledge or time to select the proper wash program, and not only, but with these almost mini computers within a washing machine the appliance is able to offer suggestions to the user with regard to proper program selection, energy consumption per cycle, and also if the program selected is most efficient choice to be made, thus subconsciously encouraging the user to make proper informed decisions using the principles of persuasive technology. This has resulted in dramatically increasing the efficiency of the washing machine, and reducing the energy consumption drastically.

In the near future major appliance companies are pushing the development of 'smart' appliances which will go beyond just a touch screen but have a full-fledged computing technology behind them with remote monitoring capabilities. Such remote monitoring capabilities will enable the appliance to accept instructions from the user through smartphones and also perform self-diagnosis of their own systems and send the information to a service representative through the phone line in the form of 'read' enabled tones. (Connected World, issue: August, 2011)

Companies such as whirlpool are developing 'demand-response' appliances where appliances are 'plugged' into the smart grid and energy management and saving will happen across tens of thousands of appliances at a time, providing automatic energy reduction to the consumer without any inconvenience (Paraplegia News, Issue: July, 2011).

Evolution of Eco-efficiency within appliances

Thus technology has played the prevalent role in the evolution most appliance categories and it is going firmly in the direction of pushing Eco-efficiency. For example looking at figure 28, it seems that washing machines haven't evolved all that much physically. Most of the changes in appliances, in fact all appliance categories and not just washing machines, have happened with the introduction of electronics and regarding the rest most of it has remained more or less unchanged. The basic physical architecture of a washing machine for example has remained constant since the 1970's Hoover machines. There is a motor, drivebelt attached to the drum, a horizontal cylindrical steel drum (front loading type) of varying capacities, and a dispenser for the detergent all enclosed within a sheet-metal cabinet. It is only the control panel which has changed the most driven by the interfacing technologies. True, that the performance and efficiency of the mechanical components has increased many fold, an A class washing machine today consumes much less electricity than its counterpart from the 70's. All the technical progress is not reflected in the design of the appliances. This trend becomes an emerging issue especially keeping in mind the increasing importance which Eco-efficiency has acquired and the importance with which it is being developed inside most appliance categories.

Product differentiation of this new segment of Eco-efficient appliances at the moment has not been achieved and is completely lacking. From a standpoint of product appearance, appliances today don't have a distinct product character. The only differentiation which Eco-efficient appliances offer depends on unique technological features often only communicated to the user through marketing literature or labelling. Such technical criteria are notoriously 'weak' when it comes to a user selecting an appliance to establish an identity which one would want to project to others (Krippendorff, Design Issues 1989). What matters are not the technical criteria but what the products 'mean' to the user. As a result home appliances are relegated to being a utility, with only the most informed user paying heed to branding or labelling to make a purchase (Lee and Lou, 1996).

Considering that marketing divisions of appliances companies spend large sums of money to create a positive image about the Eco-efficient capabilties of their product in the market, the fact that the physical appearance of the product doesn't make that same quality of communication to the user, creates a gap between the marketing efforts and the designing efforts of a manufacturer, thereby losing a significant competitive opportunity.

Case study of appliance segmentation

The next figure (figure 53) studies out how appliances are positioned in the market with respect to Eco-efficiency and design.

The vertical axis here signifies design and the horizontal axis signifies Eco-efficiency. On the lower left quadrant are appliances which are low on design input and low on environmental performance. These are the low cost mainstream appliance category. The top left quadrant stands for appliances which try to differentiate themselves according to design or rather mostly styling (therefore no meaning communication is made). These are the appliances which have a strong aesthetical appeal in the market.

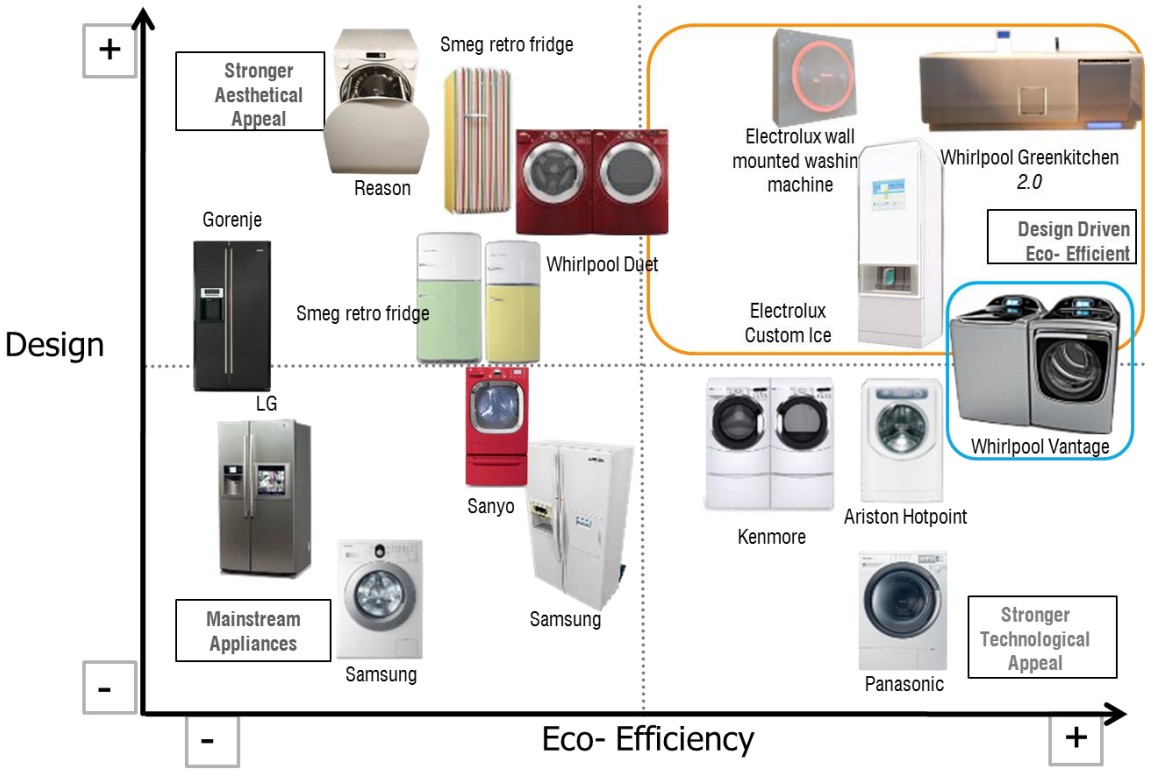


Figure 53: Market positioning of appliances

On the bottom right quadrant are appliances which are the newly emergent Eco-efficient appliances. As was previously discussed these are the appliances which have a strong technological content inside them but lack a unique visual appearance. On the top right is the highlighted quadrant which is an emerging category of appliances trying to explore a unique visual expression due to the technological innovations they possess. In this category have been highlighted concept appliances such as Electrolux Custom ice, and the Whirlpool Greenkitchen 2, 0, and the Electrolux wall mounted washing machine. These are appliances which are incorporating a typological innovation along with unique technical features which help achieve Eco-efficiency. Since such appliances force a radical departure in terms of formal features they therefore will run the danger of escaping the understanding of the users. Take the Electrolux wall mounted washing machine for example; typologically it breaks the archetype which washing machines hold in the users' mind, therefore disrupting meaning attribution and possibly opening the doors to semantic misinterpretation. From a standpoint of aesthetics, unfamiliarity reduces the attractiveness of an artifact thereby also increasing the cognitive load needed to interpret such a form.

Rampino (2010) defines typological innovation in relation 'to the deviation of the product from it formal archetype'. In this case the washing machine is hung on the wall, much like a painting, with the intention perhaps to save space, so the quality of its communication is very different from that of a normal washing machine thus effecting what such an object might *mean* to the user. And "meaning helps the user to make sense of that which is new" (Krippendorff, 2006). This might suggest that a potential user might have difficulty in even making sense of what such an object is much less what it affords him to do.

Clearly this is a problem which is not unique to just the above cited example of the Electrolux washing machine, but would apply to all the appliances in this category, especially the Whirlpool GreenKitchen 2,0 which combines several appliances into 1 platform, and therefore appears just as a monolithic island, much less an appliance. Of course the GreenKitchen depends on an interactive screen which somehow seeks to bridge this communication gap between the platform and the user.

It is not just companies but also individual designers who approach design innovation in Eco-efficiency as always a typological innovation, which speaks of certain limitations in terms of the position of Eco-efficiency in language (both ordinary users and experts) which makes it a challenge to be communicated. To illustrate this better consider the image below of the 'BioLogic' project developed during Whirlpool Europe's 'Project F' initiative in 2001. This project was developed according to Whirlpool's recent shift to human centred design methods (mainly implying involvement of user feedback in the design development process). BioLogic envisioned a future scenario of doing laundry in an Eco-efficient way reducing the impact on the environment using a slow wash approach. Instead of using a single washing drum, the laundry cycle is spread across a number of 'washing pods' based on natural processes of plant base regeneration (Future Needs report - www.dffn.org). The unit would be powered by fuel cell technology.

Figure 54: BioLogic- Whirlpool Project F
Source: Designing for Future Needs report (www.dffn.org)

4.1.3 Current state of the art of Eco-efficient features within appliances

That Eco-efficiency is a strong direction for appliances has been made evident by the previous discussion. This section seeks to investigate what are the features which Eco-efficient appliances are introducing in recent times.

For the sake of continuity, consider the example of the washing machine again. In the table (table 1) below 11 various Eco-efficient features are discussed in detail:

Low temperature cycle: The wash cycle performed at 30°, which is below the 40° default temperature setting, thus saving electricity.

Steam wash: Super-heated water is injected as steam into the wash drum during the last phase of the washing cycle, in order to remove wrinkles in the clothes, thus saving the cost of ironing and saving electricity.

Detergent management: The machine employs a load sensor, and has a detergent tank where the user pours the entire bottle of detergent in 1 go, it's a sort of like a reservoir. Upon detecting the optimum loading conditions, the machine automatically withdraws the optimum volume of detergent, thus reducing wastage, as almost all users are highly disposed to adding more than the requisite quantity of detergent.

Foam control: The amount of foam build-up is controlled through managing the volume of water.

Clothes cleaning feature: The machine releases a silver nano particles through a silver element fitted into the water inlet. The silver particles kill the bacteria present in the laundry thus saving on detergent use and also indirectly saving water. Another feature is to use micro-bubbles which shake the dirt off of the surface of the fabrics.

Inclined drum: The steel drum in a front loading washing machine is inclined backwards at an angle of 10° against the normal 4°. This reduces the volume of water required to wash the same weight of clothes apart from the obvious ergonomical advantages.

Leakage protection: A sensor attached to water inlet point detects any leakage and warns the users by shutting off water supply in case of leakage detection.

Filter cleaning feature: Appliance sounds a chime every 30 cycles to remind the user to extract the filter and clean it, thus maintaining optimum washing performance and saving energy.

Centrifuge speed management: The rotational speed of the drum is modulated according to the wash load thereby saving unnecessary energy wastage.

All these features improve the various (environmental) performance metrics of a washing machine. The inclusion of each of these features makes a washing machine having these features a higher performance appliance than one which doesn't have these features, from the point of view of environment. Is this performance advantage translated in the appearance of the appliances below? (figure 55).

Washing Machine	Brand	By Sensor	By Usage	Saves water	Saves energy	Saves chemicals
Low temperature cycle	gorenje Electrolux Panasonic	30 deg. wash cycles instead of 40 deg. 15 deg. eco wash cycle.	20 min. quick wash program at 30 deg.	■	■ ■ ■	
Steam wash	SAMSUNG Electrolux gorenje	Steam injected at desired temp to dry clothes and reduce ironing.			■ ■ ■ ■	
Detergent management	Hotpoint Ariston gorenje	Detergent is managed by external tank below drum.		■ ■		■ ■
Foam control	gorenje Panasonic	Amount of foam buildup s controlled through water volume.			■ ■	■
Clothes Cleaning feature	Kenmore SAMSUNG SAMSUNG	Silver particles to kill bacteria. micro bubbles shake dirt off.	Cold Clean Cycle using special drum movements			■ ■ ■
Inclined drum	Panasonic	Lesser water consumption.		■		
Leakage protection	Panasonic Electrolux	Sensor detects water leakage & shuts off supply.		■ ■		
Self Cleaning feature	SAMSUNG	Sensor sounds bell every 30 cycles to remind of filter cleaning			■	
Centrifuge speed management	Panasonic	Sensor alters motor's speed & output according to loading.		■	■	

Table 1: Eco-efficient features in washing machines
**(additional tables to be found in appendix 1)*

Figure 55: Panasonic (left) Ariston Hotpoint (right)

The machines above in fact communicate that they can *perform* the function of washing clothes very well. What they fail to communicate however, is that they can wash these clothes in an *efficient* way. Performance is defined as: "within a defined set of metrics, the time required to complete an assigned task" (Hennessy & Patterson, 2007). Efficiency on the other hand is "the amount of resources used to reach a goal or complete an assigned task" (Frei, 1998). So it is the difference between how fast a task is performed versus what is needed (resources) to perform a task. In fact the machines above express high performance, but they don't express efficiency or rather Eco-efficiency. It is not possible to tell if the machines above have just performance or also Eco-efficiency built inside them. This ambiguity further

strengthens the previous discussion on the difficult position which Eco-efficiency occupies in communication also.

Appliances, at this point appliances, are designed to communicate *performance*, not for communicating Eco-efficiency to the end user. Performance is largely an engineering approach to design because it is objectively measurable. In terms of appliances it would mean the time to boil 1 litre of water for a gas burner, the sound emitted in dB during a spin cycle for a washing machine, and criteria such as these which rarely take into account what kind of environmental resources are expended in order to fulfil them. Efficiency on the other hand measures the input-output ratio to perform a task, as Krippendorff puts it. He further says that the idea and also the criteria of efficiency vary according to the stakeholder. For an engineer efficiency could stand for the burner combustion efficiency on cooktop, for marketing it could mean the difference between procurement and production costs and market selling price, but what it means to designers is yet not clear. For although engineers have been clearly successful to build on a lot of efficient technologies, the designers have yet not been able to suitably express this change from performance to efficiency in terms of product appearance.

A part of the reason could be due to designers' heavy reliance on ergonomics instead of human centeredness while designing appliances. Since efficiency, in this case Eco-efficiency, is a not just a technical criteria of the appliance, this could mean designers of appliances need to change their approach to Eco-efficiency. Complex issues such as efficiency have multi-dimensional considerations. Efficiency in burner combustion means very different than a cooktop expressing efficiency in terms of its product features. A lot of design input of designers goes toward working out the ergonomics of the appliances thus making the usability confirm to an established metrics without much thought to product semantics. Ergonomics is rooted entirely in "optimising the technical rationality of (products') performance", where-as semantics is concerned more with the "symbolic qualities of manmade forms" (Krippendorff, 1989). Ergonomics is rooted in the technological centred approach to design while semantics is rooted in the human centred approach to design. Ergonomics was more intended for top-down organisations such as the military or the assembly line where the trained professionals are instructed on how to handle equipment. Ergonomics has limited applicability therefore in situations where users acquire the artefact on their own and choose the usage scenarios and context which they best enjoy.

Appliance designers generally believe that appliances have to be foremost ergonomical making them as effortless as possible to operate thereby directly reducing the psychological stress induced on the user (Paraplegia News, 2011) , where-as the human centred view of semantics states that users are willing to undergo even inconvenience and dis-comfort so long as it is the appliance they really desire to use or be seen using it. People tend to surround themselves with objects that make sense to them and they can identify with. Identity itself is a psychological construct which basically on an individual level can be defined as "the sameness which constitutes someone or something" (Krippendorff, 1989). Identities tend to remain constant, and as has been pointed out before, when selecting an identity people tend to discard technical criteria in favour of social criteria especially when it comes to ownership, use, and consumption of artefacts. *Artifacts which are described through characters also subscribe to the identity of the user*. How users identify with Eco-efficiency would be the first step designers need to undertake in order to be better able to communicate this meaning. The methods and tools adopted in this research points the way

as to a human centred approach to express Eco-efficiency through attributed product characters into appliance designs.

Perhaps some change in the design organisation of appliance companies would also be inevitable in the near future. At present the main division within design organisation in appliance companies is: Usability, Interaction Design, and Industrial Design. Companies such as Whirlpool do have 'usability labs' which spend a large part of their resources in fine tuning and benchmarking appliance ergonomics amongst other things. Usability is largely a relic of the 90's (Anderson, 2011) as within the changing and emerging information society, usability means little since it excludes the users' input in the design process. As Doug Beaudet, Whirlpool head of user experience and interaction design was quoted previously, "usability is giving way to user experience in appliance design". He talks of creating experiences which users can 'hold' on to, much like intending to understand what an appliance means to the user. He speaks of creating 'conversations' between appliances and users. Since Semantics deals with how products communicate to users through 'visual metaphors' in the end appliance companies might need to invest in developing product semantic expertise in their designers apart from just usability and ergonomics experts if they want to successfully address Eco-efficiency.

4.1.4. Integrating different appliance categories for energy saving

Integrating appliances is an interesting direction which appliance design is exploring. There are obvious advantages to this approach, which were investigated in the Industria 2015 research. From a point of view of energy consumption appliances function as islands of consumption.

All the major appliances have different modalities and patterns of operation. Figure 56 shows the major appliance categories considered in this study. The highest energy consumption is of the refrigerator followed by that of washing machine, dryer, oven+hob, and hood. In addition appliance platforms use different amounts of energy during their operation plus their consumption of energy varies, a refrigerator for example uses a short bursts of energy each time the compressor starts, which is only a few hours in a day, even though the appliance itself is switched on 24 hours a day. A washing machine in contrast runs constantly for the period of its operation, same as a clothes dryer. The oven needs a high amount of electricity but only runs for short concentrated periods of time, perhaps only a few times a month.

There are periods of overlap when more than one or possibly even more than 3 appliances are operated at the same time. Such a usage pattern is in fact quite common and normally happens in fixed times during the day such as the evenings when users return home for the day for example, although of course the usage pattern would depend on the lifestyle of the user and the household type. Never the less such usage pattern causes 'spikes' in the energy being drawn from the energy grid, placing a significant amount of strain on it. For energy companies the grid capacity can be managed better not if energy consumption at homes is reduced but rather optimised. This optimisation has to happen with the agenda of reducing these spikes, and distributing the energy consumption of the appliances as a constant amount spread out throughout the day. In short the 'delta' between the maximum consumption and minimum consumption

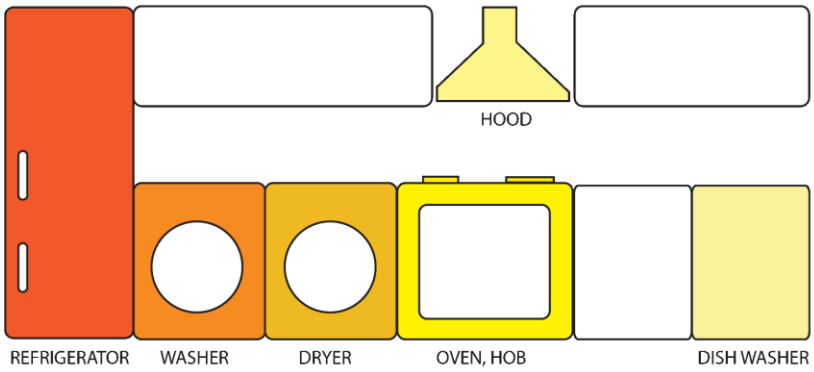
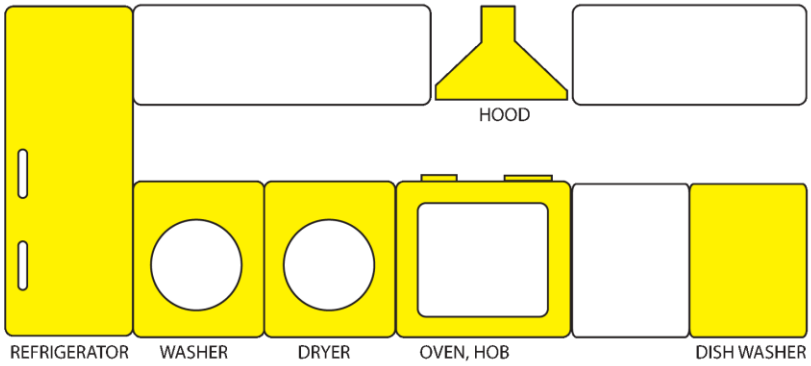
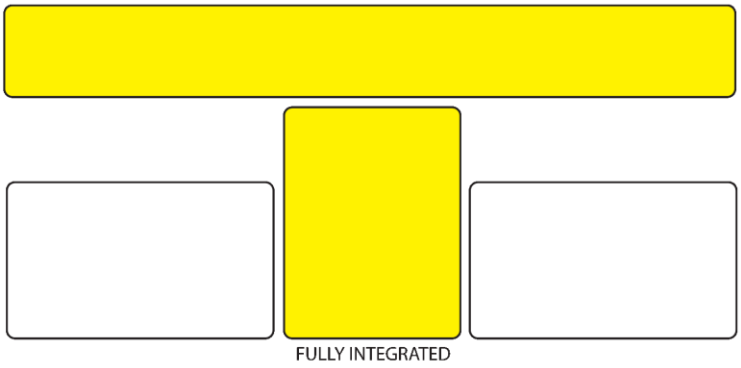


Figure 56:

A fragmented appliance arrangement with deeper colour showing higher energy consumption.



An evenly distributed and networked appliance arrangement with energy sharing but no platform sharing.



A completely integrated appliance platform with a closed energy loop having complete energy and platform sharing.

has to reduce and even out to a more flat curve.

Energy sharing between appliances can help to achieve this agenda. Seeing as appliances of the near future almost certainly be ‘smart’ appliances and networked in a national smart grid thus any usage behaviour of a standalone user will effect performance of the entire grid. Heavy usage from 1 user will have to be balanced out with a meagre user in some other location on the grid. But energy companies propose to solve these behavioural anomalies by sending input signals to the appliances to tell them the optimum time of the day to perform their most demanding tasks. If for the example there is a ‘peak hour’

during the evening, then all washing machines connected to the smart grid will be sent a signal telling them to offset their wash cycles to the late night when the demand on the grid considerably flattens out.

But on a domestic scale appliances will use the principle of conservation of energy by achieving a thermal and mechanical connection between each other. So what does this imply? A closed energy loop will be achieved between all the appliances- thus heat and water capturing and re-utilisation is possible. The refrigerator for example cools its internal compartments but generates a lot of heat through its compressor, which will be captured and used to heat water being utilised by the dishwasher. Similarly the residual heat from the gas cooktop can be captured and circulated within the oven cavity to pre-heat its cavity which can save a lot of energy when using the oven. These are just some of the possibilities between appliance integration. The ideal scenario in the end would be to have all appliances have exactly the same energy footprint, because they no longer operate as individual islands but rather an integrated system. An example of this is the Whirlpool Greenkitchen 2,0 which will be discussed in the following section.

To deepen the analysis further each of the 6 appliances were analysed according to:

1. Practical functions
2. Side effects
3. Energy sources
4. Management (maintenance)
5. Location
6. Interface
7. Improper use
8. Functioning
9. Meaning

The analysis details of each of the appliances can be found in appendix 2.

The next step was to then propose couples of appliances, thus a coupling was achieved using all the permutations and combinations within the 7 appliances. Figure 57 below shows an example of the coupling between the cooktop + oven.

Each of the appliance couples were analysed again for 5 criteria each on a 5 point scale:

1. Technology point of view
2. Use point of view
3. Interaction point of view

4. Meaning point of view
5. Domotics point of view

Finally an overall subjective grade was awarded to each of these couples on a 5 point scale. There were 12 appliance couple combinations were formed and of these *oven+ cooktop*, *washing machine+ dishwasher*, and *refrigerator+ oven* were found to be most promising based on the subjective 5 point rating they achieved (figure 57).

The details of these appliance couples can be found in appendix 2.

Looking at the final 3 couple combinations gave a realistic insight as what are the opportunities and obstacles in achieving the final integrated appliance structure where all the 7 appliances would be combined together.

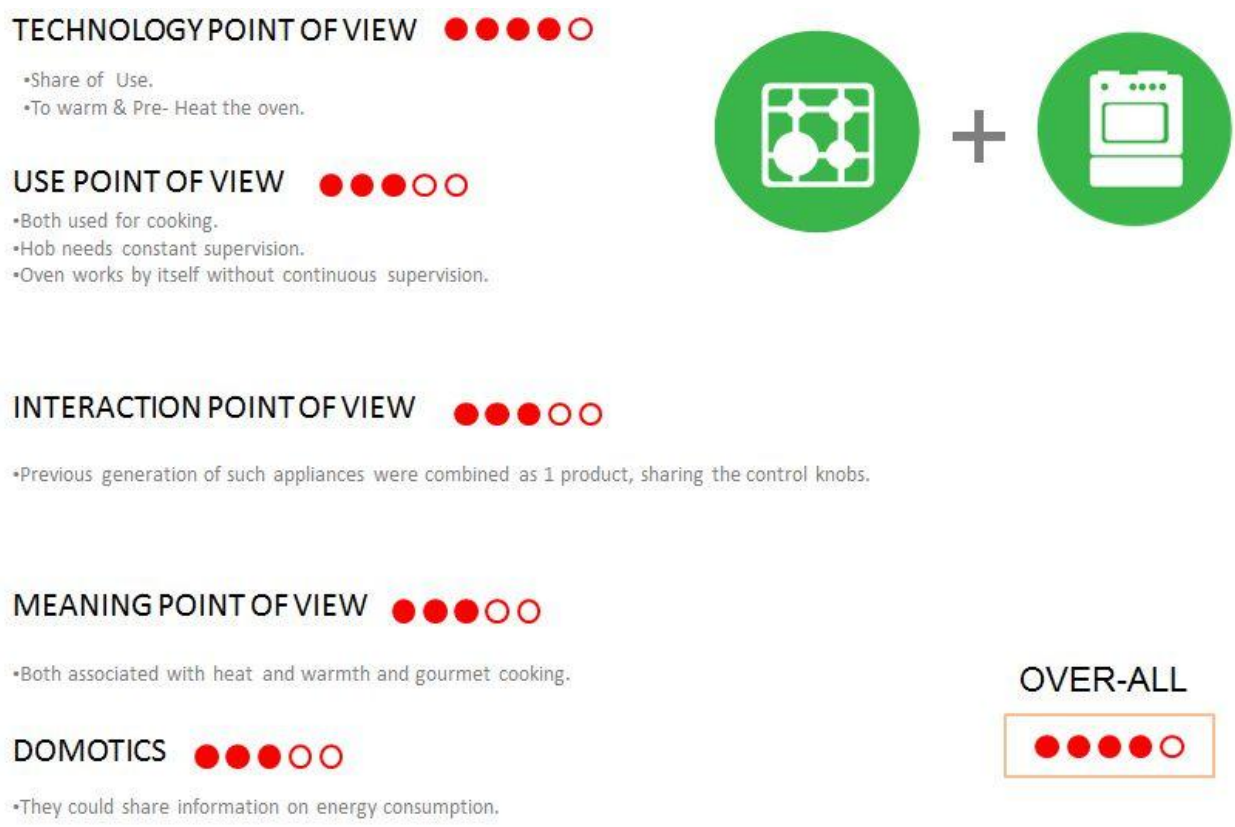


Figure 57: Appliance couple between cooktop and oven

4.2 GreenKitchen 2.0

The GreenKitchen (figure 58) was developed by Whirlpool Europe as a showcase of the possibilities of future Eco-efficient appliance technology and design. This was a showcase project developed to show the capabilities of the company to the public through exhibition platforms such as the Milan Design Week (*Salone Del Mobile 2010*). Whirlpool managed to gain extensive media coverage for this project in a bid to enhance its position as an innovation driven company. This project was an applied research activity within the author's PhD.

This platform was a development of the discussion started in the previous section, of exploring possibilities to combine separate appliance platforms into an integrated architecture for energy efficient performance advantages all which would operate within a smart grid.

The GreenKitchen combined 4 different platforms and 3 delivery systems (*energy delivery*: solar panels, *water delivery*: water collection system, *user input*: kitchen assistant) into 1 integrated platform architecture capable of operating in a closed energy loop, namely:

1. **Dishwasher** – dishwashing appliance which uses captured water from the water purifier to wash dishes in all except the last cycle, for which uses fresh water intake.

2. **Induction oven** – doesn't use gas powered heating but uses highly efficient induction heating making it 20% more efficient than a normal oven.

3. **H20 cooker**- An induction cooker, which is new typology of an appliance able to function as bowl which can be used as a kettle for preparing beverages, frying, and steaming. It works on the newly developed heating technology of induction which directly transmits heat into the cooking vessel, thus multiplying efficiency manifold.

4. **4 PUR**- which is an embedded water filtration appliance including a nozzle delivery component able to deliver hot, cold, and sparkling water to highest purification standards

5. **Solar panel**- This solar panel was developed in collaboration with InnerGround, which has the capacity to capture maximum energy regardless of the angle of inclination, thus eliminating the need to mount it on the rooftop or on the external surface of the house. The purpose of the solar panel is to heat water in water capturing tank to 60°, which is the ideal temperature the dishwasher needs in order to function optimally.

6. **Water collection system** - which is a water tank capable of capturing and recycling waste water from the kitchen sink for the dishwasher and also other cleaning and washing household activities. It is connected to the compressor (which cools the refrigerator) in order to heat the water for the dishwashing cycle. It reduces water wastage by 70% saving up to 2000lts a year for a family.

7. **7" Kitchen assistant**: This device served the purpose of communicating with the user about all the functions of the GreenKitchen and also encourages one to adopt an Eco-efficient pattern of using the platform. Based on the principles of Persuasive Technology, this eco-visualisation device is the focus of the next section. introduction of a mobile interface platform inside a kitchen environment places a strong

element of change with respect to the scenarios within which domestic appliances could operate and interact with the user. As Designer Mike Kuniavsky said "the addition of interaction design allows designers to envision a *new generation* of tools and environments"[Whirlpool *in.home*, internal report].

All this technological innovation was concealed in a single monolithic architecture, thus negating the need to build a kitchen within a home in the traditional sense. This 3.5 mt x 1.2 mt (approx) platform is the entire kitchen in itself.

Since the GreenKitchen by itself is an innovation not just technologically but also typologically, it is difficult for the user to make sense of this platform. Sense making is directly connected to what the object in question is, what it does, how does it function, how are its parts connected etc (Krippendorff, 1989). Since it is a new typology of appliance, a user would find it very difficult to attach a meaning to it, especially since it will be very difficult for a user to imagine it in context. Although sense making is a cognitive construct, it also implies that if the user is not able to make a lot of sense of the product when he sees it he may also not very well be able to understand its intended use. Literature on aesthetics has also warned that unfamiliarity with a product's form and intrinsic features also reduces its attractiveness to the user. In light of all these revelations, it becomes important that the touchscreen device (i.e. the kitchen assistant) adopt the role of helping the user understand how to use this product and what are its capabilities.

Whirlpool is not the first in exploring the potential of 'smart appliances' which monitor their running condition and pattern (Merloni-Ariston Digital). Neither was it the first to explore a digital platform to give feedback to the user and manage information within the kitchen environment, as there are several preceding examples such as the 'Electrolux Data Wall'. But GreenKitchen was the first which attempted to merge the two together, and in the process explored how to communicate the Eco-efficiency of an appliance by merging product and interaction design.

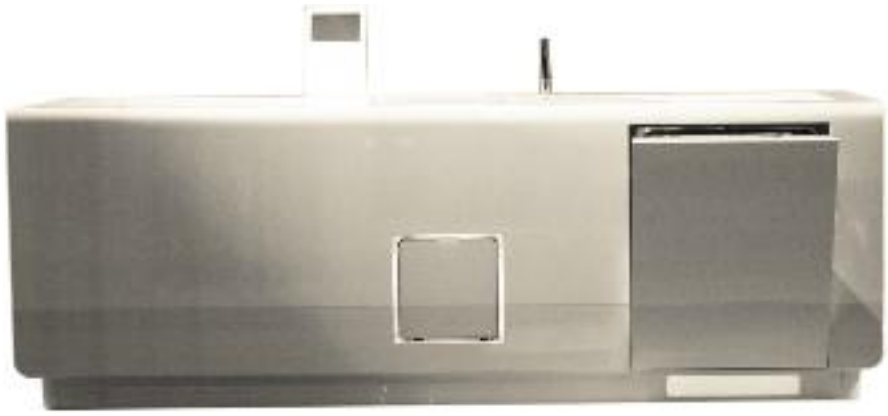


Figure 58: GreenKitchen 2, 0

4.2.1 Applying Product Semantic theory to interface design

Physically this platform was a typological innovation, it had a very unfamiliar appearance, and consequently very difficult to draw a meaning by the user based on what is sensed. Under this scenario, it

was the touchscreen interface which had the role of communicating the meaning and affordance of this system to user, to make one understand what this platform is capable of and what one can do with this platform. The primary control mechanism of the 7" touchscreen was a new mode of use for an appliance.

Since the primary motive of this platform was to save energy and resources, the perception and visualisation of energy was very central to the interface design of the touchscreen. The interface here had several challenges, most important of which was to provide feedback to user about the energy consumption and the state of the system at all times. Froehlich (2009) points out that the manner in which consumers perceive and understand energy (i.e. how they sense and understand it) has major implications on designing feedback systems. He also points out that unlike mileage of vehicles, measurement units of energy consumption at home (i.e. kWh) and also water consumption (i.e. CCM) are not well understood. With this background information in mind the development of this interface was initiated.

In essence this interface was a 'smart feedback system' apart from a command and control centre for all included appliances. Based on the principles of persuasive design, this interface not just aimed at effective sensing of energy, but also to educate the user at opportune moments about their energy consumption tendencies (Froehlich, 2009). Geller et al (1982) have argued that feedback systems are the most effective strategies in reducing energy consumption.

The 'Ten Design Dimensions of Feedback Design' (Froehlich, 2009) such as frequency, data granularity, push/pull, location, visual design, etc. had an influence in the final outcome of this interface.

The first task was to visually attribute the meaning of 'energy' based on 2D graphical elements. Extensive sketching and studies were performed on screen layout possibilities in conjunction with design experts from the Whirlpool Design centre. The visual metaphor of 'growth' or 'upward projections' was decided as a relatively stable attribution of energy, after extensive brainstorming between all the design experts participating in this project. This underlying approach is evident in all elements of this interface, but visualised using different techniques i.e. size variation, branch like geometries, and visual clustering of icons and interactive elements.

Take for example the first screen to greet the user, which is the screensaver (figure 59). In this screen is just the basic information which the user needs in order to understand the state of the system; the amount of energy consumption for the day in kWh, the average energy consumption for the whole month in kWh, and the date. The monthly average energy consumption and the daily average consumption are enclosed within 2 bubbles. The size of the 2 bubbles relative to each other tells the user if he is above or below his average energy consumption. Just this screen would give all the critical parameters to user regarding the state of the system without indulging him in too many details. The curves flowing toward the top of the screen (therefore symbolising energy rising up) originating from the bubbles signify the number of appliances which are in the active and switched on state within the GreenKitchen. Thus the user gets real-time feedback based on the state of the system and the energy being consumed even without making any operations.

Another important aspect of this interface was easy and gradual visualisation of information. The density and complexity of the information should only increase with successive operations and with the deliberate intention of the user. The idea of 'semantic layers' was utilised right from the start. Discussed by

Krippendorff (2006), introducing semantic layers in interfaces introduces the idea of layering information and affordances in interfaces with increasing amount of information and complexity in every consecutive layer. The screen saver is thus on the top most layer. Going beyond this layer, lands the user in a second screen, slightly denser in information which enables more complex operations such as selecting an appliance. Once an appliance is selected, then a more detailed readout opens which give proper operation settings of each appliance, and so on and so forth till an appliance is ready to execute it function.

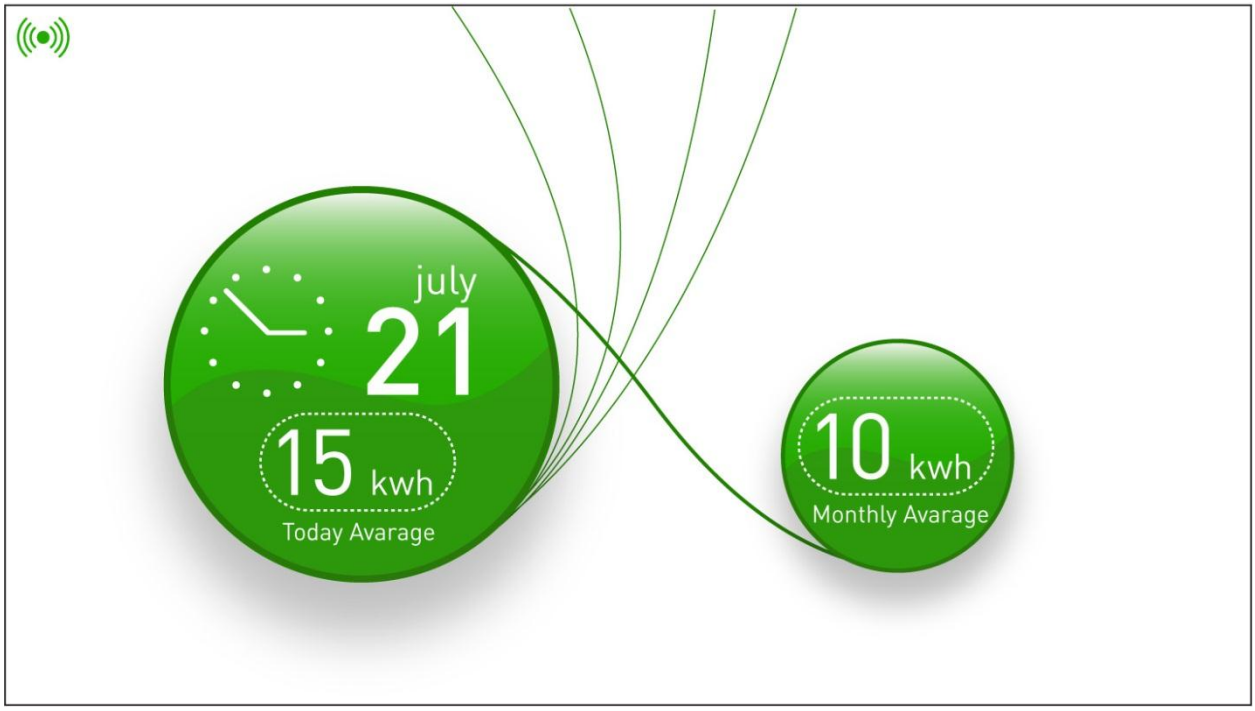


Figure 59: Greenkitchen screensaver showing the daily and monthly average energy consumption.

Touching the any of the bubbles on this screen would take the user to the homescreen. In this screen is where the user is able to see all the eco-system of the greenkitchen and all the appliances related to it. The screen is divided in 3 parts from the top to bottom: appliances which are switched off are at the bottom and in gray, appliances in standby are in center, and appliances which are active are on the top of the screen. Towards the bottom of the screen is the menu bar which gives the user additional information. This screen represents the second semantic layer of the interface. Although in this screen are visualised more number of appliances than were present in the actual prototype of the GreenKitchen, in the future the idea is to be able to incorporate all the appliance types with an integrated platform such as this one.

Apart from the icons of appliances there are also helpful tips visualised with the help of ‘light bulbs’. In keeping with the requirement of the smart grid integration, these tips give the user helpful suggestions on what time of the day to run the wash cycle of the washing machine for example, in order to save money. It is worth noting that with the smart grids was also introduced the concept of dynamic energy tarriffs during the day, which means during peak hours energy is more expensive than in off-peak hours. The

system here always suggests the user to run operation cycles in the washing machine and dishwasher in off-peak hour by dislpaying the amount of money one would saving in Euros as source of motivation (figure 60).

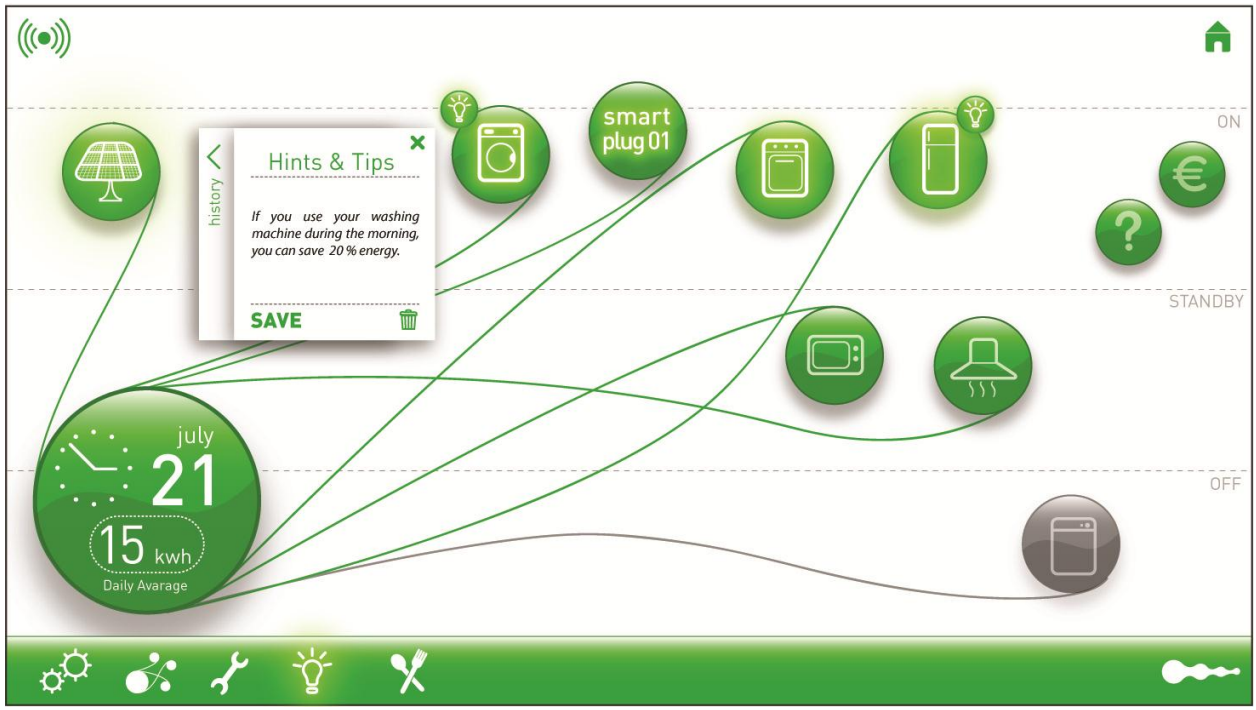


Figure 60: Homescreen- note the energy saving tips and hints highlighted by the system in the form of a light bulb.

The third semantic layer is represented when a user touches the icon of any appliance (figure 61). This layer serves to virtualize the entire physical control surface of the appliance. Here it is important to point out that from the semantic point of view this screen serves the purpose of product affordance (in this case a washing machine), since the physical product itself lacks affordance due to its supposed typological innovation which effects sense making on the part of the user. This becomes an interesting scenario where the user is made fimilar with that which is new based on iconography and digital information which serve to impose a sense of the'old' and 'fimiliar' into this entire interaction.

From a point of view of eco-visualisation, this screen presents the user with significant choices to be made effecting the Eco-efficiency of the system (i.e. Recommending Action principle, Ten Design Dimensions of Feedback Design'-Froehlich, 2009):

- In terms of start time and end time so the user can understand that should the end time overlap with the peak hour tarriffs of the day one will be first paying lots of money for it and second contribute to straining the energy grid (thus indirectly imposing a sense of guilt in him or her).

It gives the user the water and electricity consumption figures, should the user choose to run the wash cycle right away and also the cost of running this operation cycle at the current tarriff rate. The system

also offers one the ‘Go Green’ option which is the system’s automatic optimum timing suggestion based on the smart grid power tarriff rates for the day. Should the user choose to ‘go green’ the system will take over and stagger the wash cycles till the off peak hours and also show him or her the amount of savings made in euros (sort of as a reward and encouragement to make the go green choice again in the future).

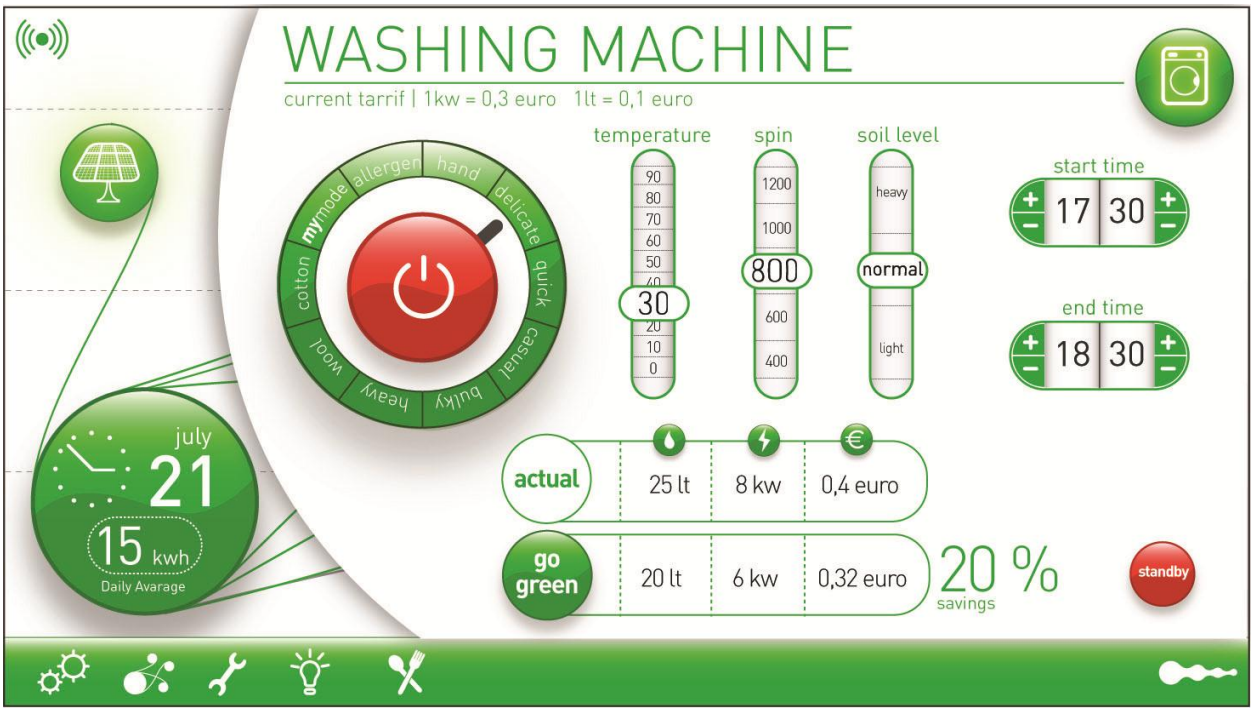


Figure 61: washing machine control screen

The user can enter the menubar at the bottom-right of the screen and go into energy consumption screen and check his weekly, monthly, or yearly energy consumption patterns (figure 62). Froehlich (2009) proposed the ‘comparison’ principle which proposed that providing comparative past and current performance information is essential in feedback systems. This screen displays a detailed readout of the consumption figures in terms of electricity, water, and Euros. The important aspect here is not just to be able to see absolute consumption figure but to also see the relative consumption patterns from daily, monthly to yearly basis thus giving the user a clear idea if one is improving or deteriorating the personal energy efficiency record. This serves as a psychological reward and a positive emotional trigger for the user which is an important contributor to the user perception that the Greenkitchen functions efficiently and better than ordinary appliances.

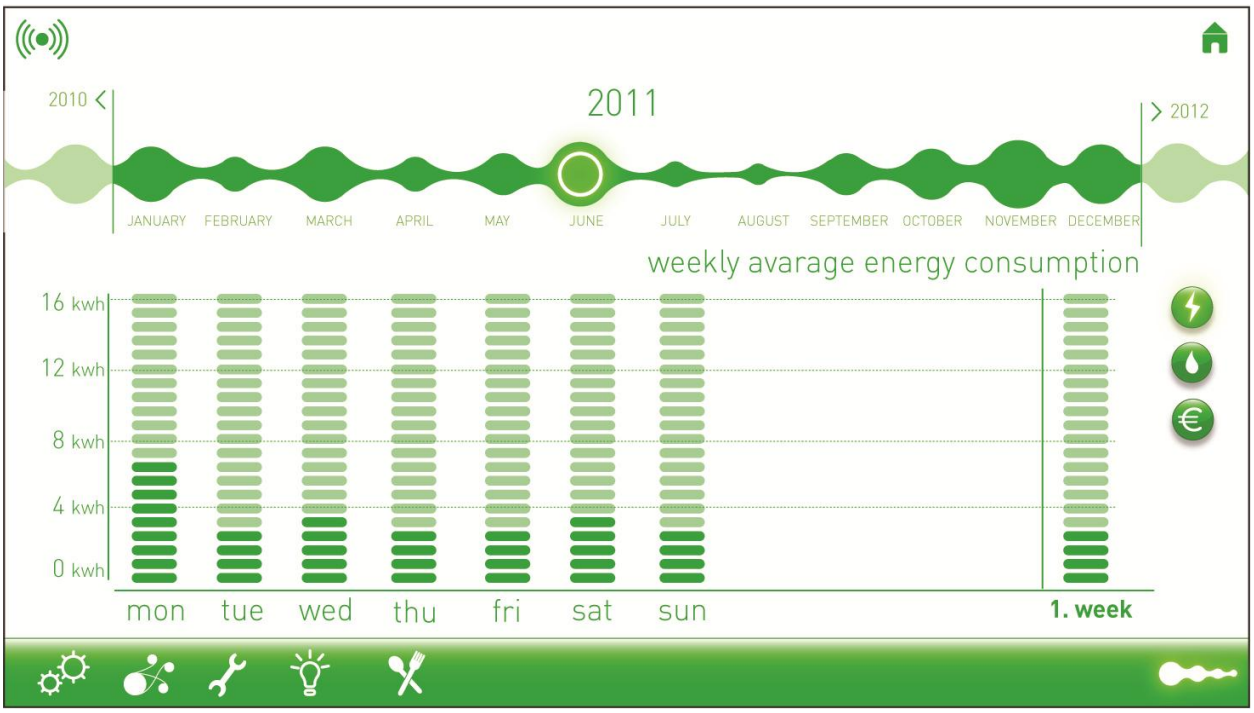


Figure 62: Energy consumption screen

Thus the interactive flow of this interface from the first screen to the next was designed to offer the easiest navigation experience to the user. The entire concept was developed in storyboards before being developed as a digital screen. One of the areas where special attention was paid was to the iconography. The meaning lost due to the unfimiliar geometry and composition of the appliance platform was somehow attempted to be reacquired using the interface. The icons tried to visualise each appliance in its archetypical 2d form, such that they are instantly recognisable. The level of detail and realism in icons had to be carefully controled (Mathis, 2010). According to Mathis (2010) in his article 'Realism in UI Design' there is a bell curve kind of relationship between level of detail and cognition (affordance) in a user. Too less detail and the user doesn't understand, add too much and the user again loses the symbolic meaning of the icon but starts looking at it as a generic image. Consider figure 63 below, there is only one correct level of detail which tells the user that an icon means 'home'.

Figure 63: Icon on the left is a house, icon on the right is 'Home'

(Source: UX magazine, January, 2011)

With this insight in mind, especially since in the GreenKitchen the users depended on the interface and its iconography to acquire both the meaning and percieved affordance, the level of detail had to be very clearly understood and executed (Figure 64).

Figure 64: Washing machine icon of GreenKitchen

Whether this was a successful approach or not, will only be evident when this system goes into user testing phase in the near future. Nevertheless this interface was an attempt to apply the product semantic theory and its concepts to Eco-visualisation, and in that capacity it served as an insightful learning experience.

4.3 Eco-efficient Whirlpool 'Ixelium' Flat cooktop development

The Flat Cooktop project was conceived as a highly Eco-efficient platform, with combustion efficiency 20% higher than all the cooktops currently in production by Whirlpool Europe.

The initial burner technology was developed by the Gas Technology Advantage team in Brazil. The burner design in itself was an innovation point as it utilized a horizontal venturi (Figure 66). Once the technology was deemed mature it was passed onto the Global Product Development teams in Cassinetta, Italy. The customer need targets were identified as *Performance*, *Cleanibility*, and *Aesthetics* in that order of priority.

Then the marketing department passed on this brief to the Global Design Center as a guideline to develop the aesthetics of this cooktop. Although it is to be noted that the marketing department had an opposite list of priority as: Aesthetics, Performance, and lastly cleanibility.

The mechanical structure team dealt with the overall development of the flat cooktop and also implementing the physical attributes of the complete product assembly such as manufacturability analysis of the various components, application of the specified finishes, and implementing all the design details such as sheet metal thicknesses, interface details between different sub-systems, structural ribs, screw embosses, and total part number counts in order to achieve the appliance assembly.

The Gas technology team, within which the author had been working, was concerned with the gas burner itself and dealt with all the gas system aspects related to it. This involved developing the burner technology itself for the flat cooktop platform, evaluating the burner performance, specifying and

designing of all the components which go within the burner box concerning the flame propagation. In addition, controlling the flame stability, flame combustion and efficiency figures plus specifying component variation (i.e. valve specifications and injector pressure) for different types of supply gases used within the different European markets.

Here below is a list of the different departments involved in the development of this project in the order of contribution:

- Technology
    - *Mechanical structure*
    - *Gas technology*
- Engineering
- Marketing
- GCD – *Global Consumer Design*
- Manufacturing
- Safety
- Procurement

Cooktop definition

The cooktop is normally defined as a horizontal surface for food preparation, which is mounted on a support structure as such called a burner box. The gas burners which discharge the flame for food preparation are mounted within the burner box, and normally extend beyond the cooking surface designated as the metal top.

The point of innovation for the flat cooktop is that the burners are mounted flush with the metal top. This required an innovative redevelopment of the burner architecture technology itself. The burner was now mounted with most of its major components concealed below the metal top and only the burner cap and spreader extending beyond the top surface in addition to having a hidden igniter and spark plug.

The major point of innovation of this project was the burner design, which is what made this platform a benchmark for Eco-efficiency and ultimately a showpiece of innovation development for the entire company.

The cooktop has 5 burners in total (figure 65): Auxiliary, Semi-rapid (2), Rapid, and Ultra rapid. These burner categories are in increasing order of power output in terms of *kw*, with the Auxiliary at 1 kw & Ultra rapid coming in at 4.4 kw. As the burner is mounted almost completely below the horizontal metal top, most of the parts are concealed.

Figure 65: Top View 'Ixelium' Flat Cooktop

Burners of this classification are identified by the presence of a horizontal *venturi*, which is the interface between the burner base and the gas pipe, facilitating the gas flow within the burner itself for combustion (Figure 66).

The surface treatment specified for the entire appliance is specified with a special type of stainless steel Nano technologically enhanced with a special scratch resistant treatment. The burner base and the spreader are going to be crafted of cast aluminum.

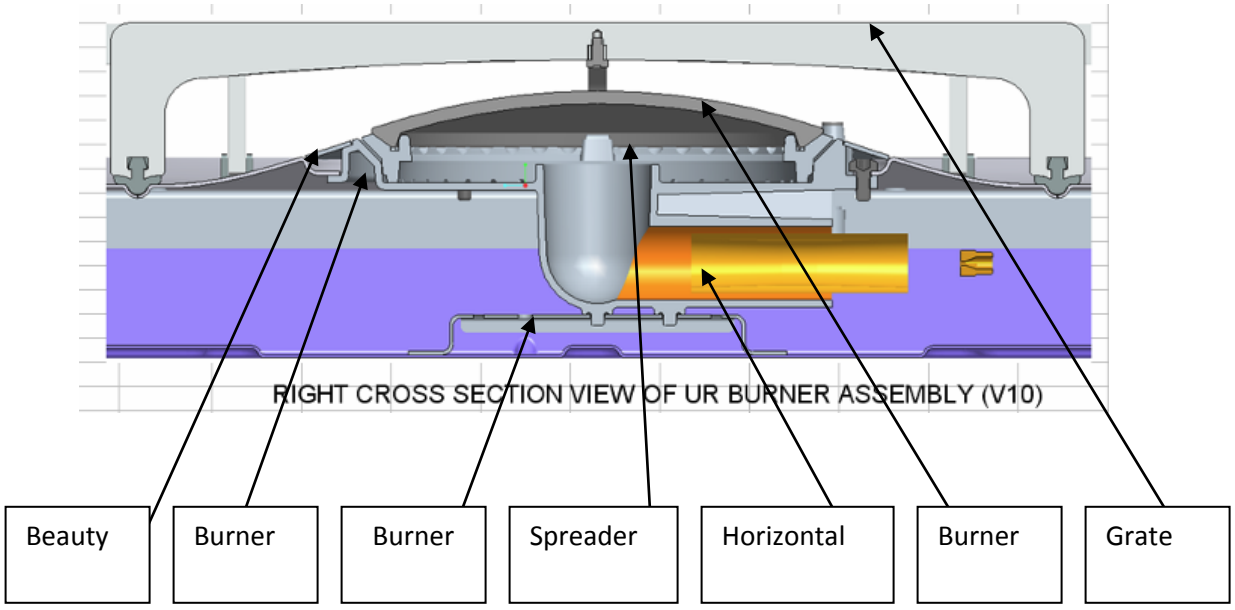


Figure 66 Burner Cross-Section

Burner Performance

The burners are rated for primarily 4 characteristics: Flame stability, Rate of combustion, efficiency, and ability to maintain the flame during air pressure fluctuations within the burner box.

Combustion and Efficiency Testing

Combustion rate and efficiency of a burner are directly related. Both of them depend upon the Grate height, on which the cooking vessels are placed. Increasing the grate height decreases the combustion level but also decreases the efficiency of the burner. Though the objective is to maximize efficiency and minimize combustion.

The combustion emissions are measured in a fractional figure between CO and CO2 emitted by the burner. Level of combustion increases the CO rate and conversely decreases the CO2 emission. The CO/CO2 fractional level should be below 0.1 % for the burner to clear this test. An ideal emission rate of 0.05% is targeted based on the *internal company specs* for flat cooktop figures, which have been kept as a performance benchmark in this project.

The EU code only stipulates the standards for efficiency & combustion levels instead of the percentage of the heat retained for cooking. Unlike other appliance categories such as a washing machine, there is no efficiency classification which exists as of this date for cooktops.

A very crucial parameter is the inclination of the flames (adjusted to 35°), heat transmission in combination with the grate height factor.

As mentioned earlier, the Grate height plays a very crucial role in benchmarking efficiency & combustion. As the grate height increases the efficiency figures go down and the combustion values increase. So a theoretical limit exists in this arrangement, the goal here is to achieve an ideal grate height such that the best compromise can be reached for burner performance figures.

Figure 67: Combustion testing

The second parameter is the horizontal distance of the venture which has to be adjusted in the gas burner intake. (Figure 68)

Thirdly the injector diameter is also a parameter which varies and influences the burner properties.

Fourthly the supply pressure of the cooking gas is a parameter. The min. and max. supply pressures are *14mbar* to *51 mbar (millibars)*.

All these settings have to be optimized according to the different supply gases used in countries around Europe. The gases being used in Italy are codified as G20, G21, G31 which differ according to their composition (eg: G20 = CH4 – 100% methane). All burners are tested in maximum and minimum power settings.

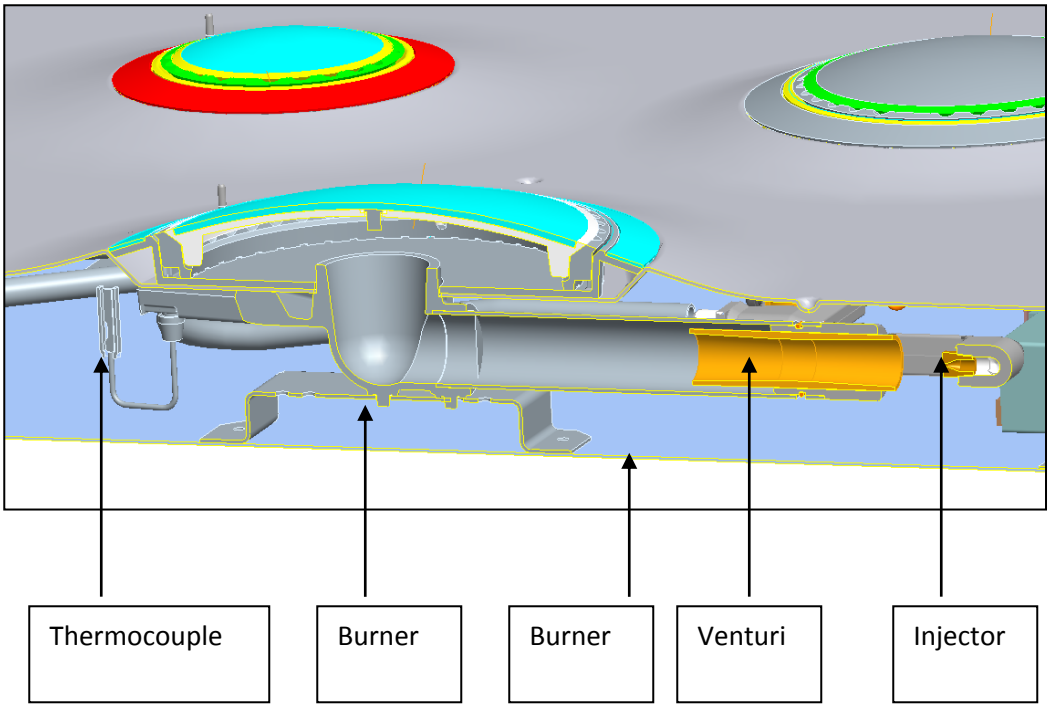


Figure 68 Cross section through metal top

Finally the material application on the grate and burner caps will also affect the final outcome of this rating as all materials and coatings have their specific heat retention and conduction properties.

Gas lab testing proved that for G20 gas: grate height of 30mm and a venturi distance of 15mm is the most optimum setting.

Door Slam Test

The burner box is mounted on top of a counter, having a depth of 45- 52mm, below which there is an empty cavity to be used for mounting the oven or as a cabinet.

The gas burner performance in this case has to be tested for the flow of air when the cabinet door is opened.

The door slam test is performed by opening and closing the shutter in rapid succession to check that the flame stability is maintained. When the shutters are opened repeatedly they cause a sudden change in air pressure within the burner box thus causing a drop in Oxygen level and extinguishing the gas combustion

within the burners. A solution to this problem is still being researched. A complete computational fluid dynamic (CFD) testing simulation had been developed in order to understand what the air flow pattern was within the cooktop bottom box (figure 69). Especially the air intake velocity and pressure fields had been mapped around all the possible openings within the bottom box.

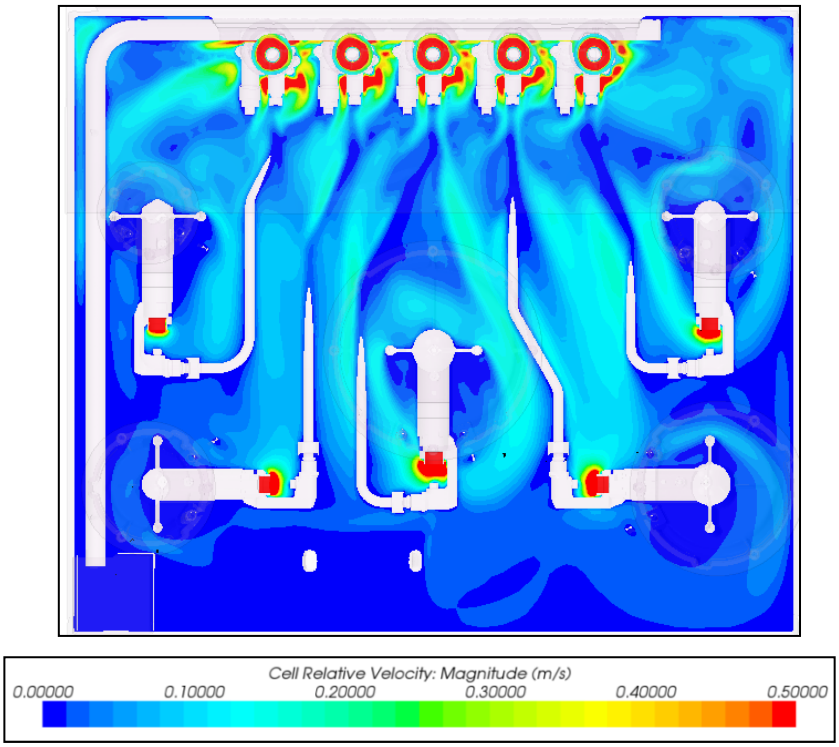


Figure 69: Air Velocity Field within the bottom box (red = high velocity and blue = low velocity)

4.3.1 Insights into the role of the designer in the development process

This project was aimed at the premium end of the market and it is going to be the flagship food preparation appliance when it is released. It is worth noting here that although this is targeted as an Eco-efficient cooktop, it is benchmarked against the competing makes in terms of burner performance and burner efficiency, in that order of priority, 2 seemingly opposite considerations. The gas technology engineers were briefed right from the start to ensure the kW output of the largest 'ultra-rapid' burner is higher than all other competing makes, even though increasing the burner output increases the gas consumption rate and impacts the effects the efficiency. So in the end a delicate balance between burner output i.e. performance and burner efficiency had to be achieved. Burner efficiency is measured by capturing the emission ratio between CO and CO2 in live testing, burner performance is more objective to measure by measuring the 'time to boil' a specific volume of water. Efficiency of the entire platform is measured in terms of a emission ratio between 2 gases which is quite fickle and can change with the smallest atmospheric impacts such as humidity and ambient temperature, while 'time to boil' figures are more robust because they will always remain the same at constant 1 atmosphere room pressure. This

deduction in a way confirms Krippendorff's (2006) assertion that engineers prefer to design for performance rather than efficiency because it is has more direct measure metrics. Design for efficiency is a more complex paradigm simply because the metrics of efficiency change depending on the point of view of the stakeholder, i.e. for procurement in this case efficiency would stand for the ratio between supplier costs vs internal manufacturing, for marketing it would be an entire cost benefit analysis i.e. cost to company vs final profit figures.

Having said this, the role of the designers themselves was not very decisive in defining the final development of this project. As the author is a designer himself, it was insightful to work with engineers as an engineer to resolve design from a production issues point of view. Although from a product semantic point of view, this project lacks any consideration, no feedback has ever been captured by Whirlpool on this cooktop to determine if the potential users do indeed feel if it communicates Eco-efficiency. Compared to the previous GreenKitchen, it becomes clear that Whirlpool much like any other appliance company lacks any clear understanding of Eco-efficiency from a design point of view. They have yet not understood how Eco-efficiency can be communicated, perhaps because of differing interpretations of it, from the different divisions of the company.

Large manufacturing companies such as Whirlpool tend to give an over-arching priority to the technical and safety issues which judge the design direction during development and are therefore very risk averse. Often the role of the designer is to follow the technical restrictions and achieve only stylistic solutions, and styling as Krippendorff (2006) notes has to do with forms not with meaning. As a consequence, Eco-efficient appliances lack any coherent character attribution losing any communicative value which they may be able to put across to the user.

4.4 Eco-efficiency within Whirlpool Product Development Process

As has been already pointed out, when dealing with Eco-efficiency, there is lack of semantic expression in the design direction of whirlpool. One of the reasons for this could be the level of design freedom which designers enjoy within such a complex organizational structure.

Generally it has been acknowledged that the earlier in the organizational decision making chain that Eco-efficiency is introduced the role of design becomes progressively stronger, and the later in the organizational chain that Eco-efficiency is introduced into a product development process, the role of engineering and manufacturing becomes stronger (Chiodo et al 1998). While this phenomenon certainly holds true for an appliance manufacturer such as Whirlpool, it doesn't mean that design and engineering work in ignorance of each other's concerns in a manufacturing environment.

The main divisions of Whirlpool are as shown below in same order of hierarchy as indicated below (figure 70).

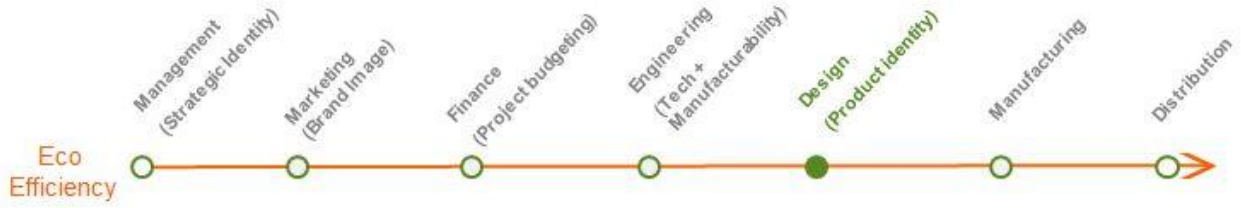


Figure 70: Organizational hierarchy of Whirlpool

The above figure shows that when any project has to be developed it passes through all those hierarchical stages, only an approval from a previous stakeholder will enable the project development to pass on to the next one. In this case the reference agenda is that of Eco-efficiency. When Eco-efficiency is introduced from the management at a strategic level very early on, then the following stakeholders tend to not shoehorn such a project into the development process of a stereotypical appliance, and the designers have more freedom to explore. The GreenKitchen 2,0 is an example of such a case. The GreenKitchen also cannot be manufactured within the current production model of this company.

On the other hand as in the case of the Ixelium cooktop, Eco-efficiency was introduced as a final project target by the Engineering and Technology division, because they happened to have invented a new highly Eco-efficient burner design. Hence the basic appliance parameters are identical to any other cooktop which Whirlpool has manufactured; the role of designers in this case is largely reduced to aesthetical fine-tuning and resolving 'perceived quality' issues. Eco-efficiency is not really investigated from the designer's point of view, which is likely to give rise to a very partial solution to Eco-efficiency and certainly lacking in any Product Semantic content. Figure 71 places the appliance platforms according to the Eco-efficiency categorization discussed in section 3.3.

But in order to successfully define the semantic expression of Eco-efficiency in such large organizations one would have to understand and properly define what Eco-efficiency means to them. Again, this thesis rests on the fact that meaning of artifacts are found in language (Krippendorff, 2006) so it's essential a company having such as multifaceted organization such as Whirlpool find a unifying definition and identity for Eco-efficiency in order for it to be attributed in products' features and character.

At the moment Whirlpool's 'Energy Efficiency Directive' spells out what Eco-efficiency stands for them in the different areas of competencies within the company:

Manufacturing:

- No CFC's used
- Reduced toxic emissions
- Paint emissions reduced

Design + Engineering

- WEEE directive for EU
- Energy Star for North America

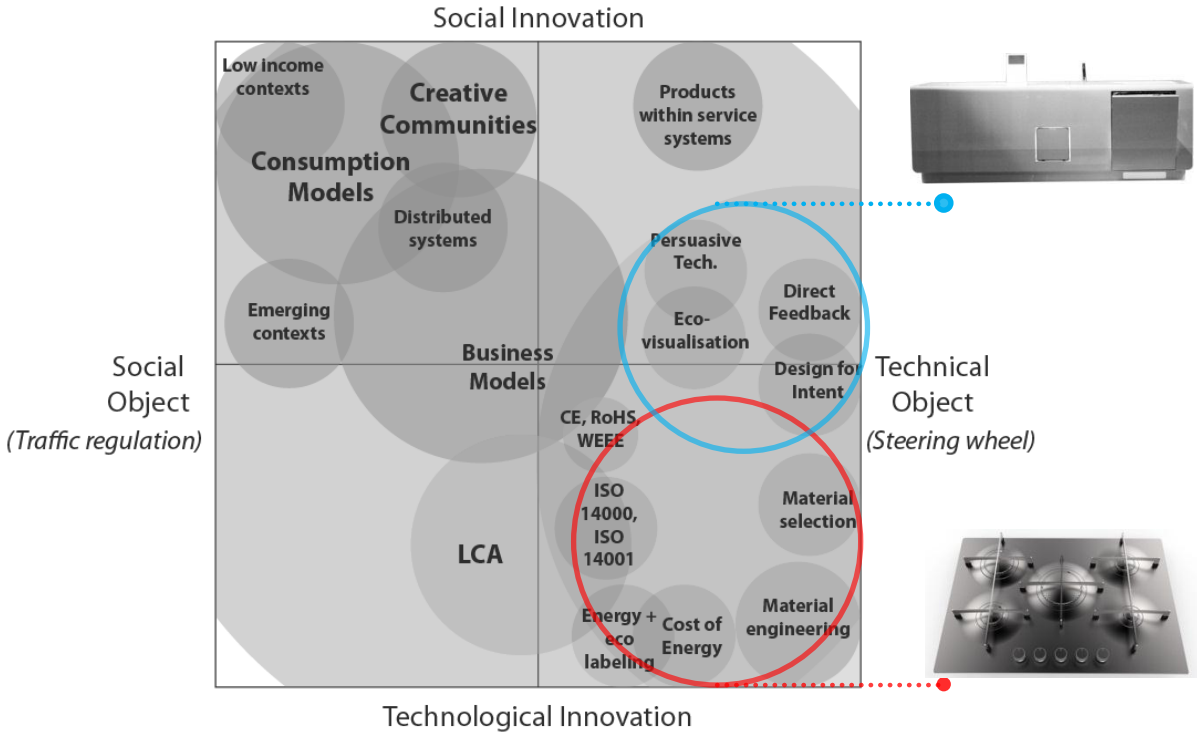


Figure 71: Position of Flat cooktop and GreenKitchen according to categorization of Eco-efficiency

- PROCEL for Brazil

Product Distribution

- Using railcars instead of trucks
- LEED certified warehousing facilities

End-of-life management

- Product take back programs (only supported not organized by Whirlpool)

So the meaning is fragmented across the different competencies of Whirlpool, evidently very much reflecting in final outcome of the expression of Eco-efficiency in their appliances.

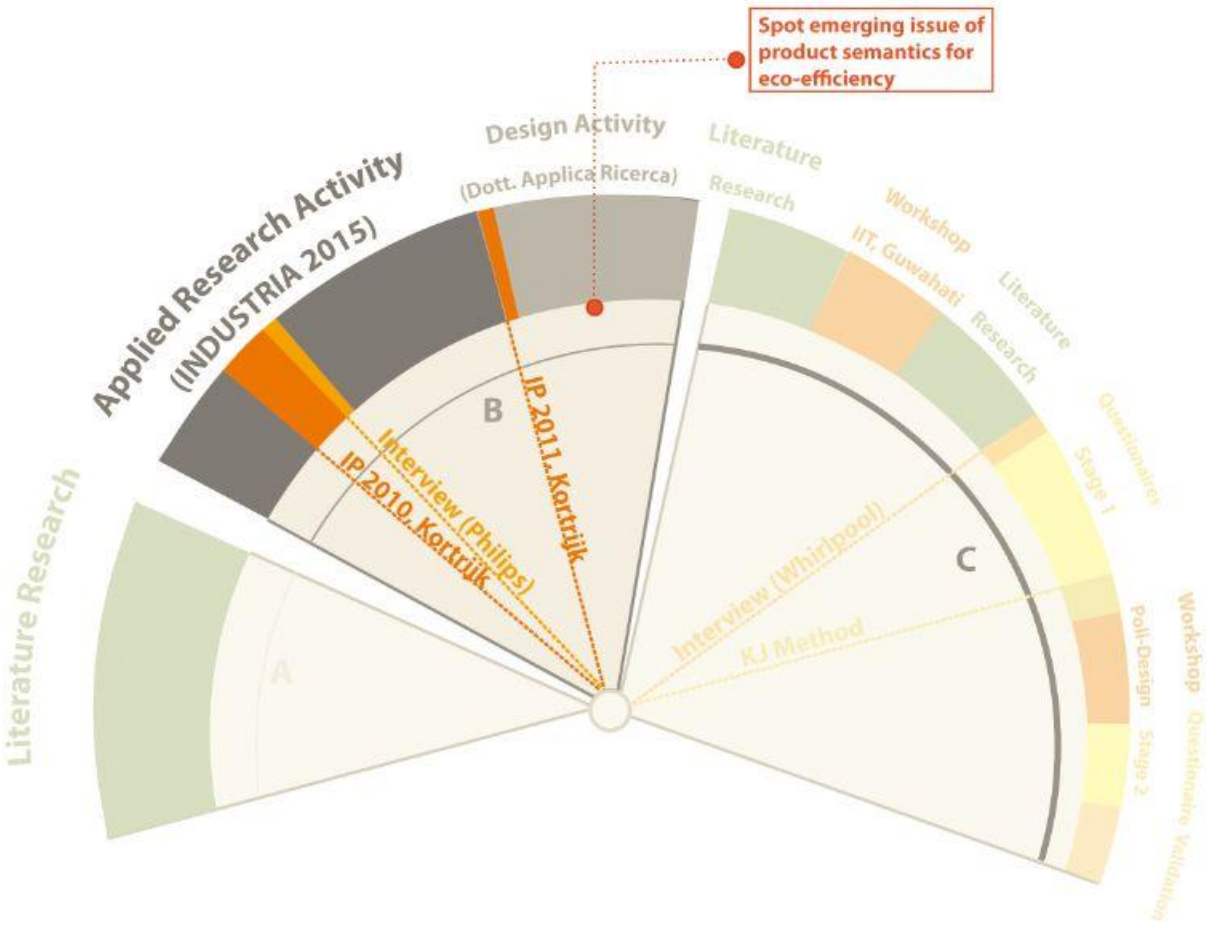
In somewhat unrelated but also deeply concerning is the fact that the directive places design and engineering together, which is an over sight as has been said by Mathews and Chambers (1998): "*Designers are not generally knowledgeable about environmental or end of (useful) life issues, and the goal of a management system should not be to make them experts in such areas*". But this is clearly what Whirlpool is directing them to do by asking them to look into legislations such as PROCEL and Energy Star, which are basically technical criteria, and consequently areas where designers have little or no understanding. Perhaps this also relates to Rob Shelton's (1998) concept of a 'Green Wall' which exists

within organizations. He says qualities such as Eco-efficiency in product design can only progress up to a certain point internally within companies unless the leading stakeholders such as senior management are convinced of its business case benefits, and thus pinning the responsibility of achieving this through good *communication*.

Often times designers are handed down information of Eco-efficiency in the form of check-lists and LCA software, tools such as these which designers are poor at adopting into their workflow. Collado-Ruiz and Ahmad-Ghorabi (2010) in their study on office chairs also concluded that exposure to hard environmental data (such as LCA) reduces the creativity of the designers during the development process. Many other times designers are altogether ignored while Eco-efficient products are being developed and they are just invited into the last stages to just provide a 'covering' for the technology already developed using the formalized appliance design guidelines.

If communication is the backbone on which the success of Eco-efficiency depends, then designers need to be trained to use communication tools which are entrenched in their core competences such as product characters which express a meaning. During the author's interaction with the internal stakeholders of Whirlpool's product development division, they confirmed this insight by saying that for the communication target should be convincing the 'marketing' manpower of a company, because they fit closest to the target audience of the 'ordinary' people which any appliance ultimately has to convince in order to achieve market success. Krippendorff (2006) defines an ordinary person as one with no engineering training and naïve scientific knowledge. Over and above all it is the marketing people who go out and convince distributers and end users to subscribe to the idea of Eco-efficiency or to invest in an Eco-efficient appliance, so it is marketing which has to be communicated the meaning of Eco-efficiency in a language which is easier for them to grasp than technical criteria. Endowing appliances with semantic content which communicates this message through a non-instrumental interaction could be the best medicine for such a scenario.

5. Multi-disciplinary design workshop: Intensive Program (IP) 2010 & 2011



5. Multi-disciplinary design workshop: Intensive Program (IP) 2010 & 2011

5.1 Teaching eco-efficient design in a multi-disciplinary design environment

This section describes the IP of 2010 edition. An Intensive Programme (IP) is a short programme of study which brings together students and staff from higher education institutions of at least three participating countries. It can last from 2 weeks or 10 continuous full days to 6 weeks of subject related work. This paper deals with the issue of Sustainability in the spheres of Design education and inter-operability between the disciplines of Design and Engineering. The issue of sustainability is very important which will face the professionals of the coming years as the greatest challenge of the 21st century, but what is equally important is to learn the aspect of team work between different nationalities and work disciplines.

The IP is an important platform to understand what companies in other sectors are doing with respect to designing for Eco-efficiency. This was also a great platform for the author to get in touch with companies such as Philips Consumer Lifestyle, and discuss this research in progress to get insights from their point of view about approaching product design for Eco-efficiency. These insights will be shared a bit later in this chapter.

The contents of this section have already been published (ConnectED 2010, Sydney) and discussed in the paper: "Green products through a multi-coloured approach, an experiment in multi-disciplinary education" (Chakraborty et al, 2010).

I.P. Organization

With all the students and tutors arriving to Kortrijk, initially the organizing and time management aspects were proving to be a real challenge, as the cultural differences between the students of different nationalities made synchronization difficult in addition to the sheer number of 170 students.

The schools brought a mix of Engineering and Design students & teachers according to their expertise. The teachers were also giving a lecture based on their expertise & vision towards sustainability. Some of the teachers were also in the form of PhD students who were using this workshop to advance their research undertakings.

In addition Howest had invited a host of specialists from the region surrounding Kortrijk (BE) to enrich the students on different issues and competencies concerning sustainability. These experts were specialist researchers, professionals, or representing regional companies (SME's).

The point being that the students should get a diversified view on sustainability from experts from different industries. As the students were coming from different disciplines apart from ofcourse different cultures and nationalities they held widely varied opinions on the issues sorrounding Green Design. The feedback sessions after the lectures as a result made for rich discussions, as the students held such diverse views. These lectures were also used as platforms to bring the students to a common understanding and vision towards sustainability for their projects which they would be developing in groups.

The Lectures

The lectures were distributed across the 2 week time period of the IP, with a majority of them being held in the first week so that the students had an opportunity to exploit the knowledge they gained in developing their projects.

The lectures, which were conducted by teachers representing each of the 7 universities as well as professionals from SME's from around the region, sought to cover all the aspects of design & manufacturing. The lectures from companies like LDV covered the challenges of manufacturing steel pressing machines and complexity management. There were lectures which covered the systemic approach to sustainability as well as those which covered sustainable design on a more product scale.

Other topics which covered included subjects such as Bio-mimicry (Leen Gorissen), Design for disability (Roger Griffiths), waste management (Hervè Boileau), energy challenges (Steven Vromman), and Life Cycle Design (Kristel Dewulf, Glenn Stocton) & classification of Green Products (Silvia Ferraris, Shujoy Chakraborty).

Projects & Companies

The second aspect of the IP was the design projects which the students were developing. These projects were conducted in collaboration with Design firms, Professionals, or companies selected and invited by Howest. The students were divided into groups of 7 students, thus totaling around 24 groups.

The Projects

In the 2010 edition there were 7 projects, each supported by a design studio or a company. The projects were the main objective of the IP to promote integration of students from different nationalities and professions. Working in groups to interpret and deliver the project, as envisaged by each of the project briefs, was a challenge to all the students involved. They were required to understand the brief at an individual level but also to come to a common understanding with other team mates who could be engineers or designers.

The project briefs were as follows:

A. Bio- digester (*Infrastructures, & Biogas–E*), **B.** Electronic signposting for Industrial sites (*The West Flanders Intermunicipal Association*), **C.** Baby nomad food warmer *(ActiveBottle),* **D.** Eco labelling for textile *(Masureel International NV),* **E.** Recycling TV *(Philips),* **F.** Portable Energy Box (Government of Rwanda) **G.** Design of a modular 50kw waste heat ORC machine (BEP Europe).

As is apparent from the list above, the projects are very diverse and will challenge the students at different levels. These projects give the students the freedom to think at a product scale or a systemic scale, as sustainability requires both.

It is important to note here that the IP was inculcating the skills of 'T- Shaped' professionals in the participating students. As envisaged by the IP, developing T- Shaped Engineers and Designers is essential to train the next generation of professionals who would be equipped to deal with the challenges of Sustainable Design in the 21st century. This thought was further reinforced and demonstrated in the lectures which the students attended in the morning sessions throughout the IP.

The projects were selected by Howest and students were all distributed across the projects in teams, such that each team contains students from all the institutions and a mix between Designers and Engineers from several specializations such as electronics, mechanical, chemical & environmental disciplines. This organization in theory gave equal standing to all the groups in question.

Following is an elaboration of each of the project briefs to give a deeper insight into challenges faced by the respective groups:

Bio-digester: Bio-gas plant for the home. Students are encouraged to explore the scale from the personal digester all the way to the community scale.

Electronic signposting: This project involves around developing an electronic signposting system for industrial parks.

Baby nomad food warmer: Mobile & sustainable baby food and milk warmer for the contemporary urban first time parents.

Figure 72: Interpreting the brief of Bio-Digester

Eco-labeling: Optimizing the production of textiles in order to achieve an eco-certification called Eco-100 for the sponsoring company by reducing waste production in the textile manufacturing process such as waste water etc...

Portable Energy Box:

This project involved developing a concept for a mobile energy platform which provides much needed power in the form of a rechargeable battery for the people of Rwanda. This project has the potential to be developed as a system scale project and not just a product scale project.

Figure 73: Developing the brief

Recycling TV: TV's have been classified as having a life cycle of 7 years so this presents significant challenges for a manufacturing company such as Philips, who have an obligation by law to deal with all the TV's returning into the waste stream. The brief challenges the students to form a list of materials which can be salvaged from a TV and fabricate them into products falling into the categories of furniture, packaging, housing etc.

Figure 74: Taking apart a TV to study all its components

50 KW waste heat ORC machine: It is possible to convert waste heat & vibrations into electricity based on the selected components (heat exchangers, pumps, expander…) the optimal integration has to be studied. This project challenges the students to design a machine in a modular fashion, having pleasing aesthetics, and a standard size fitting a shipping container and a truck in addition to being thermal insulated. The machine must allow plug-and-play installation and remote monitoring and diagnostics.

B. Projects as a process

Since this was just a 10 day IP, the projects developed would be at a conceptual level. The projects would be brief but intense in terms of the process which they would follow in order to complete the IP deliverables.

The teams of students were evaluated not just on the final project which they would develop, but also the process which they adopted to develop the project and how successfully they functioned as a team.

Figure 75: Understanding & developing the project process

This made it important that the students learn to bond as a team and learn to delegate work appropriately in keeping with the skills of each member. It was observed, that the groups were working out an appropriate strategy to develop and deliver the project.

As soon as the brief was delivered by each project leader, the teams got down to forming their initial ideas on interpreting the theme. This was presumably the most challenging task they faced as a team, in order to arrive to a common understanding about the project parameters.

Although the lectures were designed to bring the students up to a common understanding of sustainability, there was still a mismatch in perception due to the fact that Designers and Engineers have different priorities.

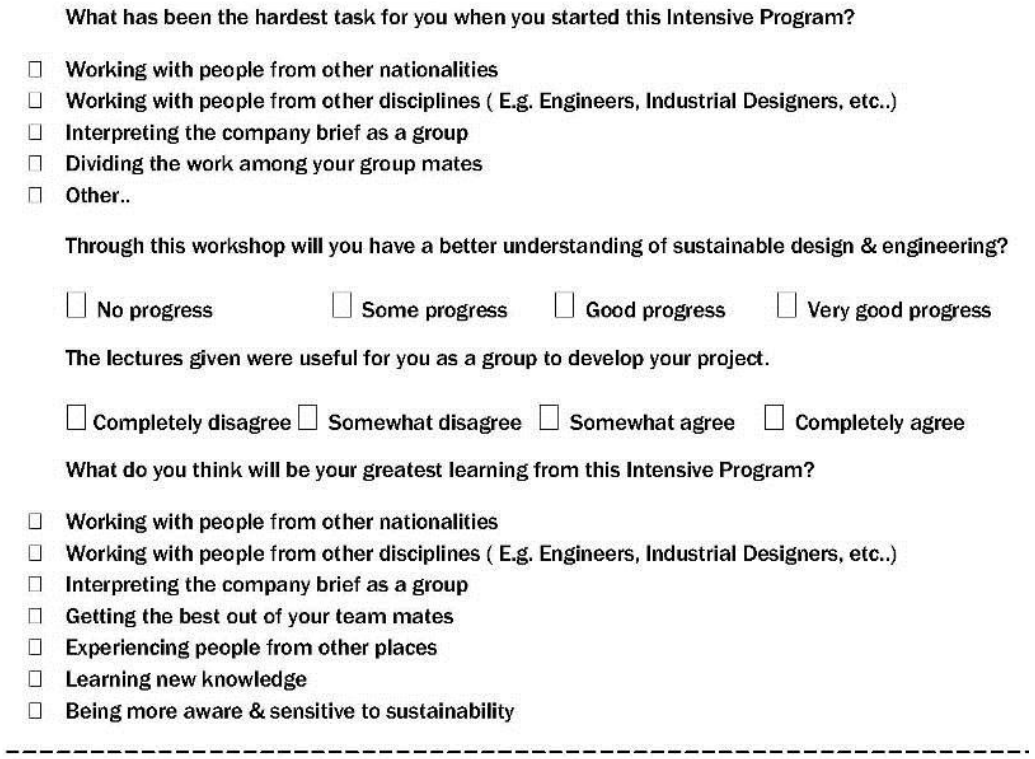
Student Feedback

At the end of the first week it was important to develop an intermediate evaluation process to judge the progress of the workshop. A questionnaire was developed in order to benchmark how successful had been the lectures and all the instructional activities of the workshop for the students to improve their understanding of the workshop theme and the greatest challenges faced by them to achieve the final output (figure 76).

The major questions asked were:

- To evaluate the greatest challenge in the IP faced by them.
- If the workshop equipped them with a better understanding of sustainability.
- If the lectures given were useful to develop their project work.
- What was the greatest learning which they took from the IP.

The answers to these questions would enable the partner institutions to understand how effective had been the workshop from the students point of view. The questionnaire illustrated below, was passed out to all the 168 participating students and the results which emerged would give a clear picture of the effectiveness of the IP. Possibly these results could be an indicator about what needs to be changed for the future IPs.



What has been the hardest task for you when you started this Intensive Program?

- ☐ Working with people from other nationalities
- ☐ Working with people from other disciplines (E.g. Engineers, Industrial Designers, etc..)
- ☐ Interpreting the company brief as a group
- ☐ Dividing the work among your group mates
- ☐ Other..

Through this workshop will you have a better understanding of sustainable design & engineering?

☐ No progress ☐ Some progress ☐ Good progress ☐ Very good progress

The lectures given were useful for you as a group to develop your project.

☐ Completely disagree ☐ Somewhat disagree ☐ Somewhat agree ☐ Completely agree

What do you think will be your greatest learning from this Intensive Program?

- ☐ Working with people from other nationalities
- ☐ Working with people from other disciplines (E.g. Engineers, Industrial Designers, etc..)
- ☐ Interpreting the company brief as a group
- ☐ Getting the best out of your team mates
- ☐ Experiencing people from other places
- ☐ Learning new knowledge
- ☐ Being more aware & sensitive to sustainability

Figure 76: The questionnaire which was filled out by the students

- 45% of the students cited interpreting the company brief as a group as their hardest task.

- 48% of the students pointed out that their understanding of sustainable design & engineering had made good progress as a result of this workshop.
- 47% of the students agreed to the fact that the lectures had helped them to develop their practical projects as a team.
- Learning new knowledge, working with people from other disciplines and places was cited as the greatest learning from the IP.

These answers give an idea of the students' experience. Clearly they struggled to bond as a team in the initial stages of the workshop, as they came from different disciplines and nationalities.

These figures also point out that the lectures had in fact fed the development of their projects as a team. Thus the lectures to a great extent achieved their objective of bringing the students up to a common understanding of sustainability which would assist them to function as a team and agree upon common objectives for their projects.

Evaluation

The evaluation process of the IP was a multi layered process. The several stages are discussed below.

Process Evaluation

After 6 days a project exposition and a mid-jury was conducted. The evaluation criteria in this jury were to judge all groups in certain key parameters: project feasibility, sustainability consideration, project development schedule. In addition, remarks were given to each group which summarized the over-all impression of the group's project by each jury member which consisted of teachers from Howest and from the visiting universities.

The exposition also required the groups to display their project development on panels such that all groups can examine how their peers are performing and benchmark each other's progress into the first week against all the teams. Of course the students were also welcome to comment & discuss the projects of other teams in order to ensure their participation in all the projects, even those falling out of their respective theme of work.

This was a good opportunity for students to re-calibrate their project development in line with the stated objectives. Those groups which had deviated too far could self-adjust their development hereon with through internal discussions within the group and direct feedback through the jurors and their peers.

Peer Evaluation

All students were also handed out peer evaluation forms, which asked them to rate the group members in their team (figure 77). The evaluation was then discussed in the group so that they learn to communicate their concerns and strengths with their colleagues. This process gave the students a chance to voice their concerns regarding certain members and an occasion to address them through mutual dialog & thus diffuse the negative dynamics & overcome any trust deficit.

The form allowed each student to award 6 points to his/her group in total. Each student could award points to their colleagues, awarding more points to those they were happiest working with. As a result, if a certain student garnered high points consistently from the group mates then that meant the student has performed well inside the group & a consistently low score by all the group mates meant that the student had problems functioning within the team or was not performing up to expectations of the team in question.

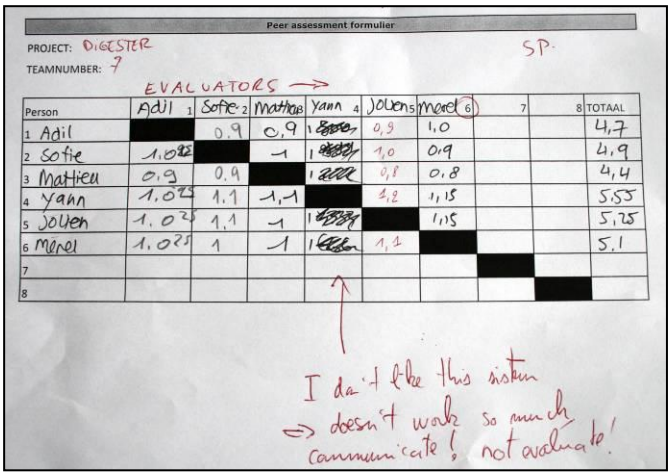


Figure 77: Peer evaluation form

This peer evaluation process was done twice, once at the end of each week. Doing this process twice allowed the students to understand if their group dynamics had improved within the course of the 2 weeks.

Final Presentation

A juried presentation was organized on the last day of the IP. All student teams were evaluated in 3 main considerations:

- The feasibility and resolution of the main idea
- The sustainability criteria of the project
- The quality of the design/ concept finally developed

Each of these criteria contained a weightage of 5 points. Thus a group could corner a maximum of 15 points. The teams were allotted 20 minutes to present their idea and prototype (if developed).

In addition 3 criteria were selected to judge best groups, these included:

- Best group in the IP.
- Best product developed in the IP.
- Best sustainable qualities in the final result

Adjudging the winner in each of these criteria gave the participating students a sense of achievement both individually and as a group. The juries consisted of teachers from all the participating universities and representatives from the participating companies. At the end of the IP, each student was awarded with a diploma, certifying the successful completion of the intense workshop.

Dissemination

The students were given a good amount of press exposure during the review day, in order to give them a chance to explain their project to a wider audience. This activity also endows the students with the added skill set of presenting their ideas in a brief and clear way in a short duration of time. A part of the press was in fact journalism students from the Howest University College.

5.2 Insights from workshop results into other product categories

After participating in this multi-disciplinary workshop for 2 consecutive years it became clear that the issue of Eco-efficiency is important in other manufacturing sectors also. Just as in the appliance sector, the manufacturers didn't have a very clear view regarding the meaning of Eco-efficiency and how to build it inside the products. As the companies themselves did not have a clear idea about what they were looking for the design students also were not very sure about which approach to adopt. As is clear from figure 78 the designers didn't necessarily succeed in communicating very well that the products they have developed are eco-efficient. In the case of the Philips Econova TV, the final project developed reduced the weight of the TV from 16 kgs to 9 kgs, by restructuring the internal components, and removing plus combining some structural components such as mounting the integrated circuit board into the main frame chassis internally thereby removing an extra steel frame which was provided just to mount the circuit boards. In addition they explored some novel materials such as structural fabrics for a flexible super structure and replace the outer plastic casing. Also the stand of the TV, which is normally a separate assembly, was integrated into the frame of the speaker system of the TV so that it can pivot vertically backwards of the TV to accommodate 2 modes of installation-tabletop or wall mounting. From a point of view of innovation this was a successful project, but from a point of view of semantic expression of Eco-efficiency it was not an improvement over the current range of Econova TV's present in the Philips' lineup.

Figure 78: Philips Econova (IP 2011)

Ridley Bike- Green Bike (IP 2011)

The same analysis also applies to the Ridley Greenbike. In this case the students analyzed the production process of a bicycle, and deemed the extrusion process to be a wasteful manufacturing process. The Greenbike in this case utilizes an aluminum which uses cut-and-bend plus laser cutting process. Although this project meets the brief of the company really well but from the point of view of communicating Eco-efficiency using product characters it is unsuccessful. It utilizes an innovative manufacturing solution to realize the eco-efficient bike but fails to communicate this innovation to the user beside perhaps the novelty factor of having a new form factor in the frame of the bike.

In conclusion, the issue of product semantics has thus proved to be existent in other manufacturing sectors as well apart from the home appliances. This serves to both deepen the validity and future application of this research.

5.3. Insights from Interview with Philips Consumer Lifestyle on eco-efficient design

At the conclusion of the 2010 edition of the Intensive Program, the author had the opportunity to have a close interaction with global innovation management representatives of Philips Consumer Lifestyle. Through this interaction the author decided to conduct a short interview and also present the development of this research to gather their insights into the validity and possible application of this research into the television industry. Such a feedback would be very useful to give the point of view of the industry experts, which would also potentially help to strengthen the theoretical point of view should the 2 overlap.

As one of the leaders in Eco-efficiency, Philips is seeking to really push the issue of Eco-efficiency into their portfolio of TV's. The flagship TV in their lineup is the Econova range. In their view also Eco-efficiency too often appears as a functional and a performance compromise, which consumers are unwilling to accept. As important as the issue of Eco-efficiency maybe to the buyers, when they enter an electronics store they just want to walk out with the best looking and performing TV for the budget they have. This point of view is in keeping with the view Byrnes (2010) offers when she quotes David Rejeski "*the immediate always drives out the important*". Such is true for Eco-efficiency as well, since energy is by and large an abstract and invisible concept to consumers.

Philips have introduced a series of Eco-efficient features in their EcoNova range which are listed below:

- The *Philips Econova ECO Smart LED TV* uses 60% less energy compared to LCD TVs.
- With *Philips Econova ECO Smart LED TV*, off is really off. The Zero power switch means that when you switch your TV off, power consumption is reduced to zero watt.
- This TV is made from previously discarded and easy to recycle materials.
- Its solar powered remote control reduces the impact on the environment even further, removing the need to replace or dispose batteries.
- Reducing material waste even further, this TV comes with a 2-in-1 stand which can be used as a table top stand as well as an easy to install wall-mount bracket, bringing convenience to consumers and eliminating unnecessary waste from discarded parts.

(Source: http://www.ifa.philips.com/pressreleases/Philips_Econova_TVs/ - *captured 27/12/11*)

The features listed out above are mostly technological innovations and really improve the environmental performance of the TV in question. Even as the first company to explore application of Product Semantics in the 80's, unfortunately even Philips is searching for a proper visual appearance which can communicate all this innovation to the end user using just product characters, i.e.: through 'non-instrumental interaction' that is before the user experiences the usability of the product.

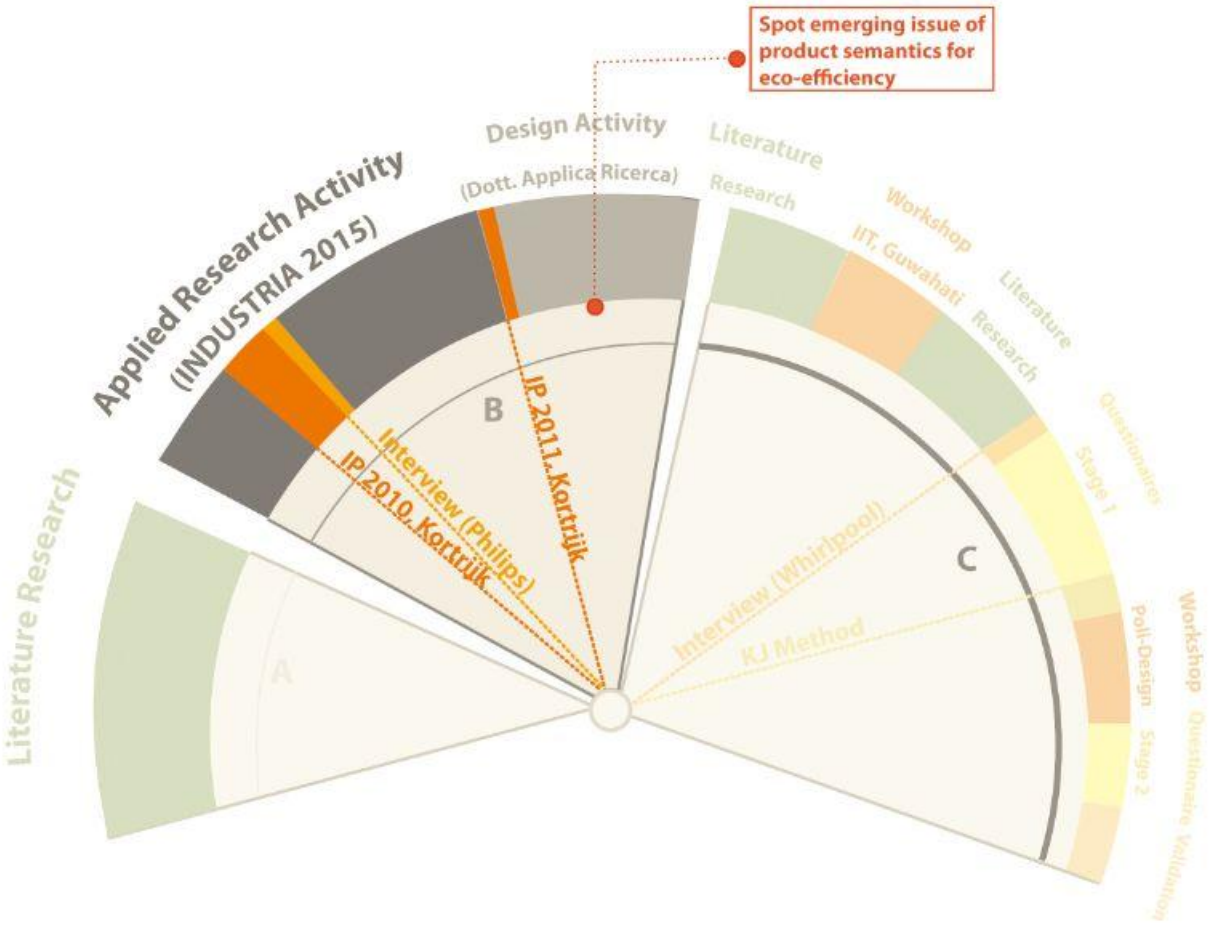
Figure 79: *Econova ECO Smart LED TV & Solar Powered Remote*

In fact Philips emphasises upon the fact that Eco-efficiency has to appear very 'attractive' to the user, and such products have to be high performance products. Furthermore they recognise as an organisation, the reality that just superior environmental performance is not enough to guarantee product success. Organisational support is necessary for Eco-efficiency to be accepted in the marketplace. Johansson & Magnussonn (1998) state that "*Awareness of this should mean that proactive companies can create bandwagons of environmentally sound technologies*." They define a bandwagon effect as an effect when one company starts through a technological trend in the market using innovation as a vehicle and provoking the competitors to follow the footsteps, until such an innovation becomes the industry standard.

Philips at this point has the capability to set a bandwagon effect in the TV industry to embrace Eco-efficiency as a source of product differentiation and a marketing advantage. They are trying to adapt their entire corporate 'identity' around the issue of Eco-efficiency, thus readily committing a lot of resources behind Eco-efficiency.

Clearly they need to still address the semantic expression of this TV, seeing as it appears similar to any other TV in the market as far as its intrinsic features go. In order for Philips to really benefit from the technological innovations underpinning this TV, they need to invest not only in technological advantage but product communication based on the intrinsic features of their TV's.

6. Emerging issue: Product Semantics for Eco-efficiency



6 The emerging issue: Product Semantics for Eco-efficiency

6.1 Communicating eco-efficiency through non-instrumental interaction

"The Instrumental Interaction model is based on how we naturally use tools (or instruments) to manipulate objects of interest in the physical world" (Beaudouin-Lafon, 2000). Non-instrumental interaction instead is how the user interacts with objects based on the senses of touch, smell, hear, taste and sight. Instrumental interaction is based on usability of the object which is acquired. Non instrumental interaction on the other hand is based on the cognitive response which is generated within the user based on the initial sensing. As has already been pointed out only the sense of sight is being considered for this research as it is the most dominant of all the senses.
The user visually acquires the object to be sensed, once the object is sensed the user has a cognitive response by virtue of the product character of the object and gives it a meaning. Following the cognitive response the user forms an opinion (appraisal) of the product leading to an emotional response which acts as a behavioural trigger.

Instrumental product experience depends upon the usability of the object (Colombo, 2010). The real functions of the object such as technical capabilities, efficiency, ergonomics and such like influence the cognitive response of the user. This cognitive response is only formed when the user operates, experiences, and manages a product (Colombo, 2010). This cognitive response triggers an emotional (affective) response following which behaviour is triggered in the user – either approach the artefact or ignore it. The user inputs an action and there is a reaction on the product which the user perceives as a feedback.

In a non-instrumental product experience there is no action-reaction paradigm involved. In addition instead of tools (such as hands) to facilitate the interaction, a non-instrumental interaction depends upon the senses of the user, sight in this case, so usability and the technical capabilities never enter the picture to influence the user final emotional and behavioural response. Here instead the user senses the intrinsic features of the (product such as geometry, details, form, arrangement) to form a cognitive response (Crilly, Moultrie, & Clarkson, 2004). This cognitive response is what product semantics is concerned with whereas the following emotional responses have been studied within Kansai engineering methods (Krippendorff, 2006).

This research is directed towards trying to understand how product characters using intrinsic product features can communicate the Eco-efficiency as a meaning within the framework of a non-instrumental product experience (figure 80). As discussed in section 3.6.1 within the product communication model meaning attribution by the user is a cognitive process.
At present domestic appliances rely purely on the instrumental product experience to convince the end user about the Eco-efficiency to the product. User depends upon usability of the appliance i.e. the efficiency of functions, efficacy (effectiveness in producing the intended results), and the ease of use (ergonomics) in order to be convinced that it is an eco-efficient appliance. What the user perceives as Eco-efficient is not taken into account in this case in order to convince him about the eco-efficiency of the appliance. Instead the user has to learn the functions and capabilities of the appliance in order to form that opinion. Such an approach also corresponds to what Krippendorff called the technology centred view.
The non-instrumental product experience being discussed in this thesis is a human centred approach. It instead relies on visual sensing to trigger a semantic interpretation of product characters which trigger a cognitive response creating an association with Eco-efficiency (figure 80). The product characters are made of intrinsic product features. At present communication of Eco-efficiency only relies on extrinsic product features. Intrinsic and extrinsic product features will be discussed in the next section.

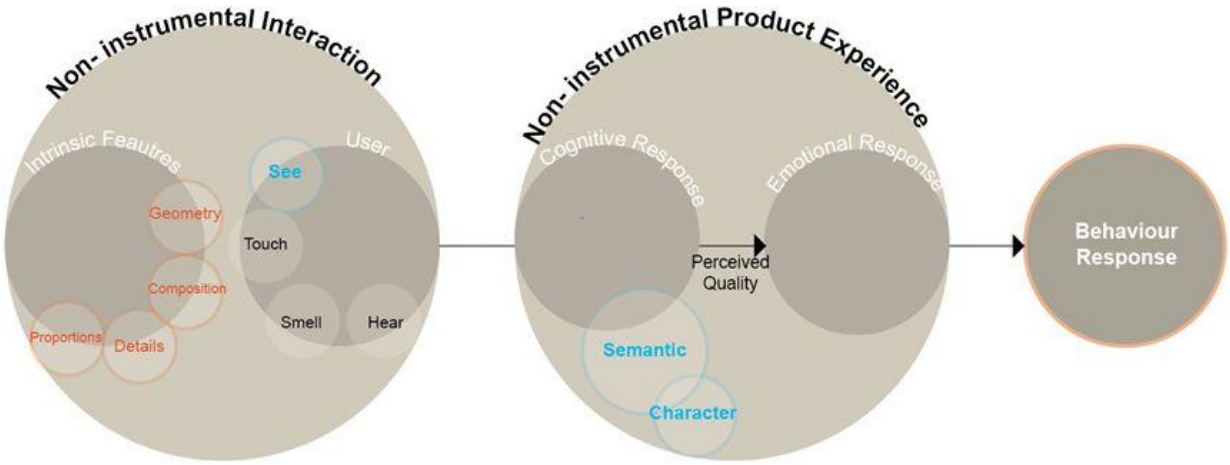


Figure 80: Author's product communication model

6.2. Intrinsic and extrinsic product features

Consumers rely on information 'cues' when evaluating products (Peter and Olson 1987; Richardson, Dick, and Jain 1994; Schellinck 1983). Consumers often rely on brand name, price, and the country of origin when evaluating a product (Lee & Lou, 1996). These product cues are divided as intrinsic and extrinsic (Olson & Jacoby, 1972; Olson, 1977). Extrinsic cues or features are 'product-related, but not part of the physical product' such as branding, price, and country of origin (Lee & Lou, 1996). Intrinsic features are physical attributes of a product such as gas mileage, styling of a car, engine specs (Lee & Lou, 1996).

Lee and Lou in their research into the effect of product attributes on product evaluations cite several important suppositions with respect to extrinsic and intrinsic product features. As a point of departure they contend that extrinsic cues are much more general than intrinsic ones and hence applicable to much wider range of products. Hence in general consumers are more familiar with extrinsic cues than intrinsic ones when making a purchasing decision.

The first supposition they propose is that consumers more familiar with a product category rely more heavily on extrinsic features when evaluating a product. This means that those not familiar with a product category will rely much more on intrinsic cues such as styling and technical capabilities when evaluating a product for purchase. In terms of appliances this has important implications because Eco-efficient appliances are a niche and upcoming appliance category thus not many consumers are familiar with them on a technical level, thus the importance of product styling and appearance can play potentially an important role in product evaluation.

Secondly consumers who have a high level of enduring involvement with a product category rely heavily on extrinsic cues such as price, branding, country-of-origin (Lee & Lou, 1997).

During their research they also observe that reliance on product features for evaluations are ultimately influenced by consumer characteristics and preferences such as price-reliance schema, patriotism, etc. thus products need to find the correct balance between intrinsic and extrinsic cues in order to gain a favourable product evaluation by the consumers based on a specific market requirement.

Currently appliance manufacturers rely almost exclusively on extrinsic product features to communicate to the consumer about the Eco-efficiency of an appliance (figure 81). These extrinsic

features are Eco-labeling or manufacturer specific labelling or stickering indicating more Eco-efficient functioning with respect to standard models. Krippendorff (1989) says such content is in realms of semiotics not concerned with semantics. Signs and labels give information regarding the product independent of meaning, and as such have no direct relation to the product appearance or character. 'Semiotic conceptions encourage artifacts that signify something unrelated to it use' (Krippendorff, 2008).

This means that manufacturers clearly (although most likely *unintentionally*) rely on expert level users to gain a positive product appraisal and largely ignore the majority of ordinary users (i.e. scientifically naïve and non-engineering trained) who would depend more on intrinsic features and product appearance in order to evaluate an Eco-efficient appliance. This approach probably explains the poor market success which Eco-efficient appliances have been dealing with presently.

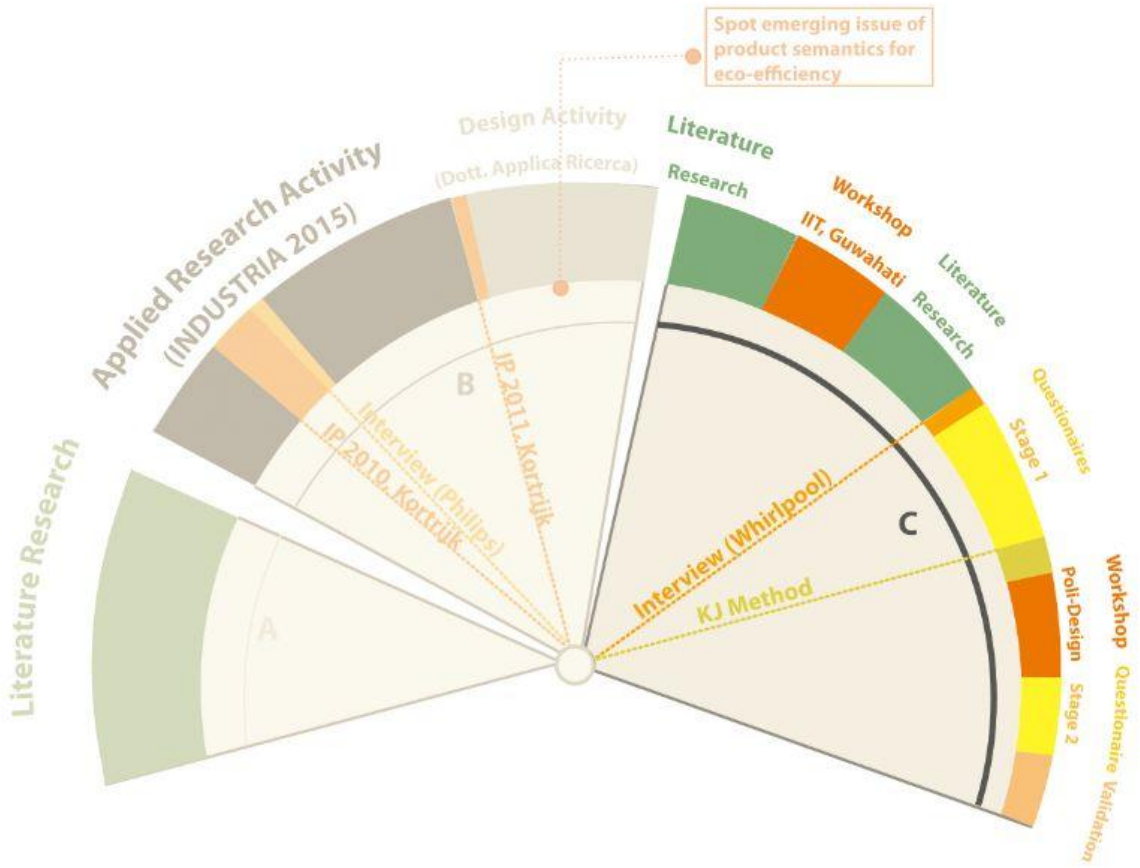
Typically home appliances are not a product category which users associate as an identity forming artefacts. A home appliance is viewed as a utility, therefore ordinary users generally have a low level of knowledge and interest in these products. While purchasing normally ordinary users ask extensively about all the technical features and capabilities of an appliance. This could explain why marketing jargon (i.e. *ixleium* for whirlpool scratch resistant steel) is attached to salient technical capabilities of an appliance, as this makes it easier for ordinary users to assimilate who have no engineering knowledge. Features which are too complex for marketing representative to themselves understand, are therefore not attributed with arbitrary jargons, and are thus not communicated to ordinary users. Eco-efficiency is sometimes associated with such features such as energy consumption per wash cycle, cubic meters of water used according to loading conditions etc. are some examples, and these parameters are the domain of engineering and design specialists. This observation highlights the importance of design in directly communicating the Eco-efficiency through the aesthetical properties of an appliance, thereby potentially bypassing marketing, and bridging the gap of understanding between expert and ordinary users.

According to the author's first-hand experience within appliance manufacturing, the extrinsic product features are in reality the domain of marketing and sales division of a company who have very limited technical understanding of appliances. These are the functionaries which work on indicating the pricing, branding, product literature, and advertising which will accompany any new product launch. The intrinsic features of an appliance are managed by the design and engineering specialists, who probably have not yet realised the potential importance and impact of their role to the marketing success of a new product.

Figure 81: Gorenje ECO CARE label (Source: www.gorenjegroup.com)

Whirlpool Ecoboost label on a Duet front loader (Source: www.whirlpool.com/laundry)

7. Redesigning Product Characters through a design process



7. Redesigning Product Characters through a design process

7.1 Main stages of the design process

The approach described here is aimed at applying the product semantics theory to a design process aimed at visually expressing the Eco-efficiency of an appliance. The redesigning process broadly consists of 4 major stages (consisting of several steps internally) which will be described below (figure 82):

Stage 1: The first stage is to perform a design workshop which is aimed at developing a series of Eco-efficient appliance design concepts through product design students. Using the projects developed within the workshop suitable adjectives will be collected describing each design concept.

Stage 2: The next stage will be to extract the most suitable adjectives amongst all the adjectives collected. These adjectives will be ranked using a group voting methodology and organised as characters.

Stage 3: These characters will be used as input for a second designed workshop also to be performed amongst product design students. The students of this workshop will also be asked to design an appliance but will be informed of the characters which are to be used.

Stage 4: Finally at the conclusion of this second workshop, the projects will be analysed for the effectiveness of the product characters attributed to the appliance design concept based on captured user feedback.

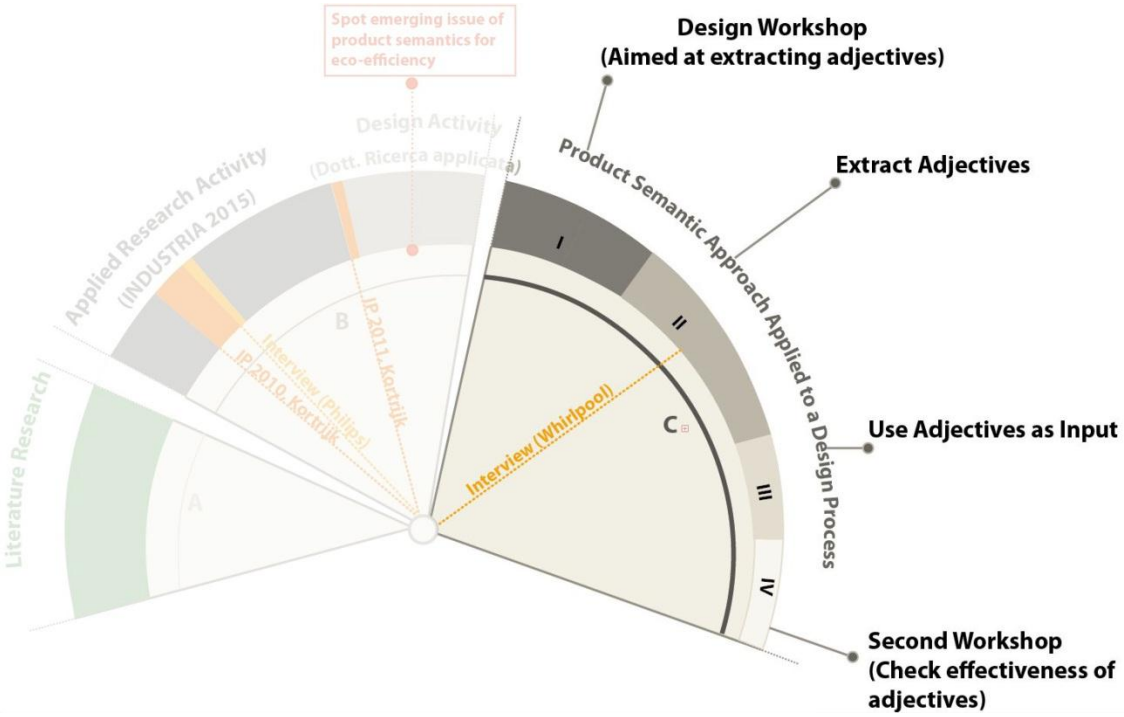


Figure 82: Product semantic approach applied to a design process for extracting product characters which express Eco-efficiency in an appliance

Using the medium of design workshops this process was utilised to understand if the product semantic approach could better equip the designers to successfully express Eco-efficiency of an appliance. The expression of Eco-efficiency of course has to happen using non-instrumental interaction, which means the user has to understand if an appliance is Eco-efficient after visually sensing just its intrinsic features i.e. dimensions, proportions, geometry, composition & details. Sensing the intrinsic features of the appliance should enable the user to attribute a meaning which in this case is Eco-efficiency. The development of the intrinsic features of the appliance was of course done with specific product characters in mind. Since this process is only seeking to address the sense of sight, the features of the design concept are not concerned so much with colour, finish, material, which are traditionally important considerations in the appliance industry, but rather with product geometry, proportions and composition.

The students developing the designs were directed also not to concern with the technological details of the appliance. Using a washing machine as test category, the distinction to be made here was to not invent a new way of washing clothes but to rethink the way existing washing machines appear based on the technology and mechanisms currently in production for Eco-efficient machines.

Finally this process is based on the 3 starting assumptions of this research also mentioned in section 2.1:

I. Eco-efficiency is based as a meaning i.e. a message to be communicated
II. The product character can be 're-designed' to communicate a certain 'meaning'. (Adapted from **Klaus Krippendorff**, *The semantic turn, p232-240, 2006,* itself an adaptation of the process suggested by **Reinhart Butter** , *Putting Theory into Practice: An Application of Product Semantics to Transportation Design*, 1989.)
III. **Product characters are described by adjectives (or visual metaphors)**. (Gorno & Colombo, *Attributing intended character to products through their formal features*, 2011) & **Klaus Krippendorff**, *The semantic turn, p157, 2006.*

Since Krippendorff (2006) says "by definition, the character of an artifact consists of all adjectival constructions that a community of stakeholders in that artifact deems suitable to that artefact" the starting steps of this entire process is to discover and capture the adjectives which are associated with Eco-efficiency.

7.2 Methods and tools of the design process

The next figure highlights the 7 major steps which were utilised in order to cross all the 4 stages described previously for designing an Eco-efficient appliance.

The first 4 steps of this process have been adapted from the process model suggested by Roberta Gorno in '*Designing emotions through industrial products features*, for her PhD thesis. These first 4 steps address the process of extracting adjectives which are used to represent each design concept and later construct the characters.

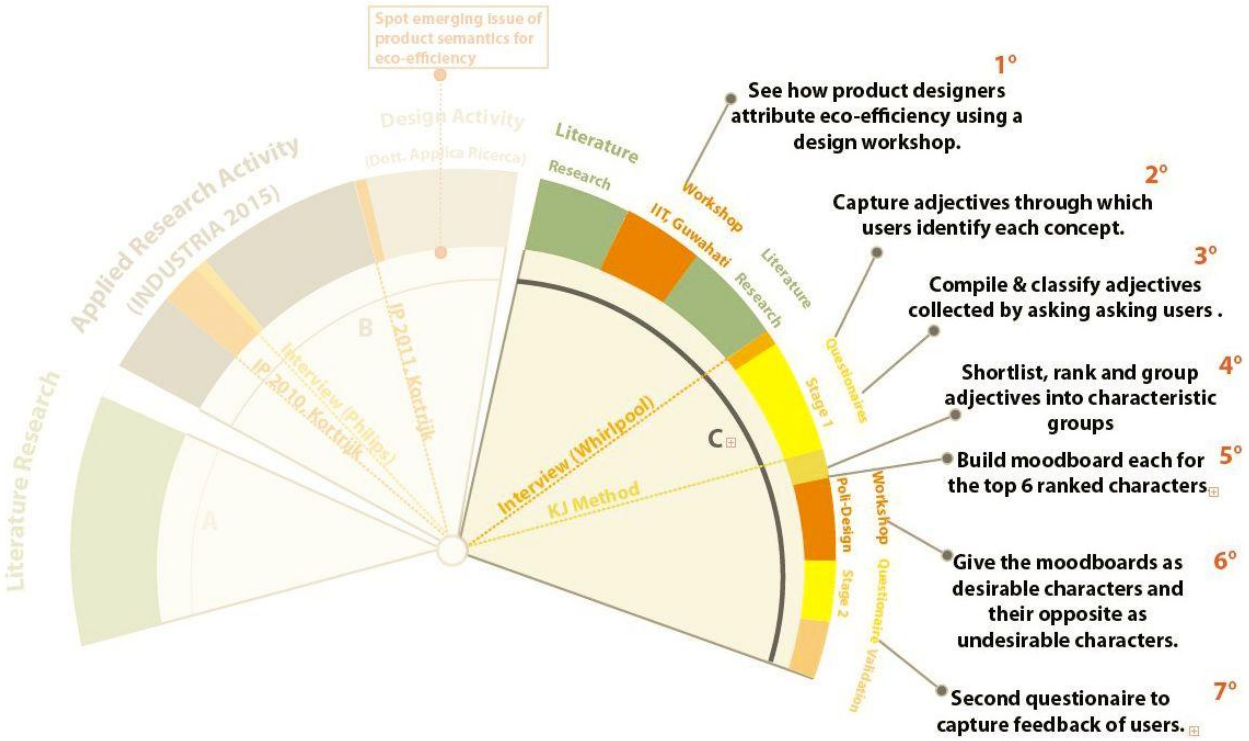


Figure 83: 7-step process to designing a washing machine which expresses Eco-efficiency

The steps 4-7 of the research process were adapted from the process suggested by Klaus Krippendorff in '*The semantic turn',2006,* itself an adaptation of the process suggested by Reinhardt Butter in '*Putting Theory into Practice: An Application of Product Semantics to Transportation Design*' (Design Issues, vol V, No.2, 1989). The 8 step heuristic (i.e. experiential) process developed and suggested by Butter was designed specifically to apply the theory of product semantics in developing products which are very clear in expressing their product characters. Butter described this process as "somewhat linear with clearly distinguishable phases", which is also applicable to the process being described here. The difference is Butter applied this process for the development of semantically relevant trunk cabin interiors, and the target product characters he had to semantically express were already known, whereas in this case the process is applied to developing semantically expressive washing machines using product characters which were unknown at the beginning of the process. Since the issue being addressed here is the expression Eco-efficiency, which in itself is a semantically uncertain entity, the first step was to discover and extract which exactly are the characters which users associate with Eco-efficiency.

Based on the process of Butter (1989) and Gorno (2010) it was substantially established that characters could be described through adjectival constructs, therefore the first step was to get hold of the adjectives to be associated with Eco-efficiency. The steps of the systematic design process used in this research are listed below in accordance with figure 64:

Step 1: See how product designers attribute Eco-efficiency in a washing machine using a design workshop

Step 2: Perform a questionnaire to capture the adjectives through which users identify each concept.

Step 3: Compile and classify the adjectives collected by asking users (adjectives describing objectively measurable qualities were discarded; only adjectives describing communicative qualities were kept).

Step 4: Shortlist, rank, and group the collected adjectives, and identify each group with a representative character.

Step 5: Build a mood-board to visually portray manifestation for each of the finalized characters.

Step 6: Give the mood-boards as manifestations of desirable characters as input for a second design workshop. Moodboards will also point out the antonym of each character, as undesirable character to be avoided by the designer.

Step 7: Perform analysis on the final outcome to see which characters resulted in washing machine designs successful at expressing Eco-efficiency through a non-instrumental product experience.

7.3 1st Design Workshop (Indian Institute of Technology, Guwahati, India)

Step 1

The design workshop in IIT, Guwahati was planned over a period of 7 days with 8 students from the Master in Design-second year students. This workshop was the first step of the research process described previously. Since a visual expression of Eco-efficiency has not yet emerged in the appliance industry, this workshop was designed to test how designers would approach the expression of Eco-efficiency through the intrinsic features of the washing machine.

Even before the first step was initiated a suitable appliance category had to be selected. The choice of choosing a washing machine was made consciously after discussion with User Experience Specialists within the Whirlpool Global Consumer Design division and subsequently based on 3 important factors:

1) Select an appliance category which doesn't change too much from region to region. A front loading washing machine was a universally recognized product category, due to the fact that the features and capabilities offered across different markets globally were quite consistent and consumers from any cultural background would recognize it easily.
2) Literature on Eco-efficient household appliances has acknowledged that a washing machine is in the centre of European energy labeling and energy efficiency policy debates (Lorentz and Woersdorfer, 2009) such as the 'Eco-design Directive' for Energy Using Products (EuP Directive 2005/32/EC). This emphasizes the relevance and importance of this appliance category.
3) Washing machines serve several consumer needs instead of refrigerators for example, and as a result afford several and more complex user behavioral variety (Lorentz and Woersdorfer, 2009). Users of refrigerators do not make as big a difference for environmental friendliness as they do for washing mahines (Datschefski, 1999). User behavior influences the Eco-efficiency of a washing machine directly through for example incomplete loading, wrong cycle selection, water temperature selection, detergent dosage to name a few. This means users have a deeper

interaction with this appliance and thus the appliance appearance could play a more important role.

Further as has already been discussed previously, a washing machine has a lot of technical features built inside of it which increase the environmental performance of the appliance thereby giving the designers a good amount of technology which they can communicate through the intrinsic features of the appliance.

The output of the workshop had to be carefully controlled, in the sense that the focus was to be strictly maintained towards expressing Eco-efficiency through the form, geometry, proportions and composition of the appliances. The students were asked not to focus on colour, materials, and finish. This consideration was taken keeping in mind the insights of Karana and Hekkert (2010) on how meaning attached to materials and colour can affect the user's perception of form and shape of the product. They define *form* as "the boundary of matter by which we distinguish these objects from each other and their environment (Muller, 2001). They define *shape* as that which "determines an object's boundary, abstracting it from other aspects, such as colour and material (Chen, 2005).Thus although not restricting the students from expressing colours and finishes, they were asked not to attach too much importance to it.

Finally this workshop is the first step to realizing the application of the Product Semantic theory into expressing Eco-efficiency in an appliance. The final output of this step should enable the author to extract adjectives associated with Eco-efficiency, hence a clear and consistent level and quality of detail was sought in all the 8 projects being developed in this workshop. A successful outcome of this process will be valid not just for washing machines but all major appliance categories.

7.3.1 Methodology

This workshop was integrated into the regular coursework of the design students in IIT, it was a voluntary workshop inviting only those students genuinely interested the topic being addressed here. There were 8 students in total who participated and all of them developed a concept on an individual basis. The theme introduced to the students was to:

'Express the Eco-efficiency of a washing machine only through its intrinsic features without disrupting too much the current technical architecture of the mechanical components'.

As a starting point, students were introduced to the theme of Eco-efficiency in general just so that all of them are brought up to a common vision and idea about what Eco-efficiency in product design means. Although the students weren't actually formally informed that the workshop they are performing is part of a bigger research process, this was done in order to not unnecessarily limit the creative freedom during the course of the workshop. Although some restrictions were put into place regarding the nature and quality of the output, they were carefully dictated to the students so as to be presented more as challenges rather than boundaries of exploration. Before the students actually started designing anything, a basic theoretical grounding was given to all of them, which aligned them to the final goals and objectives of the workshop. The 3 major insights were given to them:

1. The first insight was to inform the workshop about the general background of Eco-efficiency. What Eco-efficiency means, what in theory Eco-efficiency aims to achieve, and what are the product design implications of it.
2. The second insight was eliciting examples from the appliances industry in general to give the students a further grounding about what is the present scenario of domestic appliances with respect to Eco-efficiency, followed by a focus on the washing machine sector. This included giving them all the relevant technical and functional details of a typical front loading washing machine i.e. the standard dimensions, the different components, and present technical limitations of production. The students were also given a list of standard components of the washing machine which they had to incorporate with or without modifications. This included the steel drum, the motor, the detergent dispenser, the interface controls. Right from the beginning the students were asked to keep their concepts technically feasible. The students were asked to not innovate new technologies for a washing machine on which to base their concepts, but to use existing standard technical components and keep manufacturing limitations in mind. This was done to keep the students from getting conceptually lost and end up with designs which could not be recognized as washing machines by ordinary users.
3. The third insight was to show examples of Eco-efficiency from other product categories. This was done not so much as a creative insight but more as broadening the point of view and knowledge of the students about the possibilities of Eco-efficiency and the different mediums which designers use to address Eco-efficiency. The author used the classification of Eco-efficiency discussed in section 3.4 for the purpose of this insight.

Finally the students were informed to deliver their concepts in the form of a digital Rhinoceros model format. This was done keeping in mind the insights from Karrana & Hekkert (2010), and it for the purpose of removing backgrounds, colours and other details which might distract the user when further analysis on the results are performed in the later stages of this research process.

Further the students were asked to deliver renders of 3 clear views of their concept: front, right, & isometric; such that all the concepts could be visualized with equal clarity and quality for reasons of visually comparing the outcome of each of the concepts against each other.

At this point it was observed that the students were having significant troubles conceptualizing a design intervention for a washing machine which has to be expressive of its Eco-efficient qualities without conceptually changing the entire architecture of the machine. Designers are more dispositional to addressing Eco-efficiency from a typological innovation rather an aesthetical innovation. "Aesthetical Innovation is related to product recognition, that is to say to how much its appearance is different from that of the competitors" (Rampino,2011). "Typological Innovation relates to the deviation of a product from its formal archetype" (Rampino, 2011)[1]. An aesthetic innovation is related to what Norman describes as the visceral level and thus contributes to product attractiveness. Norman says the visceral level influences directly the senses in the user, which can in return have a strong semantic dimension of helping the user to identify product characters he associates with Eco-efficiency. The aesthetic aspects of a product are closely related to the meaning of an object as is confirmed by Rampino when she cites

[1] Rampino,L., *The innovation phenomena in the product design field*, International Journal of Design, 2011.

Kubler (1972) who says formal aspects of objects are dangerous to separate from meaning, since no meaning can be transmitted without form. She also cites Eisenmann (2007) who defines aesthetical innovation as a series of incremental adjustments to the physical appearance of a product, adjustments that neither alter its archetype nor influence its performances and its technology.

Finally aesthetical innovation can effect the user without the need for a formal interaction between the user and the artifact, thus it is all the more important for the non-instrumental product experience which this research is aiming to address. Although for designers, working on just the aesthetical level of a product without somehow manipulating its internal workings, or the architecture of its arrangement seems to be an inadequate level of intervention. The author realized a practical limitation of this design process, in the sense that the concepts of the semantic theory proposing communication of a meaning or a message through the product's appearance (i.e. intrinsic features) was not easily accepted by the professional design community. The author at this stage had to make it very clear to the students that this workshop was not a 'styling' exercise which Krippendorff describes as a concept which bypasses the issues of meanings, but on the contrary the students had to pass an intended meaning of Eco-efficiency through the appearance of the washing machine. The difficulty of this approach is illustrated by the fact that at least 2 students decided to quit the workshop after the challenges of it became clear, because they were convinced even upset that a designer ought to work on a typological level and not on an aesthetical level when addressing Eco-efficiency. Athavankar (2009) too attests to this challenge by saying '*It is a normal practice to mix issues like product function, aesthetics, technology and culture in discourses of form. Isolated discourses on form have always been seen as suspect.*'

7.3.2 Outcome

Each of the design concepts developed with 3-4 keywords in mind. These were in a way the target character that each of the concepts was trying to address. Although these keywords were generated individually by each designer, they were the result of intense discussions amongst themselves regarding what adjectives are representative of Eco-efficiency in their view. Three of the concepts are discussed here, amongst the total of 8 concepts, which can be found in appendix 3.

Concept 1: *Economical, Transparent, Reduction, Recycle, Movement*

This concept attempts to make the internal workings of a washing machine apparent to the user, as expression of honesty in saving of resources while washing clothes. Although the outcome is not an aesthetical innovation, but a typological one, it is quite expressive in its expression of making the

movement of water and the steel drum quite apparent. Although the colour has been removed from the image above it is quite clear the use of white and transparency has been highlighted by the designer as representative of Eco-efficiency in his point of view.

Concept 2: *Reduction, Balance, Minimal, Simple*

Concept 2 sought to preserve the aesthetical archetype of a washing machine when viewed from the front, but when viewed from an angle, the volume reduction achieved becomes apparent. The concept is quite close to a traditional washing machine in its architecture, although due to reduction in the depth of the steel cabinet which houses all the technical components of the appliance, the steel drum now bulges out and is spherical in its design thus it now rotates freely in all directions during the wash cycle symbolising balance in the designer's view. This outcome has come closest to fulfilling the requirements of the brief making it an aesthetical innovation, and even a uninformed user can identify it as a washing machine upon just a visual gaze.

Concept 3 visualises the washing machine as compressible appliance which can reduce when not in use. The character of collapsibility is very visible in this concept, even though it has succeeded in breaking away too much from the architecture of a conventional washing machine. Although in its collapsed state this concept doesn't really express any particular character which might distinguish it from a conventional washing machine. Its attempt to address Eco-efficiency becomes apparent upon viewing its mechanism of collapsibility, thus it has been classified as a 'mode of use' innovation in keeping with the innovation classification proposed by Lucia Rampino (2011).

Concept 3: *Collapsible, Compact, Compress*

Many amongst the rest of the concepts not discussed here were typological innovations, some of which significantly changed the architecture and composition of a washing machine such that it could be

difficult to recognise it as one by the casual observer. Apart from the 3 concepts discussed above these 2 concepts were also quite successful in addressing the brief of the workshop (figure 84).

Figure 84: Eco-efficient washing machine concepts

This outcome was in line with concern cited at the beginning of the workshop about the designers' reluctance to work just on the appearance of an artifact when dealing with Eco-efficiency. This tendency might point out that just as in language the position of Eco-efficiency is not semantically clear. As designers haven't yet understood how to visualize Eco-efficiency using existing product typologies, even those typologies which might have very Eco-efficiently performing technologies inside them, they have difficulty in giving shape to the product intrinsic features which express this quality.

After the conclusion of the workshop these results were discussed with the advanced concept development specialists in Whirlpool Europe's *Global Consumer Design* division. Even the designers there were favoring the concepts of which were typological innovative such as concept 1. In general their feedback was the designers should have been given more freedom when dealing with designing for Eco-efficiency, suggesting very futuristic ideas such as using microwaves instead of water to clean clothes, or even completely rethinking the manufacturing technologies surrounding washing machines, preferring to use scenarios which can reinterpret the meaning of a washing machine when addressing Eco-efficiency. This proves the insight that designers haven't yet figured out the expression of Eco-efficiency using just an appliance's intrinsic features.

7.4 Test activity 1: Visual questionnaire with non-expert users

Step 2

The step 2 of the research process was to collect a list of adjectives which potential non-expert might utilise to identify each concept. In order to do this, a visual questionnaire was designed which clearly displayed all of the 8 concepts developed in the earlier design workshop from 3 angles. In keeping with the earlier pointed out concerns of maintaining visual clarity and focus on only the form and geometry of the concepts, all colour, finish, material, and backgrounds were removed. All the concepts were visualised in black and white against neutral or white backgrounds.

The users were asked to simply put 3 adjectives against each of the concept in a spontaneous manner. Upon performing a pilot feedback amongst a few users this task proved more difficult than imagined.

Users from non-technical and creative backgrounds had significant difficulties in articulating their thoughts in the form of 1 adjective while attributing it to an object. As designers are trained in such a skill, they tend to take it for granted. The structure of the questionnaire was thus modified.

Right at the beginning of the questionnaire was inserted an image of a standard front loading machine with all its standard dimensions. Instead of just adjectives the users were asked to use 3 descriptive words to describe each of the washing machine concepts. In all 30 participants were asked to fill up this questionnaire, they were evenly split between 15 females and 15 males within the age group of 23-53. Their nationalities and cultural backgrounds were very diverse and mixed, as was their professional background and none of them came from a design background.

The respondents faced difficulties in articulating their feedback into single words and associating adjectives with non-animate objects such as appliance (Blijlevens et al, 2009). This observation is also in-line with what Gorno (unpublished doctoral thesis, 2010) faced during her research process of asking users to describe pens using adjectives.

There was a second part of the questionnaire which asked users to rate the Eco-efficiency of each concept. At this point they were informed that these are Eco-efficient machines and were given a brief definition of Eco-efficiency so that understand what it means. The users were asked to rate if they believed the concept appeared: *very Eco-efficient, some-what Eco-efficient,* or *not at all Eco-efficient*. A complete sample of this questionnaire can be found in appendix 4.

7.4.1 Results and insights

The 3 concepts discussed above were also the most highly rated concepts in the questionnaire. 60% of the respondents voted for concept 1 as appearing highly Eco-efficient, while 50% of the respondents said concept 2 and concept 3 appeared highly Eco-efficient. The respondents were free to rate each of the concepts independently of other concepts. In addition no clear patterns were noticed in terms of adjective usage and appearance preference with respect to nationalities or gender. This could be explained by the fact washing machines are appliances, and unlike products such as cars they do not really have any cultural identity or preferences with respect to appearances or features. People across all nationalities and cultural backgrounds view appliances as a necessity and more of a convenience than something through which they can be identified. As Krippendorff (2006) said, users tend to surround themselves with objects which make sense to them and with which they can construct their unique identity. Well appliances are more of a utility in the eyes of the users than a source of identity.

Furthermore appliances which appeared closer to the appearance of a conventional washing machine architecture vis-à-vis the arrangement of their major components such as: the opening to insert the laundry, the shape of the major components such as the steel drum, believability of placing the technical components such as the motor, were rated as the most Eco-efficient. Users automatically excluded the concepts which appeared too conceptual and deviated too much from the identity of a washing machine in terms of shape, geometry, composition and other such intrinsic considerations. In fact amongst the above 3 concepts which received the maximum votes, concept 2 and concept 3 appear almost emulating the traditional appearance of a washing machine, the cleverness of their design solutions doesn't detract their visual arrangement as a washing machine to the untrained eye. Concept A though a typological

innovation could still be easily identified as a washing machine and users could imagine easily how they would operate it. On the other hand concepts such as the ones in figure 85 below were rated low in terms of Eco-efficiency, because users would find it difficult to image how they would use this machine, thus not believing that such a machine is capable of functioning well and consequently therefore not an Eco-efficient design.

Figure 85: Eco-efficient washing machine concepts

This also confirms Krippendorff's insight that users never really look at an artifact in isolation but always sense it in a context, such as how will it be used, how will it behave, how will the user appear using such an artifact etc. Just as well, the designers might find this insight useful and a case in point that effective communication of Eco-efficiency is more important than just typologically re-conceptualizing the entire product. In the end appliance concepts which were conventionally structured by virtue of the internal arrangements of the technical components, but paid attention to using appropriate visual cues were more welcomed and better understood than concepts which relied more on breaking the archetype of the washing machine. The latter category couldn't communicate well with the users because users didn't know how to interpret such concepts. In the end the most valuable insight gained was that if users aren't convinced that a design concept is functionally and technically capable of performing as a good washing machine, due to the ambitiousness of the concept, then they will also rate it low in terms of Eco-efficiency.

Figure 86 shows the data distribution of the evaluation captured in terms of percentage of respondents for the 3 highest rated concepts.

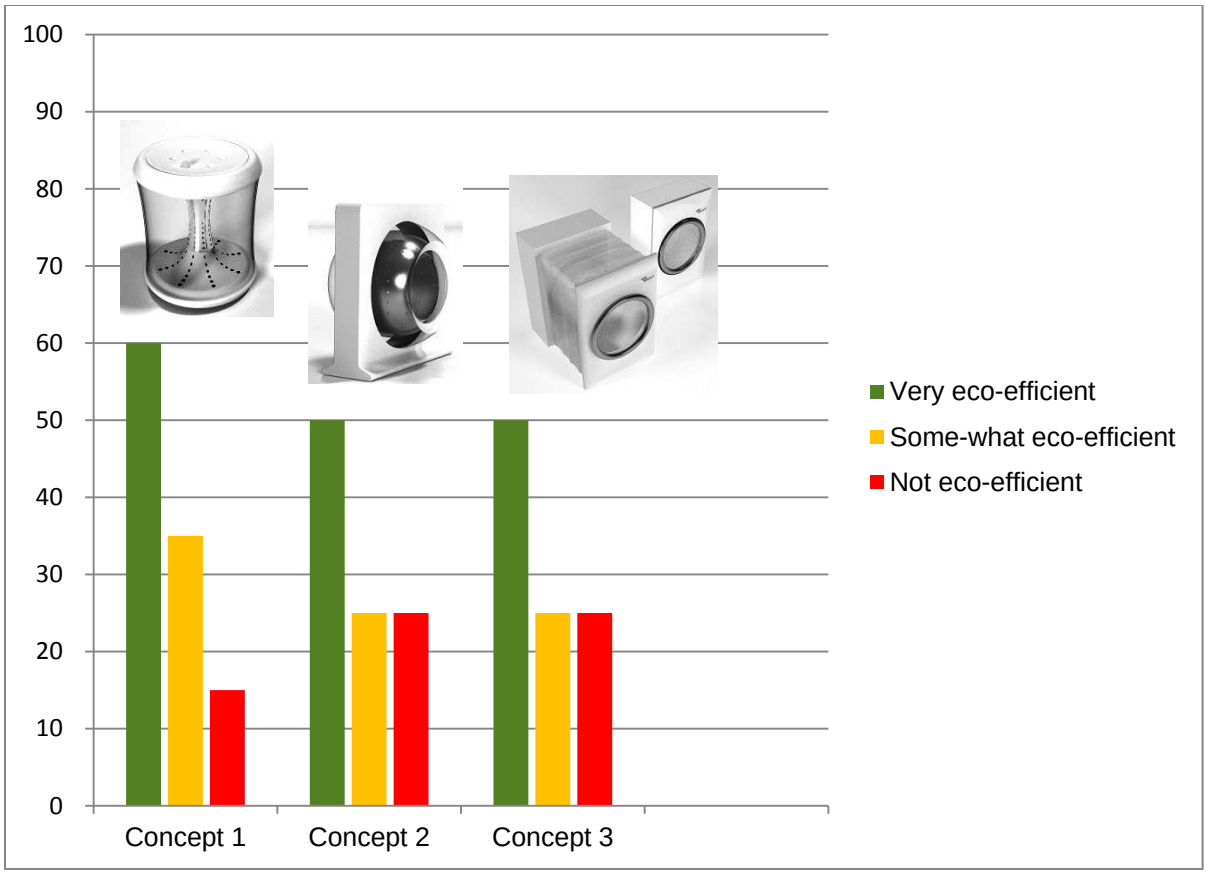


Figure 86: Distribution of respondents in percentage (%)

7.5 Compilation and classification of captured adjectives

Step 3

Only the adjectives which correspond to the 3 highest rated concepts were collected and classified according to the classification proposed by Krippendorff in his adaptation of Butter's process of applying product semantics to designing artefacts. He proposes the following 5 classifications of adjectives:

I. *Objective adjectives* – they measure the physically measurable properties of an artefact.

II. *Aesthetic adjectives*- they evaluate the different aesthetic aspects of an artefact.

III. *Adjectives of social value*- they measure the social aspects and positions of an artefact.

IV. *Adjectives of emotions*- they measure the different emotional states triggered by the artefact.

V. *Adjectives of interface qualities*- they measure the quality of usability, aspects related to the user experience of the artefact.

Of these categories the objective adjectives were discarded, keeping in mind the observations of Butter (1989), who compares objective adjectives to 'factual attributes' and warns that such attributes only describe "*measurable qualities of how something works*" which are not as important as 'expressive and semantic' attributes which measure the communicative quality of a product. Krippendorff also confirms this point of view when he says designing characters of artefact means designing 'sensory experiences' that confirm the attributes desired by the community of stakeholders who will use the final artefact.

Table 2 below then shows the adjectives captured for concept 1.

Table 2: Captured adjectives

transparency, portable, solid, speed(fast), delicate (fragile), voluminous, spinning, air tight, powerful, tall, compact, cylindrical, narrow, tall, delicate, fast, spacious, light, SLIM, Slender	Objective
stylish, dynamic, muscular, attractive, stable, mechanical, closed, good, mobile, oblong, feminine, rough, stable, dynamic, beautiful, fancy, fluid, symmetrical, harmonious	Aesthetic
different, classy, average, essential, modern, expensive, high-tech, elegant	Social Values
interesting, amusing, nice, fun, closed	Emotions
cyclic, directional, simple, simple, clear, practical, easy-loading, Utilitarian.	Interface Qualities(of use)

Table 3 shows the adjectives captured for concept 2.

Table 3: Captured adjectives

portable, space saving (compact), rotatable, spacious, light, quiet, small capacity (compact), round, spacious, delicate, light,	Objective
suspended, floating, decorative, spinning (dynamic), rotating (dynamic), stable, mixed, swing (dynamic), pacman, circle, squat, twirling (dynamic), round, equilibrium (stable), pretty, air-wash, polished	Aesthetic
unique, futuristic, iconic, cool, different, cool, attractive, modern, simplistic, modern, glamorous, modern, different, futuristic, original, archetypical, nice, modern, different, nice, groovy.	Social Values
attentive	Emotions
container, bucket, practical,	Interface Qualities(of use)

Table 4 below shows the adjectives captured for concept 3.

Table 4: Captured adjectives

space saving (compact), condensed (compact), compact, delicate, space saving, space saver, light, large capacity, weak, spacious, compact, foldable,	Objective
neat, smart, novel, elegant, stable, sleek, sleek, minimalist, sharp, concise, slender	Aesthetic
clever, classy, amazing, unconventional, awesome, ecological, modern, expensive, traditional, modern, antiquated, modern, profound,	Social Values
subtle, nice, great, surprise, brilliant, genius,	Emotions
safe, mobile, collapsible, folding (collapsible), flexible, practical, extendible, flexible, collapsible, simple, folding, easy, practical, complex, conceptual, practical, efficient, convenient, practical, simple	Interface Qualities(of use)

7.6 KJ Method- Shortlisting, clustering & ranking of product attributes

Step 4

The KJ Method is a technique which simplifies effective group decision making. It is based on the premise that when participants are informed of each other's perspectives on the same subject their decision making power can increase drastically (Spool, 2004).[2]

This process which was performed within a focus group (constituting of 4 researchers within the research unit IDEA) was utilised here to select and rank the most appropriate adjectives amongst the ones above and organise them into characteristic groups, with a representative character for each of the groups. Of course before the KJ method was started all the objective adjectives were discarded.

The steps of the KJ method are described next.

I. Determine the focus question- in this case the question was to organise the above adjectives into characteristic groups.

II. Organise a group- in this case the group was a focus group organised within the research unit IDEA consisting of 4 researchers.

III. Put data onto sticky notes- having discarded all the objective adjectives, the remaining adjectives were now treated as attributes and each attribute was written on 1 post-it.

IV. Put sticky notes on wall- In this case all the post its(similarly coloured) were put onto the wall where all the researchers could see them.

V. Group similar items together- all the participants are asked to go to the wall and group similar adjectives into groups according to their meaning. The use of a thesaurus is recommended in this stage. All the participants asked to refrain from discussion and take turns in arranging the notes into groups. If a participant disagrees on a grouping he is free to rearrange a grouping performed by another participant. It could so happen that some attributes don't fit into groups and they can be left individually in a group by themselves. Although a discussion is permitted in case of a dispute regarding the classification of some particular attribute, but normally the dispute of just 1 or 2 attributes has no significant impact on the final outcome of the process.

VI. Once the groups are arranged to everyone's satisfaction, each participant is asked to select a name for each of the groups. This name is one of the attributes within the group and will later become the character representative of the entire group. Each participant is asked to write the name of the groups in separate coloured post it and stick it next to the group. A participant is excused from naming a group if a previous participant has already given the name he had in mind. At this stage a group can have more than 1 name.

VII. Finally each participant votes for each of the groups. In this step a discussion was allowed and through detailed discussions and debating the most important groups were marked out which

[2] Source: Spool, Jared M., *The KJ Technique: A Group Process for Establishing Priorities*, 2004, http://www.uie.com.

satisfied everybody's choice. The groups which everyone felt were not important were discarded. Since the purpose of the KJ method here is to extract characters which will be used as input for the next stage workshop on designing Eco-efficient washing machines, it was decided that 6 characters with their representative attribute groups would suffice for the target workshop. Finally a definitive character was selected amongst the candidate names decided in the previous stage. Here consideration was given to the number of times the adjective showed up in the previous questionnaire analysis. Adjectives with the highest number of occurrences within an attribute group were selected as the representative character of the group, unless everyone disagreed.

VIII. A ranking can be performed here based on a group voting, but in this case that was not necessary. The selected characters were ranked according to the number of respondents who used them in the previous questionnaire stage. For example the adjective 'futuristic' was used 12 times, feminine was used 12 times, unconventional was used 9 times so on and so forth. Hence amongst the final 6 characters selected, the top 3 characters were designated as 'dominant' characters, and trailing 3 characters were named 'recessive' characters.

Character	Futuristic (12)	Feminine (12)	Unconventional (9)	Practical (7)	Simple (5)	Smart (5)
Attributes	Modern	Light, Slender, Delicate	Unique, Different, Original, Surprising, Novel, Amazing	Convenient, Utilitarian	Easy	Brilliant, Genius, Sharp, Clever
Antonym	Traditional	Agressive	Conventional	Unpractical	Complex	Naive
	Dominant Characteristics			Recessive Characteristics		

Figure 87: The final outcome of the KJ method

The figure 87 illustrates the final outcome of the KJ method. In addition once the final characters were decided their opposites (antonyms) were marked. The characters will act as desirable attributes for the next stage design workshop, and their opposites will act as undesirable attributes which the designers have to definitively avoid.

7.7 Building mood boards

Step 5

Mood boards are visual manifestations of the characters shortlisted above. In total 6 mood boards were constructed representing each of the characters. If characters represent the sensory experience of the object, then mood boards are the manifestation of that experience in the form of product features depicted visually. Krippendorff (2006) suggests including images of competing products, factory samples, magazine cut-outs, sketches, and drawing as all appropriate sources. A factor to be considered here is the

role of the designers and the users in building these mood boards. Although the users were the primary contributors in the previous steps of capturing and classifying the adjectives, but this step was entrusted to design experts to come up with the attributions and manifestations of the characters to be designed into artefacts. In the view of the author end users with no design training would simply lack the competence to be entrusted with what is potentially a complex activity of associating adjectives with product features visually. This view is in keeping with what was pointed out in section 2.1 with respect to Liz Sander's map of design research, placing this research firmly in the *'Design-led, Expert mindset'* quadrant.[3] Butter reinforces this approach with his point of view on the mood boards; he says mood boards are the most important step in the entire 7 step process being discussed here. He suggests to use the technique of free association entrusting designers to come up with all and any tangible manifestations of the characters thus ensuring creativity and avoiding 'sterility' in the end results. He also warns only trusting designers with this delicate task since only they possess the necessary skills to associate an adjective to a tangible product feature.[4]

Figure 88: Moodboard of Futuristic and Unconventional characters (note that they also point out the undesirable characters – traditional and ordinary, which are to be avoided by the designers).

Figure above shows the moodboards of the character futuristic and Unconventional. Although the images were selected as a visual manifestation of the characters, the moodboards also mentioned the other characteristic attributes which are synonimous to the character according to the grouping done in the KJ method in the previous step. The moodboards also point out the opposite of the desirable character (in the case of futuristic its traditional) which would be the undesirable character which designers have to definitively avoid attribution of.

In the case of this research the mood boards were built with the participation of the researchers from the author's research group. Each of the researchers suggested images which they associated for each of the 6 characters, these suggestions were then discussed and debated amongst the researchers to finalise a definitive selection of the images which were then arranged on to a slide. The images were collected from

[3] Sanders,L., *An Evolving Map of Design Practice and Design Research,* Interactions, Vol. 6, (Nov, 2008), pp. 13-17.
[4] Butter,R., *Putting Theory into Practice: An Application of Product Semantics to Transportation Design,* Design Issues, Vol. 5, No. 2 (Spring, 1989), pp. 51-67.

various online sources, books, design magazines, and product websites. An interesting insight to this process came to light upon searching for a perticular character using Google image search, which brought out the popular attribution of the character, such as the over whelming association of the colour white and geometric patterns to the character 'futuristic'. It was ensured that borderline examples which could perhaps be debated between 2 characters were intentionally avoided; in the end only those images were used which were very distinct from the images representing the other competing characters. This was done to ensure that the designers who would utilise these mood boards would face no confusion when attributing these characters as intrinsic features of the products. Refer appendix 5 for all the moodboards.

7.8 2nd Design Workshop (PoliDesign, Italy)

Step 6

The second workshop was also based on designing the expression of Eco-efficiency in a front loading washing machine. It was planned to relfect the learning from the first workshop. This step enforces the moodboards developed into the previous step into "semantically feasible" (Butter, 1989) solutions. Although output of this workshop was the same as the previous one i.e. *the expression of Eco-efficiency through intrinsic product features of an appliance*, the means of achieving the output were now dictated by the attribution of product characters and the use of moodboards.

This workshop was a test to see if utilising product semantics can improve the communication of Eco-efficiency in a washing machine in comparision to the previous workshop results. Instead of just giving a brief for designing the expression of Eco-efficiency, in this case the designers were asked to primarily design for the expression of the characters provided to them, keeping Eco-efficiency as a background concern.

The output of this workshop would determine if the 7 step approach adapted here would work sufficiently well to be applied in the appliance industry. In addition the output was again requested as a Rhinoceros digital file, to control the final quality using the same considerations of colour, finish, materials, and background as already pointed out in step 1.

7.8.1 Methodology

The 6 characters arranged in 7 combinations of 3 characters each (table 5). This was done to achieve the best fit between the number of students (14) and the number of characters (6). Each character combination setting consisted of 2 dominant characters and 1 recessive character. The design students were asked to prioritise the expression of the dominant characters with the expression of recessive character acting as a support for the overall character attribution of the washing machine.

Dominant Character	**Dominant Character**	*Recessive Character*
Futuristic	**Feminine**	*Smart*
Futuristic	**Feminine**	*Practical*
Futuristic	**Unconventional**	*Simple*
Futuristic	**Unconventional**	*Smart*
Feminine	**Unconventional**	*Practical*
Feminine	**Unconventional**	*Simple*
Feminine	**Futuristic**	*Simple*

Table 5: 7 combinations of desirable characters

Using 7 combinations meant each combination would be given to 2 students, thus ensuring that the final result is not too characteristic of just 1 designer's approach. Gorno (2010) pointed out in her doctoral thesis[5] that having just 1 example of each character can be illustrative of only that product's features and ideosyncrasies thereby potentially disrupting the results of the final feedback analysis to be performed in the next step. Although Butter (1989) has also lent his thoughts to this aspect by saying that " *there is obviously never just one single set of semantic manifestations for a given design*", thereby confirming that if more number of examples could be developed for attribution of each character, then the results would be more illustrative of the actual attribution of the character in question.

The same restrictions were imposed upon the students as in the first workshop by asking them to preserve the internal technological mechanisms and workings of a washing machine and address only the external appearance (figure 89).

[5] Gorno,R., *Designing emotions through industrial products features*, PhD thesis, Politecnico Di Milano, 2010.

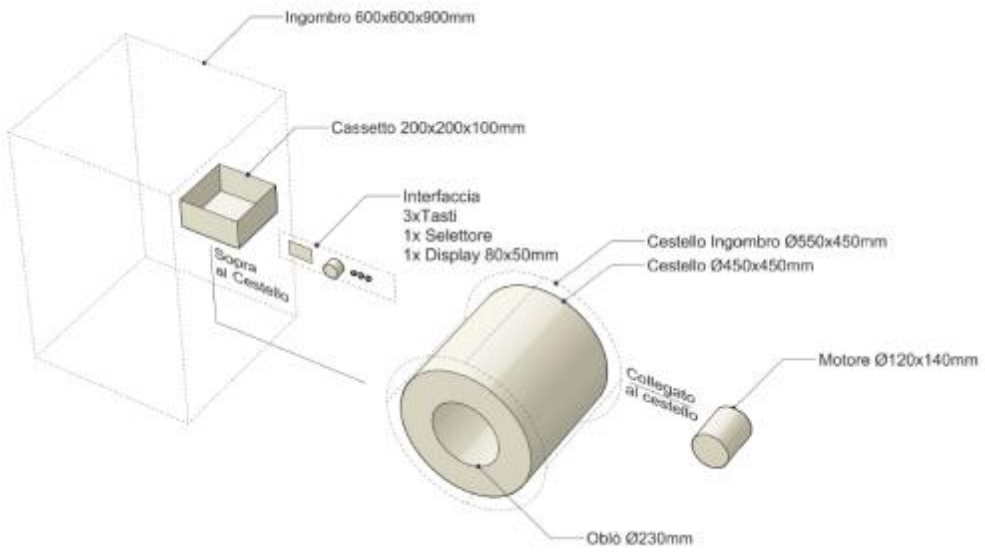


Figure 89: The technical components and the outer dimensions of a washing machine which the designers were asked to respect

The final output would thus end up with 14 washing machine concepts each one semantically expressive of the characters set given to them. It should be pointed out that though the semantic expression of the appliances are the primary concern of the research here, and by itself the semantic expression is an interesting outcome, but in reality this expression should not interfere with the technical performance of the appliance in question. Although during the discussions generated in the concept development stage topics of usability, technical feasibility of the proposal, and manufacturabilty was given their due diligence, but the concern for these factors was placed secondary to main over riding concern for clear semantic expression.

7.8.2 Outcome

2 of the 14 students couldn't complete the objectives of the workshop to a desired level therefore only 12 concepts were considered the final output of this workshop. The first 2 characters in each set represent the dominant characters.

Character set **1**: *futuristic, unconventional, simple*

Concept 1

Concept 4

Character set **2**: *futuristic, feminine, simple*

Concept 6

Concept 8

Character set **3**: *feminine, unconventional, simple*

Concept 5

Concept 9

Character set **4**: *futuristic, feminine, smart*

Concept 10

Concept 12

Character set **5**: *futuristic, feminine, practical*

Concept 2

Concept 11

Character set **6**: *feminine, unconventional, practical*

Concept 3

Character set **7**: *futuristic, unconventional, smart*

Concept 7

The above 12 concepts demonstrated a wide breadth of design approaches and creative solutions to develop a washing machine reflecting a certain character set. All of the designs didn't strictly respect the brief of designing a washing machine which can be operated from the front, though they all respected the Although certain common design features were already beginning to emerge, but these will be discussed after the results of the next questionnaire feedback are captured. From a point of view of design innovation all concepts extensively explored a variety of aesthetical appearances not traditionally associated with a conventional washing machine (thus strongly aligned towards aesthetical innovation), projecting a new identity which a washing machine could potentially acquire in the domestic scenario. Some designers developed their concepts with a scanario in mind, thus meaning attribution was subconciously a priority through out the design development process.

7.9 Test activity 2: Visual questionnaire with non-expert users

Step 7

This questionnaire was performed online utilizing a semantic differential scale to evaluate each concept and consisted of 20 respondents (11 females and 8 males) of age group 19-54 with mixed nationalities. According to the SD scale (figure 90) the range of votes varied between -3 (not at all Eco-efficient) to +3(Very Eco-efficient) for each concept, thus 'zero' being the over-all neutral median.

The structurre of the questionare randomised the arrangement of the concepts to ensure that 2 concepts using the same product characters did not appear one after the other. This was done in order to ensure a more balanced and unbiased feedback. Since this questionaire only asked the users to rate the appearance of the washing machine concepts, unlike the previous one where complex adjectival attributions had to be made for each visual, the respondants found it much easier to respond.

In order to make it clear to the ordinary users what Eco-efficiency means a simple definition was included in the beginning of the questionaire. Also included was an image of a standard washing machine in order to make it easier to make a relative association between the conceptual machines and a standard machine. In the initial pilot studies where this image was not included, it was noticed that ordinary users had trouble recaling how a washing machine functions and the intrinsic details of its appearance. Upon including this image users found it easier to evaluate the 12 design concepts. This observation could indicate that ordinary users have a lesser capacity to make visual connections between 2 shapes, especially based on memory, and it seemed having the image of a standard machine gave them a baseline against which to evaluate a conceptual and thus an unfimiliar appearance.

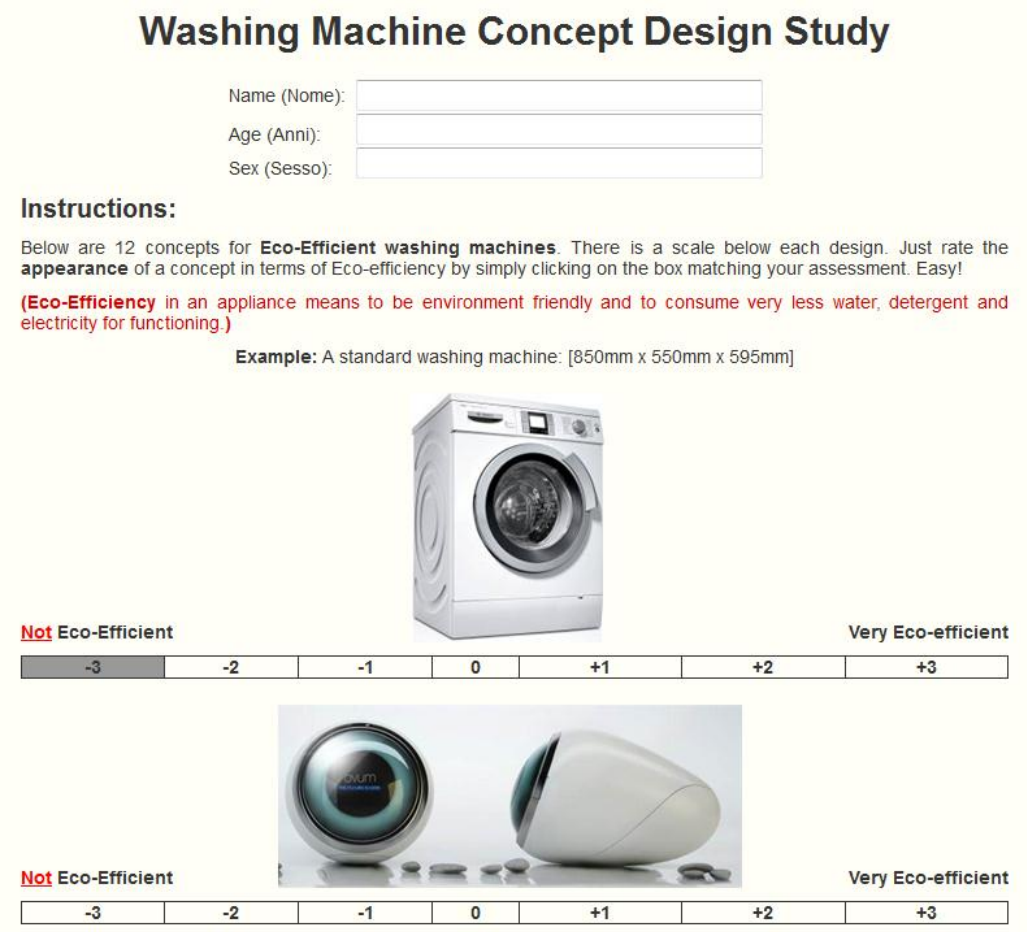


Figure 90: Online questionnaire with semantic differential (SD) scale

7.10 Results and insights

At the conclusion of the study the scores of all the concepts were tallied. According to the SD scale (figure 90) the range of votes varied between -3 (not at all Eco-efficient) to +3(Very Eco-efficient) for each concept, thus 'zero' being the over-all neutral median as a result -60 to +60 being the extremes thus achieving a range of 120 points. (as a sum result of 20 user feedbacks). A perfect concept receiving a very Eco-efficient rating from all 20 respondents would have a SD score of 60. Upon final analysis all but 1concept succeeded in communicating the attributed meaning of Eco-efficiency to the end users. The criterion for success was defined as any concept which scores higher than 50%, or 60/120 or in other words scoring a 'zero' on the -60 to +60 scale. The function used to determine the success rate of each concept was thus:

[(Semantic Differential score + 60) / 120] x 100 = final score (%)

A graphical analysis of the captured data was made for each pair of concepts resulting from a perticular character set (figure 91). Figure also gives an idea of the level of success each concept met, by looking at the individual graph pattern and how much above the median zero it remains. The below graph shows for example that concept 1 was voted very Eco-efficient(+3 on the scale) by 3 out of 20 users and not at all Eco-efficient (-3 on the scale) by 2 user thus getting a SD score of 11 from 20 users and a cumulative score of 71/120 (or a success rate of 58%) on a scale of -60 to 60 (supposing if all the users had rated either -3 or +3 on the SD scale). Concept 4 on the other hand received a SD score of 24 from 20 users or a cumulative score of 84/120 or a success rate of 70%. A full detailed table of the individual scores of all the concepts can be found in Appendix 6.

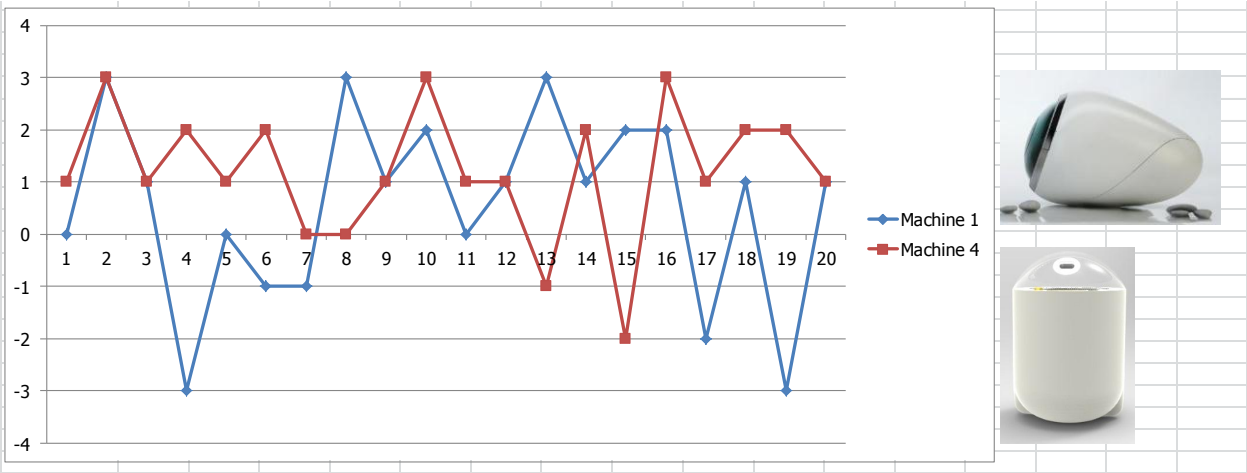


Figure 91: Concept 1 and Concept 4 with product characters: *futursitic, unconventional, simple*.

The next figure compares concept 2 and concept 11, which although using the same character set show quite different results. Although concept 2 got a SD score of 18 and cumulative score of 78/120 or a success rate of 65%, concept 11 got a SD score of only 5 and cumulative score of 65/120 or a success rate of 54%.

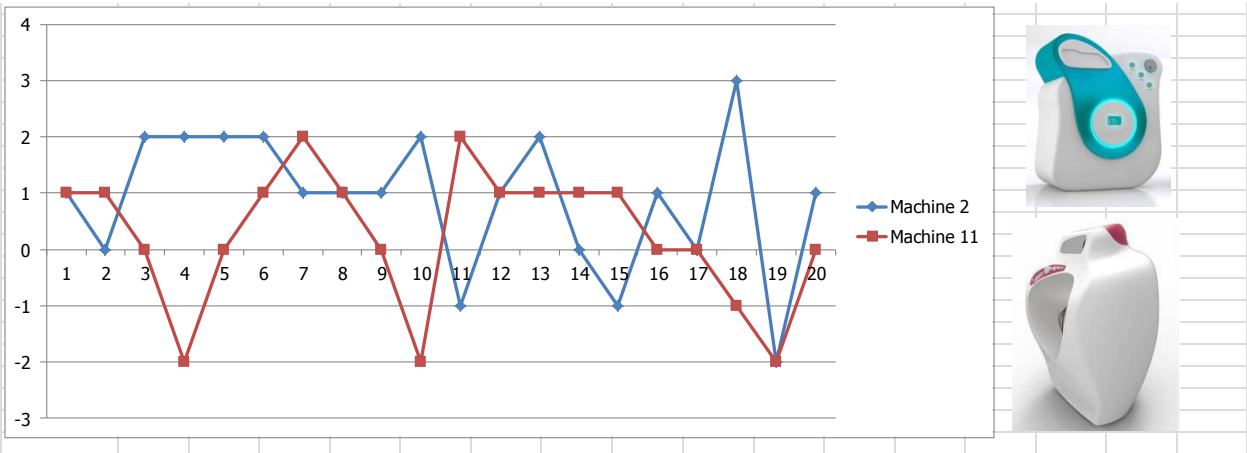


Figure 92: Concept 2 and Concept 11 with product characters: *futurisitc, feminine, simple.*

What the above graphs show is that for the same character set, a significant variation can result, which can be put down to the individual approach and competence of each designer. Even then certain patterns in the appearances of all the concepts could be spotted. All the highest voted concepts exhibited rounded organic forms and rounded geometries subduing or outright avoiding the use of sharp corners and stark geometries. Additionally the use of certain colours such as white, lighter tones of grey, and transparency were predominant in these concepts. These observations could point towards the product intrinsic features which consumers prefer to associate with Eco-efficiency (figure).

The top 3 concepts achieved a score of 83/120, 84/120, and 86/120 on the SD scale therefore achieving a success rate of 69% (concept 10- *futuristic, feminine, smart*), 70% (concept 4- *futuristic, unconventional, simple*), and 72% (concept 6- *futuristic, feminine, simple*).

Figure 93: Concept no.**6** concept no. **4** concept no.**10**

It can be said that all the above three most voted concepts are aesthetically quite innovative. Concept 6 and concept 4 have not strictly respected the brief of designing a front loading washing machine, come across looking quite unique with respect to a traditional washing machine. Although perhaps because they paid proper attention to all the interface details, providing the proper 'use cues' with detailing such as a handles which indicate a opening surface, dials which afford turning and other such details which are omni-present in all ordinary washing machines, they come across as quite successful in convincing respondants that they are functioning and efficient washing machines. Concept 10 on the other hand closely resembles the traditional appearance of an ordinary washing machine, though incorporates the contours and physiological indicates of a woman's body form, thus beaking the rigid box-form which ordinary washing machine cannot seem to break.

In fact the only concept which failed to convince the majority of users about its Eco-efficiency is shown below in figure 94. Two respondants voted it with a -3 and three respondants with a -2. In fact the overall SD score of from 20 respondants was a -10 or a cumulative score of 50/120 (success rate of 42%). This concept had appearance feautres which were unique to it. For one it uses a woodgrain finish on its outer surface, which has been typically associated with a clichèd (section 3.4) approach of expressing Eco-efficiency. In fact due to large scale dishonest representation of wooden surfaces in otherwise ordinary consumer products which claim to be Eco-efficient, has resulted in this visual metaphor representing trees to become a dead metaphor or a clichè. Buyers and consumers have perhaps learnt to disbeleive such attempts by designers.

The second pecularity of this concept was the starck geometry which it used, with fractured and angular surfaces, intersected by visible ribs runnig through the external faces. All other concepts gravitated towards organic forms, without corners and well defined edges, using ligher coloured hues on the outer surfaces.

The second project developed with this character set (Character set **7**: *futuristic, unconventional, smart)* could not be considered for final evaluatoin, because the designer faced difficulties in attributing these characters to develop a satisfactory level of finishing and quality in the final delivery. Perhaps this character set could point towards a semantic incompatibility which even Butter (1989) had forewarned against while selecting a character set to be attributed. But it is not possible to definitevely state this, unless a larger number of concepts are developed using this character set.

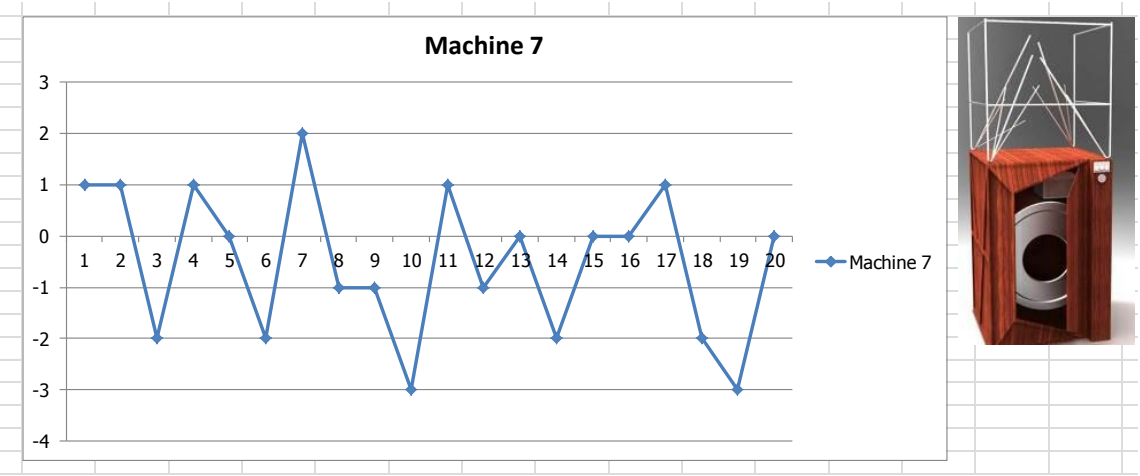


Figure 94: Concept 7 with product characters: *futuristic, unconventional, smart*

A complete list of the graphical analyses of all 12 designs can be found in Appendix 7.

7.11 Limits

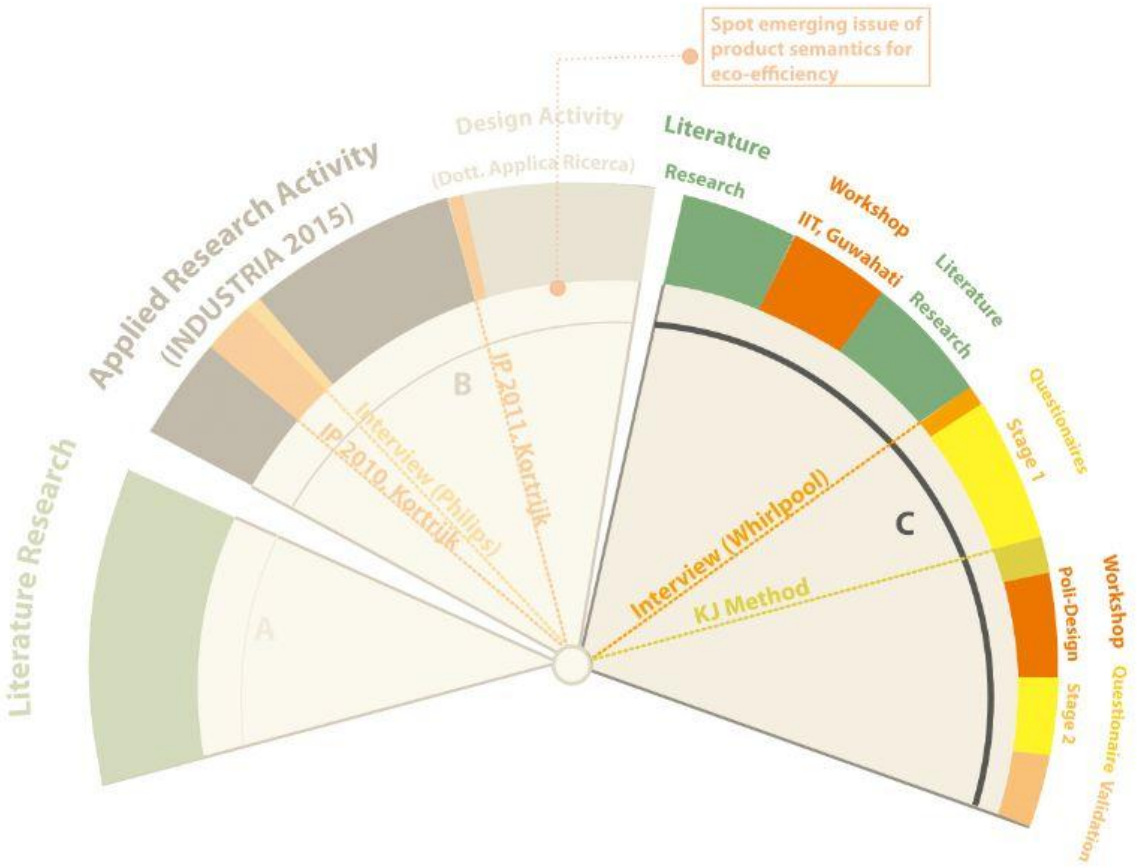
Experts in literature of Product Semantics have adopted design processes similar to the one performed here (Butter, 1989; Krippendorff, 2006, Athavankar, 1990). Clearly the issue of Eco-efficiency is a complex one in relation to energy using products. In addition, the area of product appearances and aesthetics has traditionally been regarded as highly subjective domains, and this process seeks to introduce a level of objectivity through adopting human centred methods (Syarief and Hibino, 2003). Although certain tools such as moodboards have been subject to much debate and contest in relation to product semantic design processes since they still rely on fair bit of intuition rather than objective scientific reasoning or direct user involvement. Athavankar (2009) and Syarief and Hibino (2003) have specifically singled out moodboards as undermining the objective rationale of the product semantic design processes since they ignored the user input and relied on design experts. Although Butter(1989) has argued that the construction of moodboards is strictly the domain of design experts, since only they

possess the necessary skills to make visual attributions of complex verbal adjectives, a position reinforced by Blijlevens et al (2009). The position of Butter aligns with the Design Research map by Liz Sanders'(Interactions, vol-XV.6, pp-14) which presented the Design-Led and Expert Mindset driven approach adopted in this research. From a point of view of literature Athavankar (2009) has proposed alternatives to using moodboards such as building a 'semantic space' to study visual attributions. For the purposes of this research ofcourse, the utilisation of moodbaords as suggested by Butter and Krippendorff worked effectively, as was also attested to by the 12 participants of the second step workshop.

Apart from the visual moodboards, this process still ultimately relies on the unituitveness of the individual participants, who attributed the product characters into the washing machine concepts. This level of subjectivity is difficult to eliminate, though its influence can be somewhat contained by involving designers of equal competence and skill sets who think on the 'same page'. It was noticed that individual capabilties were severly hindenring the successful application of this design process, which also resulted in 2 character sets not resulting in a successful project. Some participants were distinctly more skillful than others in utilising the specific tools such as moodboards, and basically possesed better 'designerly' skills. Unfortunately this meant that all character sets could not be attributed to the same level of quality thereby to some degree effecting the final analysis. This means that even if some character sets were more successful than others, it is difficult to attest to to their effectiveness keeping in mind that only 2 concepts were developed that too by designers with clearly varying levels of expertise. As a result 2 concepts using the same character sets met with such different final scores. For example both concept 2 and concept 11 used Character set **5**: *futuristic, feminine, practical* but while concept 2 received a success rate of 65% concept 11 only received a success rate of 54% (figure).

For the purposes of this research all the character sets have which have resulted in positively voted concepts have been accepted as successful. To prove these results as robust beyond a doubt, much more extensive application of these character sets will have to performed in other appliance categories or perhaps in a different Energy Using Product (EuP) category such as Televisions for example.

8. Design Guidelines for Eco-efficiency



8. Design guidelines for Eco-efficiency

8.1Product characters for Eco-efficient appliances

Although all the product characters can be considered as successful based on the outcome of this research, the individual character sets have been ranked based on the final votes which each concept gained. This has been done not as a definitive indication of which character sets are going to result in designs more expressive of Eco-efficiency, more as an insight to the outcome of this research to generate further discussion. The Character sets have been ranked as following, the constituent characterisitcs of each character have been indicated as enclosed:

1. Futuristic (*modern*), Feminine (*light, slender, delicate*), Simple (*easy*)
2. Futuristic, Unconventional (*unique, different, original, surprising, novel, amazing*), Simple
3. Futuristic, Feminine, Smart (*brilliant, genius, sharp, clever*)
4. Feminine, Unconventional, Simple
5. Futuristic, Feminine, Practical (*conventional, utilitarian*)
6. Feminine, Unconventional, Practical
7. Futuristic, Unconventional, Smart

The six product characters making each of the character sets are: **futuristic, feminine, unconventional, simple, smart, practical**. This research has demonstrated that these characters used in combinations such as above can be successful in communicating Eco-efficiency, although clearly some combinations are more successful as others. For now these characters should be taken as a work in progress which have attempted to throw some light on the issue of Eco-efficient design.

8.2. Future application within other product categories

There are several categories of Energy Using Products (EuP's) which can be candidates for future application of these product characters as design guidelines. The product characters extracted here have merely thrown a light into meaning transmission of Eco-efficiency. Though premature to say, but successful application in another product category will also prove the robustness of these characters beyond a doubt. Although in all likelyhood these characters were extracted for home appliances, and for another product category the design process used here can be performed afresh to extract new characters perhaps more relevant to the product category. The consumer association with Eco-efficiency might differ in language from category to category. The guidelines proposed here are not a rule but merely a suggestion, to the designer, based on experience based investigation carried out here.

The author's experience with Philips LCD TV's and Ridley Bikes discussed in section 5.2 and 5.3 brings to light the validity of this research topic. Similar to home appliances the consumer electronics industry

has also identified Eco-efficiency as an important technical feature of products. In the LCD TV industry for example, Philips has been pushing the development of Eco-efficient televisions for several years without actually building unique product features (section 5.3) specific to Eco-efficiency. The next figure illustrates 2 models of televisions marketed by Philips, the one on the right is their Eco-efficient model and marketed as such, more or less a special model possessing additional qualities which ordinary TV's don't. Clearly in trying to describe the appearaces of both the TV's to distinguish their technical capabilites one would not be very successful.

Figure 95: Philips LED TV Philips EcoNova TV

There is no attempt to project a product character distinct from that of an ordinary product. The Intensive Program on 'Green Products' discussed in section 5.2 was an attempt to design the visual appearance of an Eco-efficient TV which 'speaks' its purpose (figure 96). Although this was just a one-off exploration, it informed the author very clearly that similar to home appliances, Eco-efficiency hasn't yet found an expression in terms of meaning communication even in other Energy using Products.

Figure 96: Philips EcoNova (IP 2011)

At the moment televisions utilise energy labeling similar to home appliances to communicate their Eco-efficient qualities. Hence clearly the premise exists to redesign product characters of even Eco-efficient TV's. Gorno and Colombo (2011) in their research on extracting product characters based on intrinsic features of pens cite the need to endow products with 'soft' values beyond hard technical and functional qualities in order to gain a competitive advantage. The attribution of product characters which communicate Eco-efficiency can be such a soft feature which appliances have upto now lacked. Literature

on Eco-efficient design has discussed how hard information such as life cycle assessment tools, and bill of materials (BOM) reduction guidelines can reduce the creativity of designers due to a fixation effect which such rigid information provides (Collado-Ruiz and Ahmad-Ghorabi, 2010). Collado-Ruiz and Ahmad-Ghorabi in their study on reducing the environmental impact of office chairs discussed that designers are inept at internalising complex environmental data and material analysis tools, which anyway impede upon their creative thinking and end up producing predictable solutions. They instead propose to provide designers with soft information with low amount of objective data to maximise creativity when dealing with Eco-efficiency.

One such source of soft information can be product characters which designers can be asked to attribute without effecting their designerly creativity. The character attribution process has demonstrated to push designers to creatively reflect upon ways to communicate the technical efficiency of appliances.

Finally the salient feature of the design process discussed in this research was its human-centredness. Gorno et al (2011) have attested to the simplicity and easy implementation of certain methods such as creative questionaiers and focus groups which even inhouse design centres of manufacturers can utilise. Involving users in key milestones of the PDP can maximise the effectiveness of the final design solution.

This research then concludes by proposing that the potential for redesigning product characters of EuP's to communicate Eco-efficiency exists, and the re-application of the product characters extracted in this research on a wider scale can be interesting to throw more light in this subject area.

9. Conclusions

9 Conclusions

It has been said more than once in existing literature that theoretical concepts relating to product semantics have been notoriously difficult by the professional design community to accept (Brown, 2006; Evans& Thomas, 2011). Boess (2008) further points out that most designers find it confusing to work with attributing meanings in product design. Keeping these observations in mind the design students in the final workshop were only asked to deal with the concept of attributing specified characters to their washing machine design solutions, without too much concern of dealing with the overall meaning of Eco-efficiency which these characters were eventually going to communicate. Thus the students were not given too much of an academic grounding regarding the background and theoretical constructs of Product Semantics and meaning communication, seeing as such information would be very difficult to internalize by them in the short period of time, reinforcing the similar observations made by Evans & Thomas (2011) in their design workshop of exploring application of product semantics with design students.

The results discussed in section 7.1 demonstrated that of the 12 washing machine concepts, all but 1 succeeded in communicating the attributed meaning of Eco-efficiency to the end users. The criterion for success was defined as any concept which scores higher than 50% in the user feedback study. According to the semantic differential scale discussed in the previous chapter the range of votes varied between -3 (not at all Eco-efficient) to +3(Very Eco-efficient) for each concept, thus 'zero' being the over-all neutral median and -60 to +60 being the extremes (as a sum result of 20 user feedbacks). A perfect concept receiving a very Eco-efficient rating from all 20 respondents would have a SD score of 60 and a concept with 50% success would have a SD score of zero. The function for evaluating the success rate of each concept was thus:

[(Semantic Differential score + 60) / 120] x 100 = final score (%)

Concepts **6** (72%), **4** (70%), & **10** (69%) score the highest in the overall tally thus making them reasonably successful in achieving successful communication of Eco-efficiency. Even concepts **2** (65%) and concept **8** (63%) can be cited as being quite successful in the communication of intended meaning. Only concept 7 gathered a negative score of -10. Though the overall positive feedback of these results validates the selection of the 6 Product Characters as effective design guidelines; some characters were more successful than others which can aid in drawing some conclusions about the appearances most favored as Eco-efficient by consumers. All the highest voted concepts exhibited rounded organic forms and rounded geometries subduing or outright avoiding the use of sharp corners and stark geometries. Additionally the use of certain colours such as white, lighter tones of grey, and transparency were predominant in these concepts. These observations could point towards the product intrinsic features which consumers prefer to associate with Eco-efficiency.

According to the design process discussed in the previous sections, the design guidelines consisted of a set of 6 product characters-*Futuristic, Feminine, Unconventional, Practical, Simple, Smart.* Each character set consisting of 3 characters was appointed to 2 designers (total of 14 designers were present) in order to not make the final outcome too characteristic of the capabilities of a single designer. Each character set contained 2 dominant characters and 1 recessive character, so marked according to the ranking process carried out earlier in the design process.

Figure 97: Washing machine concepts

Concept 6: Futuristic, Feminine, Simple

Concept 4: Futuristic, Unconventional, Simple

Concept 10: Futuristic, Feminine, Smart

The overall success of all the concepts could also be put down to the selection of the product characters (or appearance attributes) assigned to the designers. Blijlevens, Creusen, & Schoormans (2009) cite Simplicity, Modernity, and Playful as appearance attributes universally best recognized by non-professionals (i.e. ordinary users). According to them appointing these appearance attributes within design guidelines increases the likelihood of a successful communication of intended meaning to non-experts. By no means are these attributes meant to replace the expert based attributes described in literature. Among the 6 characters which the design students were asked to attribute in the final workshop at least 2 of them, i.e. Futuristic (modern) and Simple, corresponded to the universal appearance attributes cited above. This could be an underlying reason for the success of the of the 11 washing machine concepts, as they were attributed with appearance attributes or product characters which non-experts can comprehend relatively easily when trying to read the intrinsic features of a designed artifact, seeing as they have limited skills in reading products and even differentiating amongst them in the first place (Blijlevens et al, 2009). All but one of the design solutions (concept no.1) which contained both futuristic (modern) and simple in their character set were each voted one of the highest amongst all the concepts (concept 4-70%, concept 6- 72%, and concept 8- 63%).

The set of product characters were in fact user generated in the first place so it is not surprising that they correspond to the ones cited by Blijlevens, Creusen, & Schoormans. The same design theorists have also demonstrated that these appearance attributes are universal in nature and can be applied to any product domain, thus lending more credibility to the product characters shortlisted here as having relevance in consumer products beyond home appliances. The author's own experience with designing Econova LCD televisions with Philips cited in the previous sections can be a promising domain for near future application of these product characters.

In comparison to the first workshop performed in the Indian Institute of Technology without the assistance of any product characters, the Polidesign workshop results were definitely more successful. Though performed with similar technical design restrictions and the same structure, the first workshop only resulted in 1 concept (figure 72) out of the 8 which was voted by 60% of consumers as appearing Eco-efficient. Only 2 out of the remaining concepts could reach a vote of 50% in appearing Eco-efficient.

In this light, the introduction of the product characters has improved the communication quality of the washing machines designs in appearing Eco-efficient.

Figure 98: Concept 2 – Indian Institute of Technology workshop

Finally it can be said that this research has attempted to shed more light in the complex subject matter of communicating Eco-efficiency. The application of product semantics has attempted to objectively deal with an inherently subjective issue though of course this research remains a work in progress and holds much promise for future development. Although the overall positive results of the final washing machine designs in convincing consumers of their Eco-efficiency could be achieved, the results would have to be replicated on a much wider application platform in diverse product domains in order to prove their robustness beyond a doubt.

9.1 Considerations about the process

On further analysis there was found a differing point of view on certain concepts between design experts and consumers. Discussions post questionnaire analysis revealed that several users cited difficulties in comprehending Eco-efficiency in terms of a product's physical properties and not being able to justify why a certain concept design amongst several proposals appeared more Eco-efficient. Design experts (in the form of professional designers, design researchers, and human factors experts) were on the other hand explicitly able to articulate which physical properties are most communicative of Eco-efficiency in each concept. This insight is confirmed by Blijlevens, Creusen, & Schoormans (2009) when they mention that non-professionals are unable to distinguish between commonalities and differences between different objects owing to their shallow knowledge and interest of design. Further this phenomenon is also repeated in non-professionals being unable to make complex categorizations between product samples and utilize more simplified and inferior appearance attributes (such as playful as opposed to dynamic) when describing appearances. Non-professionals also exhibit a much lesser level of abstraction when working on categorization suggesting an inferior level of mental agility on issues concerning design knowledge and vocabulary (Tanaka &Taylor, 1991). These insights have also been mentioned by Butter (1989) when he thinks it best to leave complex design 'techniques' such as making associations between characters and their visual attribution to 'creative' people. Such discussions lead one to believe that non-designers think in a qualitatively different manner than designers when thinking of product appearances. The term

'appearance attributes' used by Blijlevens et al is applied in the same context as Product Characters (Janlert et al, 1997), adjectives (Butter, 1989; Krippendorff, 2006), and Metaphors (Athvankar, 2009). In light of these facts it could be explained why professional designers evaluated concept 1 (Figure 99) as qualitatively very well resolved and quite expressive of Eco-efficiency (discussions with Steven de Boer, Richard Vos – Human Factors Specialists) even though the non-experts rated it significantly lower than other concepts, despite the other concepts being finished to a much lesser degree from a qualitative point of view.

Figure 99: Washing machine concept 1

An important limitation of the entire design process was the individual skills of the designers involved. Crilly, Moultrie, & Clarkson (2008) have pointed out that the individual skill of a designer has profound impacts on a design process and on the final product form. Athavankar (2009) too mentions that it is the designer's job to "find relationships and connect what appears unconnected" to achieve innovative forms, thus reinforcing the importance of the designer's creativity. The students in the final workshop of the design process were not all similarly capable in attributing the provided character sets into a product form. The reason for this could also be put down to the limited time period of interaction between the instructors and the students apart from the limited knowledge of the semantic process of which their efforts were a part of. Although at the end of the workshop, the students of the Polidesign workshop were shown the results of the previous workshop in India, thus allowing them to comparatively benchmark their results in expressing Eco-efficiency with respect to their Indian peers.

9.2 Final Discussion

Traditionally communicating an intended meaning through products has been cast as a very difficult objective to achieve by design theorists (Crilly, Maier, & Clarkson, 2008). This is because Designer intentions which shape an artifact are always interpreted by the consumer in a context independent of the original intentions. Berlo (1972) identified communication skills, attitude, knowledge, and culture of both the sender (designer) and receiver (consumer) as factors which influence the success of the designer's intentions in his model of 'ingredients' that comprise communication. Although the final analysis of this research is based on results which have been captured by users of very diverse nationalities, geographic location, and subsequent cultural influence and still exhibited considerable commonalities between feedbacks from individual users. This could be attributed to perhaps the peculiarity of product domain being studied here. Consideration was shown to select an appliance category in the beginning of the

design process which is fairly standardized across different markets and cultural domains. An appliance such as a washing machine has traditionally been viewed as a convenience provider rather than an artifact of symbolic association by the user.

The issue of addressing a design problem such as the one taken up in this research of Eco-efficient design has been associated with Horst Rittel's concept of 'wicked problems' (Erlhoff & Marshall, p-108, 2008). Wicked problems are a typology of problems with no consensus on what the problems are and how to resolve them. The application of the product semantic process has been discussed by design theorists as a credible approach to tame wicked problems (Syarief & Hibino, 2003) as it lends an element of objectivity to an otherwise very subjective domain of design problems. The 5-step 'metaphoric links' process introduced by Athavankar which is closely related to the 8-step 'character attribution' process discussed by Butter and Krippendorff allows the designer to "communicate their reasoning, the logic of their work, and formation of judgments" (Syarief & Hibino, 2003). Above all application of such a method to a design process makes it communicable to others, thus relying to a lesser degree on intuition and personal experience.

It remains to be seen how successful the application of these product characters as design guidelines would be to appliance designers in the real world scenario with a lot of influencing factors. Crilly (2008) has cited that the consumer interpretation as intended rarely happens due to the moderating effects of the environment (issues related to cost, manufacturing capabilities, material properties, packaging, and engineering etc.) which many times severely effect the final outcome of a designers activity. Thus artifact as intended, artifact as realized, and artifact as experienced are very often 3 different things. Many times designers are 'contractor designers' (Crilly et al, 2008, p-243) who have 'stylistic' restrictions on their design proposals due to their corporate employer and consequently limited influence on the final design outcome of a product. This final observation can also be confirmed by the author's personal experience within Whirlpool Europe. On a closing note it's sufficient to say that to achieve a very robust validation of the product characters proposed in this research as design guidelines, they would have to be utilized by an appliance manufacturer to realize an Eco-efficient platform. This research has attempted to throw some light into the topic of redesigning product characters of Eco-efficient Energy using Products (EuP's), and can be used as a foundation for further exploration.

10. Bibliography

1. Appliances made to order. (2011, August 1). *Connected world*, 75-78. DOI: www.connectedworldmag.com
2. Anastas, P. T., & Zimmerman, J. B. (2003). Designing through the 12 principles of green engineering. *Environmental science and technology*, 95-101.
3. Aoe, T. (2007). Eco-efficiency and ecodesign in electrical and electronic products. *Journal of cleaner production*, *15*, 1406-1414. doi: 10.1016/j.jclepro.2006.06.004
4. Athavankar, U. A. (2009, October). *From product semantics to generative methods*. Paper presented at International association of societies design research Iasdr 2009: rigor and relevance in design, Seoul, South Korea.
5. Athavankar, U. A. (1987, January). *Web of images within*. Paper presented at Arthaya: Proceedings of a conference on visual semantics, Bombay, India.
6. Barbero, S., & Cozzo, B. (2009). *Ecodesign*. (1 ed.). China: Ullmann.
7. Beaudouin, L. F. (2000). Instrumental interaction: An interaction model for designing post-wimp user interfaces. *CHI Letters*, *2*(1), 446-453.
8. Bieling, T. (2010). *dynamic perspectives: looking forward to a better past*. In Fabrizio Ceschin, Carlo Vezzoli, Jun Zhang (Eds.), *Sustainability in Design:NOW! Challenges and Opportunities for Design Research, Education and Practice in the XXI Century* (pp. 98-105). Retrieved from www.lens.polimi.it
9. Bilingsley, L. (2011, august 1). My dryer has a brain. *Connected world*, 75-78. DOI: www.connectedworldmag.com
10. Blaich, R. I. (1989). Philips corporate industrial design: A personal account. *Design Studies*, *5*(2), 1-8. Retrieved from http://www.jstor.org/stable/1511511
11. Blijlevens, J., Creusen, M. E. H., & Schoormans, J. P. L. (2009). How consumers perceive product appearance: The identification of three product appearance attributes. *International journal of design*, *3*(3), 27-35. Retrieved from www.ijdesign.org
12. Boess, S. (2008). *Meaning in product use: which terms do designers use in their work?*. In Loe Feijs, Martina Hessler, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 20-27). Koninklijke: Philips Electronics N.V.
13. Boess, S., & Heimrich, K. (2008). Meaning in product use: a design perspective. In H. N. schifferstein & P. Hekkert (Eds.), *Product Experience*doi:www.elsevier.com
14. Brezet, J. C., Bijma, A. S., Ehrenfeld, J., & Silvester, S. (2001). *The design of eco-efficient services: Methods, tools and review of the case study based'designing eco-efficient services' project*. Informally published manuscript, Design for Sustainability Program, Faculty OCP, Delft University of Technology, Delft, The Netherlands. Retrieved from www.io.tudelft.nl/research/dfs
15. Brown, C. (2006). *Product semantics: sophistry or success?*. In Loe Feijs, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 98-103). Koninklijke: Philips Electronics N.V.
16. Butter, R. (1989). Putting theory in practice: An application of product semantics to transportation design. *Design Issues*, *5*(2), 51-67. Retrieved from http://www.jstor.org/stable/1511514.
17. Burdek, B. (2005). *History, theory and practice of product design*. Basel: Birkhäuser.
18. Byrnes, A. (2010). *Sound judgements: Considering the comparision between theory & practice in sustainable design*. In Fabrizio Ceschin, Carlo Vezzoli, Jun Zhang (Eds.), *Sustainability in*

Design:NOW! Challenges and Opportunities for Design Research, Education and Practice in the XXI Century (pp. 106-112). Retrieved from www.lens.polimi.it

19. Cagan, J., & Vogel, C. (2002). *Creating breakthrough products: Innovation from product planning to program approval*. Upper Saddle River, NJ: Princeton-Hall.
20. *CE marking and european environmental directive*. (2002). Retrieved from http://www.techhelp.org/upload/pdf/CE Mark.pdf
21. Chakraborty, S., Dewulf, K., Ferraris, S., & D'hulster, F. (2010, June). *Green products through a multi-coloured approach, an experiment in multi-disciplianry education*. Paper presented at ConnectED 2010 Connected: 2nd international conference on design education, Sydney.
22. Chakraborty, S. (2011, June). *Communicating eco-efficiency through interface and product design: the case of domestic appliances*. Paper presented at DPPI'11 Dppi: international conference on designing pleasurable products and interfaces, Milan.
23. Charter, M., & Chick, A. (1997). Introductory editorial. *The journal of sustainable product design*, (1), 5-6. Retrieved from http://www.cfsd.org.uk
24. Charter, M. (1997). Managing the eco-design process. *The journal of sustainable product design*, (2), 48-51. Retrieved from http://www.cfsd.org.uk
25. Chang, W., & C.C., J. C. (2009). The underlying factors dominating categorical perception of product mobile phones. *International journal of industrial ergonomics, 39*, 667-680. doi: 10.1016/j.ergon.2009.02.012
26. Charter, M., & Chick, A. (1997). Introductory editorial. *The journal of sustainable product design*, (3), 5-6. Retrieved from http://www.cfsd.org.uk
27. Charter, M., & Chick, A. (1997). Introductory editorial. *The journal of sustainable product design*, (6), 5-6. Retrieved from http://www.cfsd.org.uk
28. Charter, M. (1998). Sustainable value. *The journal of sustainable product design*, (6), 57-59. Retrieved from http://www.cfsd.org.uk
29. Charter, M., & Tischner, U. (2001). *Sustainable solutions: developing products & services for the future*. Greenleaf Publishing, Sheffield
30. Chick, A. (1997). The 'freeplay radio. *The journal of sustainable product design*, (1), 53-56. Retrieved from http://www.cfsd.org.uk
31. Cooper, T. (1999). Creating an economic infrastructure for sustainable product design. *The journal of sustainable product design*, (8), 7-17. Retrieved from http://www.cfsd.org.uk
32. Cramer, J. (1997). Towards innovative, more eco-efficient product design strategies. *The journal of sustainable product design*, (1), 7-11. Retrieved from http://www.cfsd.org.uk
33. Crilly, N., Moultrie, J., & Clarkson, J. P. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies, 25*, 547-577. Retrieved from www.elsevier.com/locate/destud
34. Crilly, N. (2011). Do users know what designers are up to? product experience and the inference of persuasive intentions. *International journal of design, 5*(3), 1-15. Retrieved from http://www.ijdesign.org/ojs/index.php/IJDesign/index
35. Crilly, N., Moultrie, J., & Clarkson, J. P. (2009). Shaping things: intended consumer response and the other determinants of product form. *Design Studies, 30*, 224-254.
36. Darby, S. (2000). *Making it obvious: designing feedback into energy consumption*. Proceedings of the 2nd International Conference on Energy Efficiency in Household Appliances and Lighting, Italian Association of Energy Economists / EC-SAVE program.

37. Datschefski, E. (1999). Progress towards sustainable design in the white goods sector. *The journal of sustainable product design*, (10), 43-52. Retrieved from http://www.cfsd.org.uk
38. Demirbilek, O., & Sener, B. (2003). Product design, semantics and emotional response. *Ergonomics*, *46*(13/14), 1346-1360.
39. Earl, G., & Clift, R. (1998). How important is environmental performance? a case study measuring the environmental preferences of . *The journal of sustainable product design*, (6), 19-29. Retrieved from http://www.cfsd.org.uk
40. Evans, M., & Thomas, P. (2011, September). *Products that tell stories: The use of semantics in the development and understanding of future products*. Paper presented at City University International conference on engineering and product design education, London.
41. Evans, M., & Sommerville, S. (2007, September). *Seeing is believing: The challenge of product semantics in the curriculum*. Paper presented at Conference on engineering and product design International conference on engineering and product design education, Newcastle upon Tyne.
42. Fiksel, J. (1996, summer). Achieving eco-efficiency through design for environment. *Total quality environmental management*, 47-54.
43. Fiksel, J., McDaniel, J., & Spitzley, D. (1998). Measuring product sustainability. *The journal of sustainable product design*, (7), 7-18. Retrieved from http://www.cfsd.org.uk
44. Froehlich, J. (2009, february). *Promoting energy efficient behaviors in the home through feedback: The role of human-computer interaction*. Paper presented at HCIC 2009 Human computer interaction consortium (hcic) 2009, Colorado.
45. Fogg, B. (2009, April). *Creating persuasive technologies: an eight-step process*. Paper presented at Persuasive '09 4th international conference on persuasive technology, Claremont, USA.
46. Fogg, B. J. (1999). Persuasive technologies. *Communications of the ACM*, *42*(5), 26-29.
47. Frei, M. (1998). Eco-effective product design: the contribution of environmental management in designing sustainable products. *The journal of sustainable product design*, (7), 19-29. Retrieved from http://www.cfsd.org.uk
48. Gibson, J. J. (2002). A theory of direct visual perception. In A. Noe & E. Thompson (Eds.), *Vision and mind: Selected readings in the philosophy of perception*USA: MIT press.
49. Gorno, R. (2010). *Designing emotions through industrial product features*. (Unpublished doctoral dissertation, Politecnico Di Milano- INDACO).
50. Gorno, R., Colombo, S., Rognoli, V., *Correlation between intrinsic characteristics of industrial products and user's perception,* ICoRD 2011, International Conference in Research into Design, Bangalore
51. Gorno, R., & Colombo, S. (2011, June). *Attributing intended character to products through their formal features*. Paper presented at: DPPI'11 Dppi: international conference on designing pleasurable products and interfaces, Milan.
52. Goto, H., Goto, M., & Sueyoshi, T. (2010). Consumer choice on ecologically efficient water heaters: Marketing strategy and policy implications in japan. *Energy economics*, doi: 10.1016/j.eneco.2010.09.004
53. Hassenzahl, M. (2008). Aesthetics in interactive products: Correlates and consequences of beauty. In H. N. schifferstein & P. Hekkert (Eds.), *Product Experience*doi:www.elsevier.com
54. Hassenzahl, M. (2004). The thing and i: Understanding the relationship between user and product In *Funology - Human computer interaction series* (Vol. 3, pp. 31-42). USA: Kluwer academic publishing.
55. Hekkert, P., & Leder, H. (2008). The aesthetic experience. In H. N. schifferstein & P. Hekkert (Eds.), *Product Experience*doi:www.elsevier.com

56. Hekkert, P., & Schifferstein, H. N. J. (2008). Introducing product experience. In P. Hekkert & H. N. Schifferstein (Eds.), *Product Experience* (1 ed., pp. 1-8). USA: Charon Tec ltd.
57. Hermosilla-Carrillo, J., Rio, P. D., & Konnola, T. (2010). Diversity of eco-innovations: Reflections from selected case studies. *Journal of cleaner production, 18*, 1073-1083. doi: 10.1016/j.jclepro.2010.02.014
58. Huang, T., & Henry, K. (2009, October). *How does "green" mean the emerging semantics of product design*. Paper presented at Mx design conference, 2009, Mexico city, Mexico.
59. Hummels, C., & Overbeeke, K. (2010). Special issue editorial: aesthetics of interaction. *International journal of sustainable engineering, 4*(2), 1-2.
60. Janlert, L. E., & Stolterman, E. (1997). The character of things. *Design Studies, 18*(3), 297-314.
61. Johansson, G., & Magnusson, T. (1998). Eco-innovations- a novel phenomenon? . *The journal of sustainable product design*, (7), 7-18. Retrieved from http://www.cfsd.org.uk
62. Kammerer, D. (2009). The effects of customer benefit and regulation on environmental product innovation. empirical evidence from appliance manufacturers in germany. *Ecological economics, 68*, 2285-2295. doi: 10.1016/j.ecolecon.2009.02.016
63. Kandachar, P. (2010). *Designing for global sustainable solutions: challenges and opportunities*. In Ceschin, F., Vezzoli, C., Zhang, Z. (Eds.), *Sustainability in Design:NOW!: Challenges and opportunities for design research education and practice in the XXI century* (pp. 60-78). Sheffield, UK: Greenleaf Publishing.
64. Karana, E., & Hekkert, P. (2010). User-material-product interrelationships in attributing meanings. *International journal of design*, 4(3), 43-53. Retrieved from www.ijdesign.org
65. Karjalainen, T. M. (2003, June). *Strategic design language – transforming brand identity into product design elements*. Paper presented at 10th International Product Development Management Conference 10th international product development management conference, Brussels.
66. Karlsson, R., & Luttropp, C. (2006). Ecodesign: what's happening? an overview of the subject area of ecodesign and of the papers in this special issue. *Journal of cleaner production, 14*, 1291-1298. doi: 10.1016/j.jclepro.2005.11.010
67. Kiefer, C. (2008). *The effect of worldview and culture on industrial design*. In Loe Feijs, Martina Hessler, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 35-40). Koninklijke: Philips Electronics N.V.
68. Kitzinger, J. (1994). The methodology of focus groups: the importance of interaction between research participants. *Sociology of health & illness, 16*(1), 103-121.
69. Kostecki M. (editor), 1998, *The durable use of consumer products*. Dordrecht: Kluwer academic publishers
70. Krippendorff, K. (2007). Design research, an oxymoron?. In R. Michel (Ed.), *Design Research Now- Essays and selected projects* (pp. 67-80). Basel : Birkhäuser
71. Krippendorff, K., & Butter, R. (2008). Semantics: Meanings and contexts of artifacts. In H. schifferstein & P. Hekkert (Eds.), *Product Experience* doi:www.elsevier.com
72. Krippendorff, K. (2006). *the semantic turn, a new foundation for design*. Boca Raton, FL: Taylor
73. Krippendorff, K. (2008). *The diversity of meanings of everyday artifacts and human-centered design*. In Loe Feijs, Martina Hessler, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 12-19). Koninklijke: Philips Electronics N.V.
74. Krippendorff, K. (1989). On the essential contexts of artifacts or on the proposition that "design is making sense (of things)". *Design Issues, 5*(2), 9-39. Retrieved from http://www.jstor.org/stable/1511512.

75. Lawson, R., & Storer, I. (2008). *'styling-in' semantics*. In Loe Feijs, Martina Hessler, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 41-49). Koninklijke: Philips Electronics N.V.
76. Lee, M., & Lou, Y. C. (1996). Consumer reliance on intrinsic and extrinsic cues in product evaluations: A conjoint approach. *Journal of applied business research, 12*(1), 21-29.
77. Lee, J.J., & Lee, K.P. (2009). Facilitating Dynamics of Focus Group Interviews in East Asia: Evidence and Tools by Cross-Cultural Study. *International Journal of Design*, 3 (1), 17-28.
78. Lim, Y. K., Stoltermann, E., Jung, H., & Donaldson, J. (2007, August). *Interaction gestalt and the design of aesthetic interactions*. Paper presented at DPPI'07 Designing pleasurable products and interfaces, Helsinki.
79. Lockton, D., Harrison, P., & Stanton, N. (2008). Making the user more efficient: Design for sustainable behaviour. *International journal of sustainable engineering*, *1*(1), 3-8. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/19397030802131068
80. Lorenz, T. (2009, Summer). When will white goods be revolutionised. *Design Council Magazine*, (6), 30-33.
81. Lorentz, A., & Woersdorfer, J. S. (2009, june 5). *Energy-efficient household appliances and the rebound rffect- a model on the demand for washing machines*. Retrieved from http://www.esee2009.si/papers/Woersdorfer-Energy.pdf
82. Luttropp, C. (1998). Design for disassembly: A new element in product development. *The journal of sustainable product design*, (6), 30-40. Retrieved from http://www.cfsd.org.uk
83. Maeda, J. (2006). *Laws of simplicity: Design, technology, business, life*. Cambridge, Massachusettes: MIT press.
84. Maier, J. R. A., & Fadel, G. M. (2008). Affordance based design: a relational theory for design. *Research in engineering design*, *20*(1), 13-27. doi: 10.1007/s00163-008-0060-3
85. Manzini, E. and Vezzoli, C. (2006, April). *Design for sustainable consumption and production systems.* Proceedings: Changes to Sustainable Consumption, Copenhagen, Denmark.
86. Marcus, A. (2002). Dare we define user-interface design?. *Interactions*, 19-24.
87. Mathews, H. C., & Chambers, G. (1998). Unraveling the environmental product design paradox. *The journal of sustainable product design*, (4), 18-25. Retrieved from http://www.cfsd.org.uk
88. Mills, B., & Schleich, J. (2010). What's driving energy efficient appliance label awareness and purchase propensity?. *Energy Policy*, *38*(2), 814-825.
89. Mont, O. K. (2001). Clarifying the concept of product-service system . *Journal of cleaner production*, *10*, 237-245.
90. Nagamichi, M. (1999). *Kansei engineering: The implication and applications to product development.* Paper presented at Systems, Man, and Cybernetics, IEEE SMC'99 Conference Proceedings, Tokyo, Japan.
91. Nefs, H. T. (2008). On the visual appearance of objects. In H. N. schifferstein & P. Hekkert (Eds.), *Product Experience*doi:www.elsevier.com
92. Norman, D. (2008). Signifiers, not affordances. *interactions*, *XV.6*, 13-17. doi: DOI: 10.1145/1409040.1409044
93. Norman, D. A. (1988). *The design of everything things*. USA: Currency Doubleday.
94. Odom, W., Pierce, J., & Roedl, D. (2008, December). *Social incentive & eco-visualisation displays: toward persuading greater change in dormitory communities*. Paper presented at Public and situated displays to support communities Workshop at ozchi 2008, Cairns, Australia.
95. Polak, J. (2008). *Global ecolabelling network: Annual report*. Retrieved from http://www.globalecolabelling.net/GENdocuments/annual_reports/

96. Proctor Rebecca. (2009). *1000 eco design*. China: Logos
97. Rampino, L. (2011). The innovation pyramid: A categorization of the innovation phenomenon in the product-design field. *International journal of design*, *5*(1), 3-16.
98. Rampino, L. & Colombo, S. (n.d.). A taxonomy of Design Research Methods. *Unpublished manuscript*
99. Repair or replace it?. (2011, august 1). *Consumer reports*, 24-29. DOI: www.consumerreports.org
100. Roy, R. (1997). 'design for environment' in practice-development of the hoover 'new wave' washing machine range. *The journal of sustainable product design*, (1), 36-43. Retrieved from http://www.cfsd.org.uk
101. Ruiz, D. C., & Ghorabi, H. O. A. (2010). Influence of environmental information on creativity. *Design sdtudies*, *31*, 479-498. doi: 10.1016/j.destud.2010.06.005
102. Sanders, L. (2008). An evolving map of design practice and design research. *interactions*, *XV.6*, 13-17. doi: 10.1145/1409040.1409043
103. Schwab, C. (2011, July 1). Universal designed & 'smart' appliances. *Paraplegia news*, 13-14.
104. Sherwin, C., Bhamra, T., & Evans, S. (1998). The 'eco-kitchen' project-using eco-design to innovate. *The journal of sustainable product design*, (7), 57-59. Retrieved from http://www.cfsd.org.uk
105. Stevels, A. L. N. (1997). Moving companies towards sustainability through eco-design: Conditions for success. *The journal of sustainable product design*, (3), 47-55. Retrieved from http://www.cfsd.org.uk
106. Sweatman, A., & Gertsakis, J. (1997). Mainstream appliance meets eco-design. *The journal of sustainable product design*, (2), 31-37. Retrieved from http://www.cfsd.org.uk
107. Syarief, A., & Hibino, H. (2003, October). *Evaluating the semantic approach through horst rittel's second-generation system analysis*. 6th Asian design international conference, Tsukuba, Japan.
108. Thomas, R. (2006). *A new dialog*. In Loe Feijs, Steven Kyffin, Bob Young (Eds.), *Design and semantics of form and movement DeSForM 2006* (pp. 10-18). Koninklijke: Philips Electronics N.V.
109. Tischner, U. (2006, march 27). *From ecodesign to sustainable design*. Retrieved from www.econcept.org
110. (2008). M. Erlhoff & T. Marshall (Eds.), *Design dictionary: Perspectives on design terminology*Basel: Birkhäuser.
111. Vezzoli, C., & Manzini, E. (2008). *Design for environmental sustainabiltiy*. London: Springer.
112. Vezzoli, C., & Manzini, E. (2008). *Design for environmental sustainabiltiy*. London: Springer.
113. Vezzoli, C., & Sciama, D. (2003). *Domestico sostenibile*. Milan: Environmental Affairs AB Electrolux Sweden and Electrolux Italia.
114. Vezzoli, C. (2007). *System Design for Sustainability*. Milan:Maggioli Editore.
115. Vihma, S. (2007). Design semiotics- institutional experiences and an initiative for a semiotic theory of form. In R. Michel (Ed.), *Design Research Now- Essays and selected projects* (pp. 219-232). Basel : Birkhäuser
116. Walker, S. (2006). *Sustainable by design: Explorations in theory and practice*. Sterling, USA: Earthscan. DOI: www.earthscan.co.uk
117. Walker, S. (1998). Experiments in sustainable product design. *The journal of sustainable product design*, (7), 42-56. Retrieved from http://www.cfsd.org.uk

118. *Whirlpool sustainability report-2009*. (2009). Retrieved from www.whirlpoolcorp.com
119. Whirlpool, Europe.(2006). *In.home thought and vision*. Milan: SYNEO
120. Yeang, K., & Woo, L. (2010). *Dictionary of ecodesign*. Abingdon, Oxon: Routledge.
121. You, H. C., & Chen, K. (2003). *A comparison of affordance concepts and product semantics*. Paper presented at the 6th Asian design international conference, Tsukuba, Japan.
122. You, H. C., & Chen, K. (2007). Application of affordance and semantics in product design. *Design studies, 28,* 23-28. doi: 10.1016/j.destud.2006.07.002

Weblinks:

1. http://www.**fastcompany**.com/magazine/149/whats-wrong-with-green-design.html?page=0%2C1
2. http://www.**wired**.com/science/planetearth/magazine/16-06/ff_heresies_intro
3. http://www.**expocasa**.it/toBEeco/partecipare.php
4. http://www.**uie**.com/articles/kj_technique/
5. http://www.**ted**.com/talks/skylar_tibbits_can_we_make_things_that_make_themselves.html
6. http://www.**fastcompany**.com/magazine/60/chalktalk.html
7. http://www.**crown**.com/usa/products/index.html
8. http://www.**slideshare**.net/LENSAFRICA/design-and-sustainability-by-carlo-vezzoli-090909
9. http://**uxmag**.com/articles/user-experience-research-design-research-usability-research-market-research
10. http://**uxmag**.com/articles/realism-in-ui-design
11. http://www.**environment-agency**.gov.uk/business/topics/waste/32102.aspx
12. http://www.**bbc**.co.uk/news/business-16315624
13. http://**architectures.danlockton**.co.uk/2007/10/01/water-on-the-membrane/
14. http://www.**ifa.philips**.com/pressreleases/Philips_Econova_TVs/index.html
15. http://www.**connectedworldmag**.com/10_2_magazinearticle.aspx?id=MAZ0110623141143690
16. http://**blog.kissmetrics**.com/loading-time/
17. http://www.**domusweb**.it/en/interview/**jasper-morrison-design-languages**/
18. http://**uxmag**.com/articles/the-expanding-role-of-user-experience-design
19. http://**uxmag**.com/articles/why-persuasive-design-should-be-your-next-skill-set
20. http://**uxaid**.com/
21. http://www.**wired**.com/gadgetlab/2012/01/lg-fridge-blast-chiller/
22. http://www.**uxmag**.com/articles/visual-design-and-usability-yellow-brick-road
23. http://**uxaid**.com/apple-design-philosophy-and-the-great-imac
24. http://www.**uxmag**.com/articles/change-blindness
25. http://www.**usabilityfirst**.com/usability-methods/hci-design-approaches/
26. http://**ec.europa.eu**/enterprise/policies/sustainable-business/ecodesign/index_en.htm
27. Design for future needs report. (n.d.). Retrieved from http://www.**dffn**.org/index.html

11. Appendix

Appendix 1: Eco-efficient features of major appliance categories

Eco-efficient features of a washing machine

Washing Machine	Brand	By Sensor	By Usage	Saves water	Saves energy	Saves chemicals
Low temperature cycle	gorenje Electrolux Panasonic	30 deg. wash cycles instead of 40 deg. 15 deg. eco wash cycle.	20 min. quick wash program at 30 deg.	■	■ ■ ■	
Steam wash	MAYTAG SAMSUNG Electrolux gorenje	Steam injected at desired temp to dry clothes and reduce ironing.			■ ■ ■ ■	
Detergent management	Hotpoint ARISTON gorenje	Detergent is managed by external tank below drum.		■ ■		■ ■
Foam control	gorenje Panasonic	Amount of foam buildup s controlled through water volume.			■ ■	■
Clothes Cleaning feature	Kenmore SAMSUNG SAMSUNG	Silver particles to kill bacteria. micro bubbles shake dirt off.	Cold Clean Cycle using special drum movements			■ ■ ■
Inclined drum	Panasonic	Lesser water consumption.		■		
Leakage protection	Panasonic Electrolux	Sensor detects water leakage & shuts off supply.		■ ■		
Self Cleaning feature	SAMSUNG	Sensor sounds bell every 30 cycles to remind of filter cleaning			■	
Centrifuge speed management	Panasonic	Sensor alters motor's speed & output accord-ing to loading.		■	■	

Eco-efficient features of a refrigerator

 Refrigerator	Brand	By Sensor	By Usage
LED efficient lighting	Panasonic Kenmore	Uses blue LED lighting for efficient lighting performance. LED lighting for better illuminartion and save energy.	
Air flow management	MAYTAG Kenmore	Temperature control and restoration is optimised after opening door. "Easy Flow" ensures cold air temperature is managed optimally.	
Bacteria control	Panasonic SAMSUNG	Silver ions are passed through blue LED to clean bacteria. Silver ions are circulated to clean air.	
Compressor power management	Panasonic	"Inverter technology" dynamically adjusts compressor setting.	
External digital control panel & display	Panasonic SAMSUNG		Ensures easy selection & modifi-cation of tempera-ture settings without opening the door.

Eco-efficient features of a clothes dryer

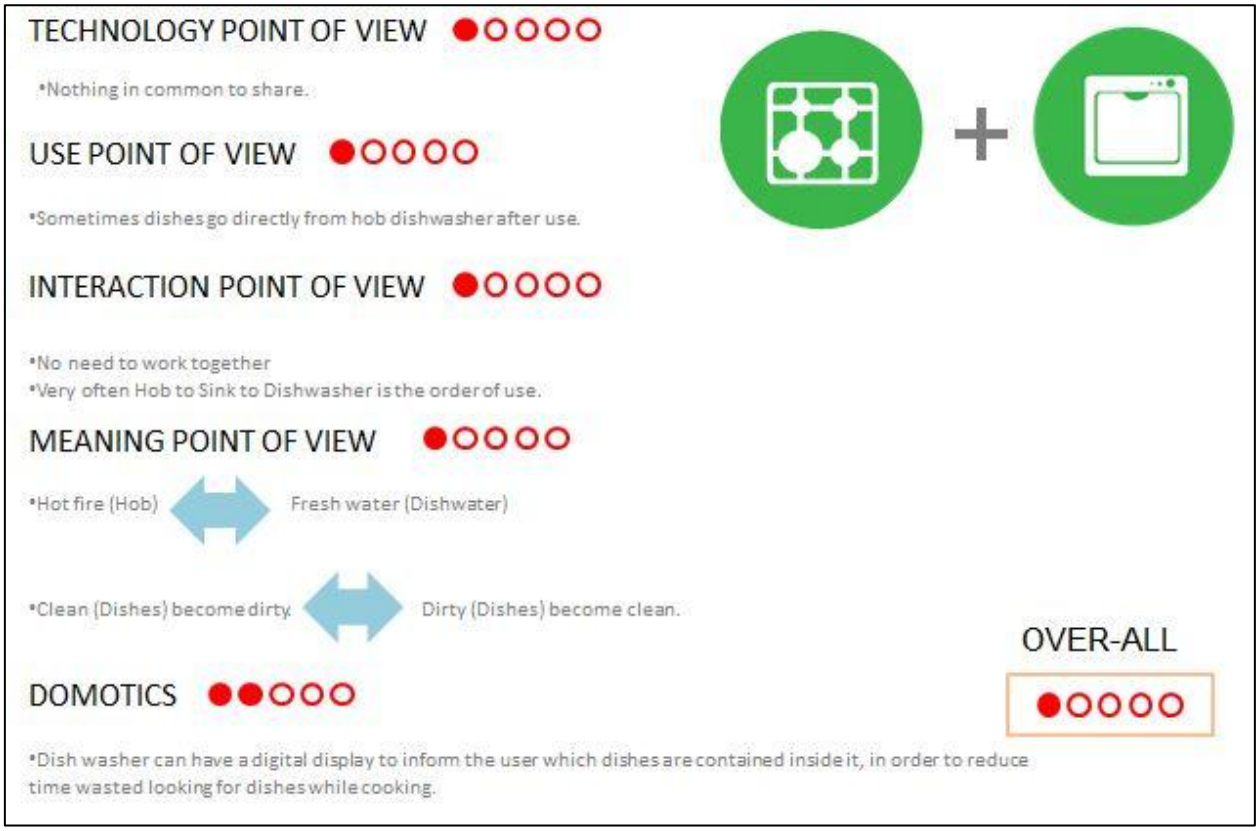
Dryer	Brand	By Sensor	By Usage	Saves water	Saves energy
Humidity sensor	gorenje	Sensor senses the presense of water in clothes to prevent overdrying.			■
Steam dry	gorenje Electrolux	Using steam to dry clothes and remove wrinkles to eliminate ironing.			■
Heat pump	Electrolux	Capture as much residual energy like a fridge working backwards.			■
Freshen up function	Electrolux		Uses steam on lightly worn clothes which dont need a full wash making them fresh.	■	■
Self cleaning function	SIEMENS	Extracted water is passed through a filter before the heat exchanger. Filter never needs cleaning.		■	

Eco-efficient features of a dish-washer

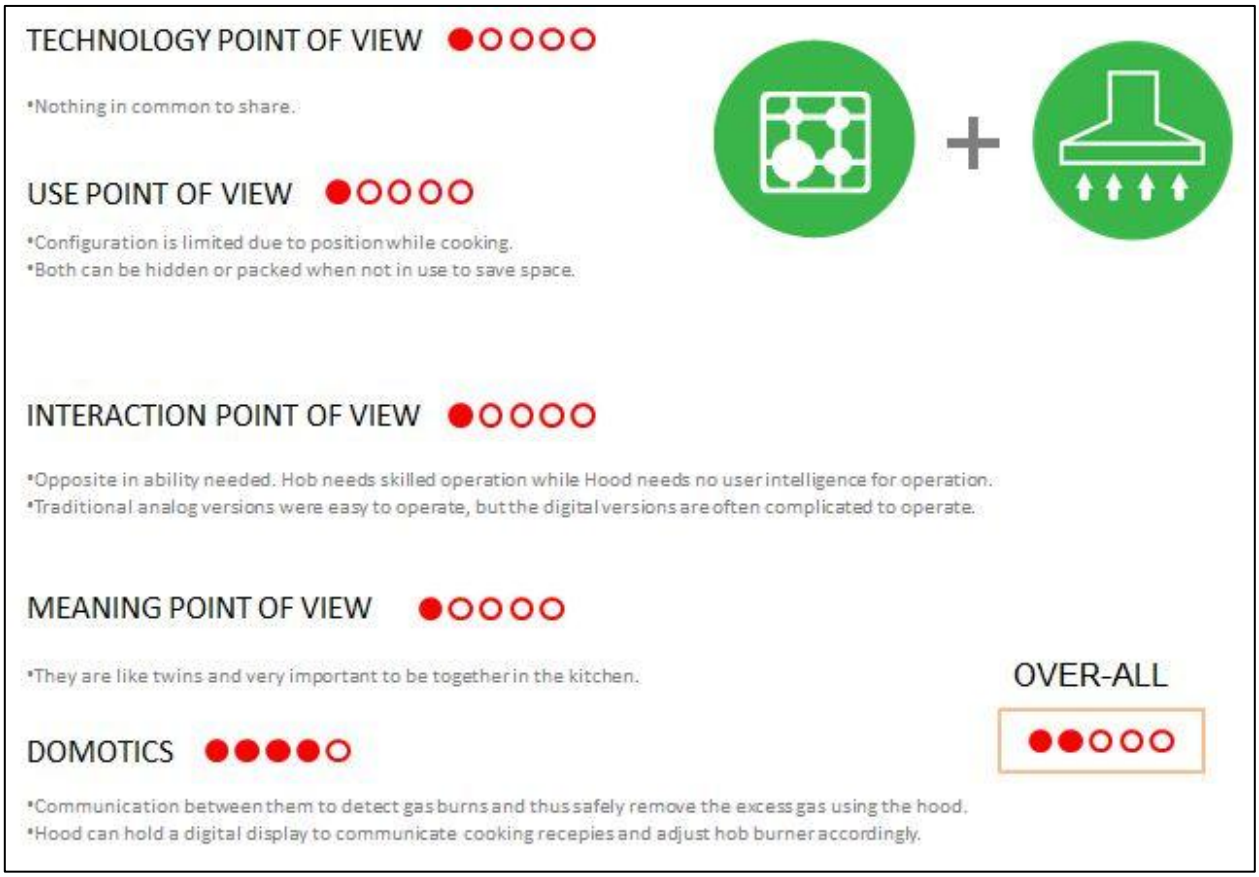
Dish-washer	Brand	By Sensor	By Usage	Saves water	Saves energy	Saves chemicals
Food filter	Kenmore	water stays cleaner and sensor detects if that water can be reused in the washing cycle.		■		
Stainless steel cavity	Kenmore SIEMENS		Steel cavity reduces the need for using chemicals to clean the inner cavity by the user.	■		■
Super sized cavity	MAYTAG		Maximum internal dimensions to reduce the number of wash cycles.	■	■	
Heat absorption	SIEMENS	Special mineral "Zeolit" absorbs heat during wash cycle and releases it during drying cycle.			■	
Soil sensor	Kenmore MAYTAG SIEMENS	Sensor detects the how dirty the dishes are and adapts the wash cycle accordingly.		■	■	

Appendix 2:Integration of appliance couples

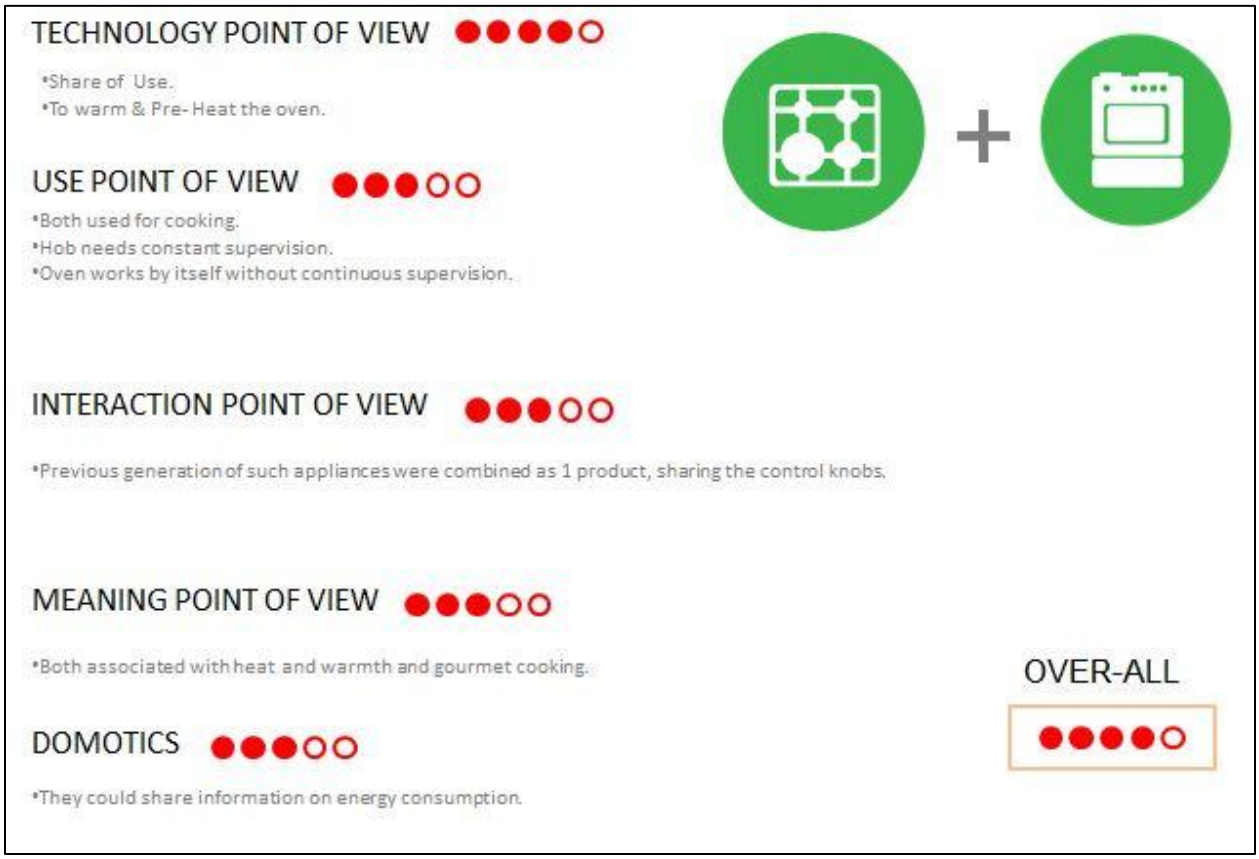
Gas cooktop + Dishwasher



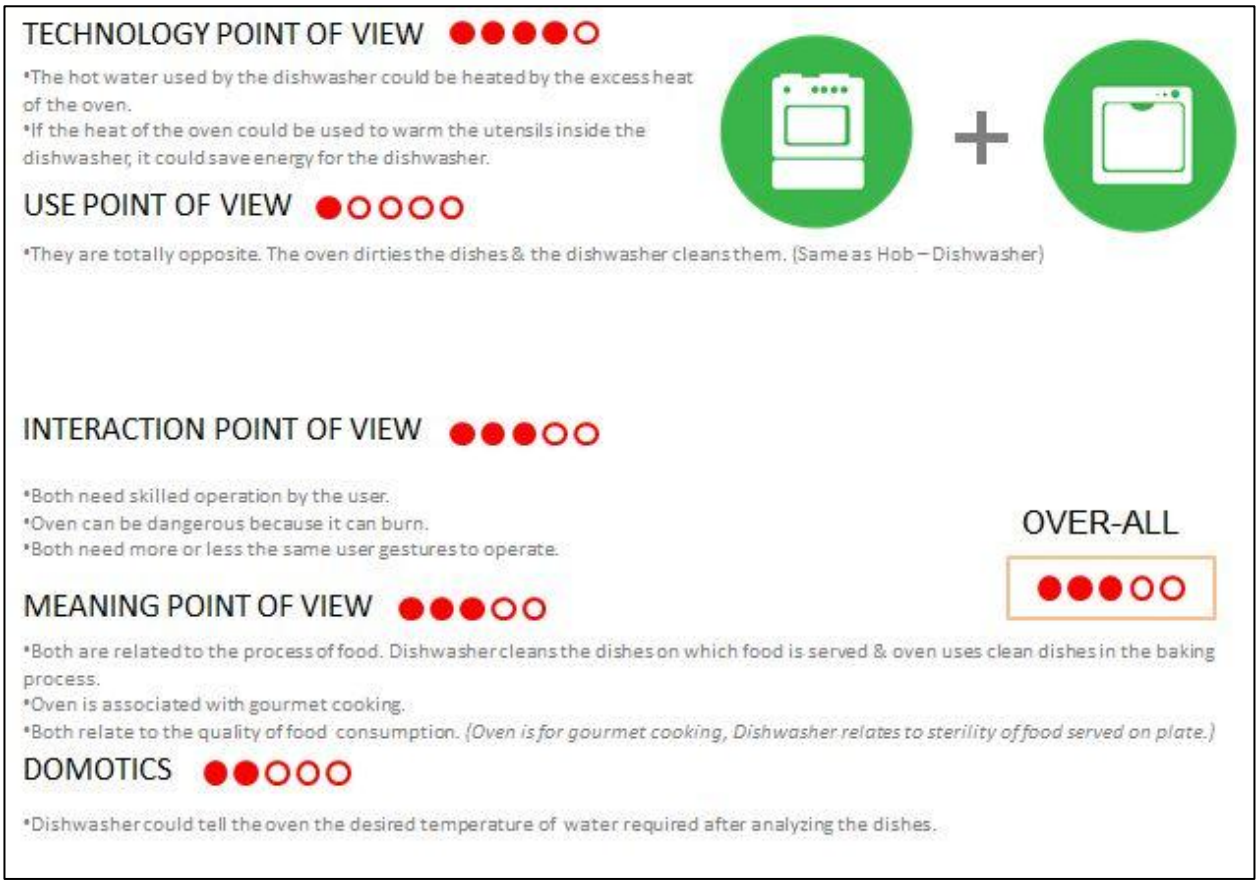
Gas cooktop + Hood



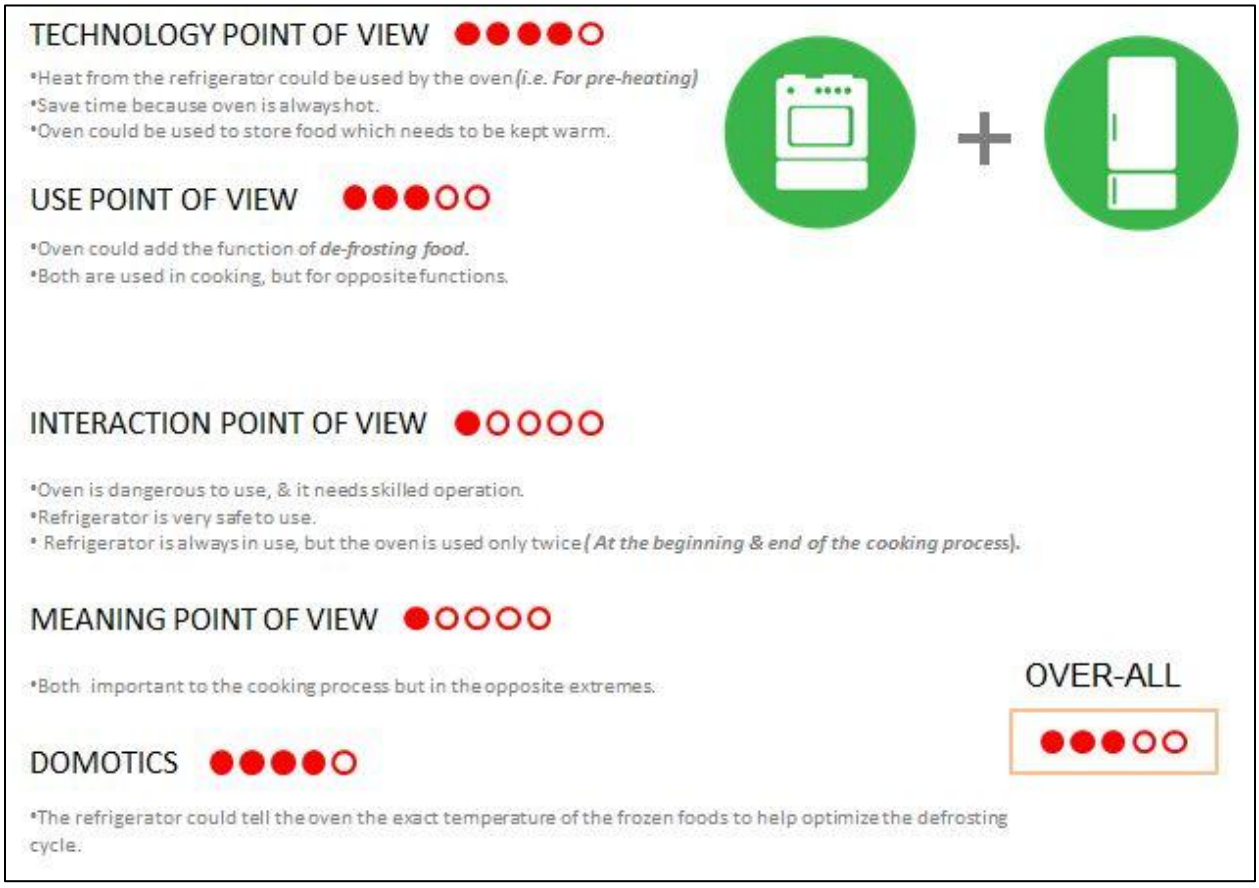
Gas cooktop + Oven



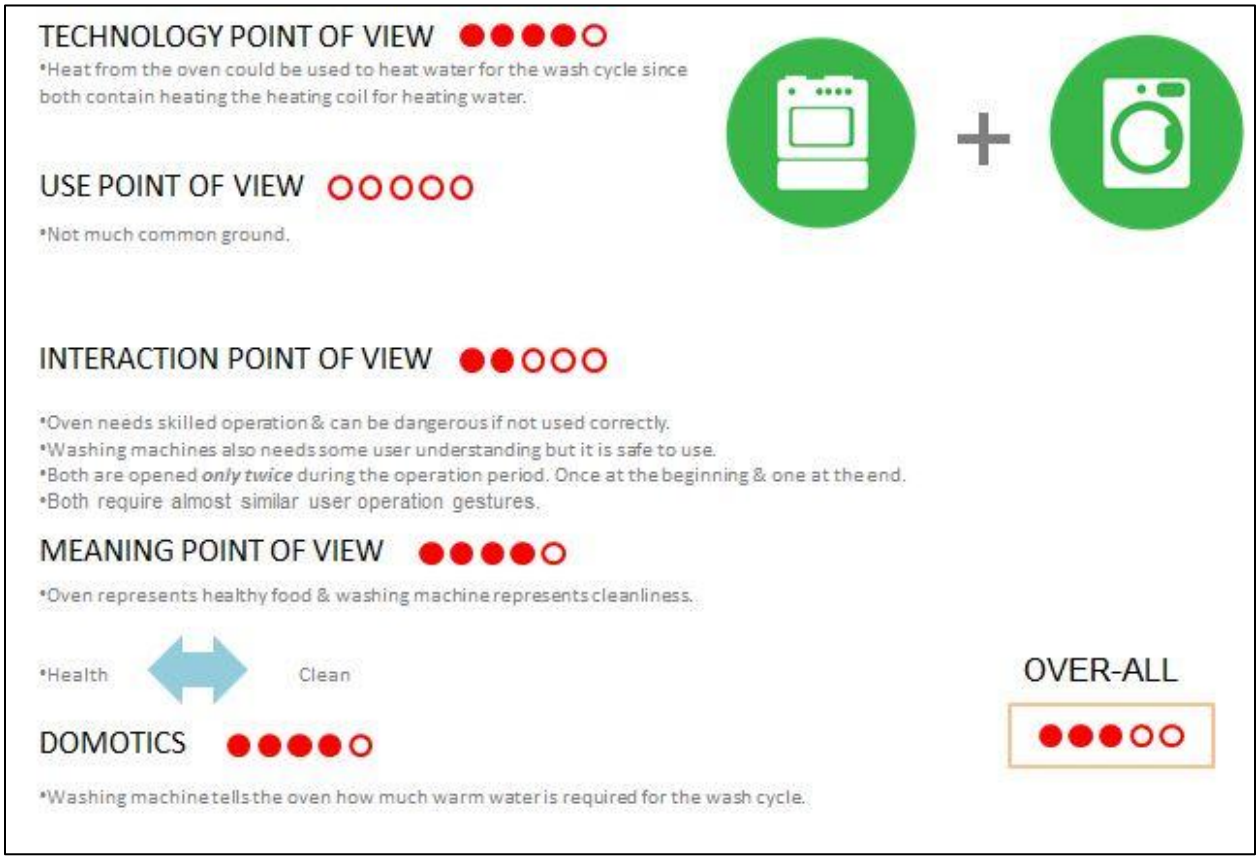
Oven + Dishwasher



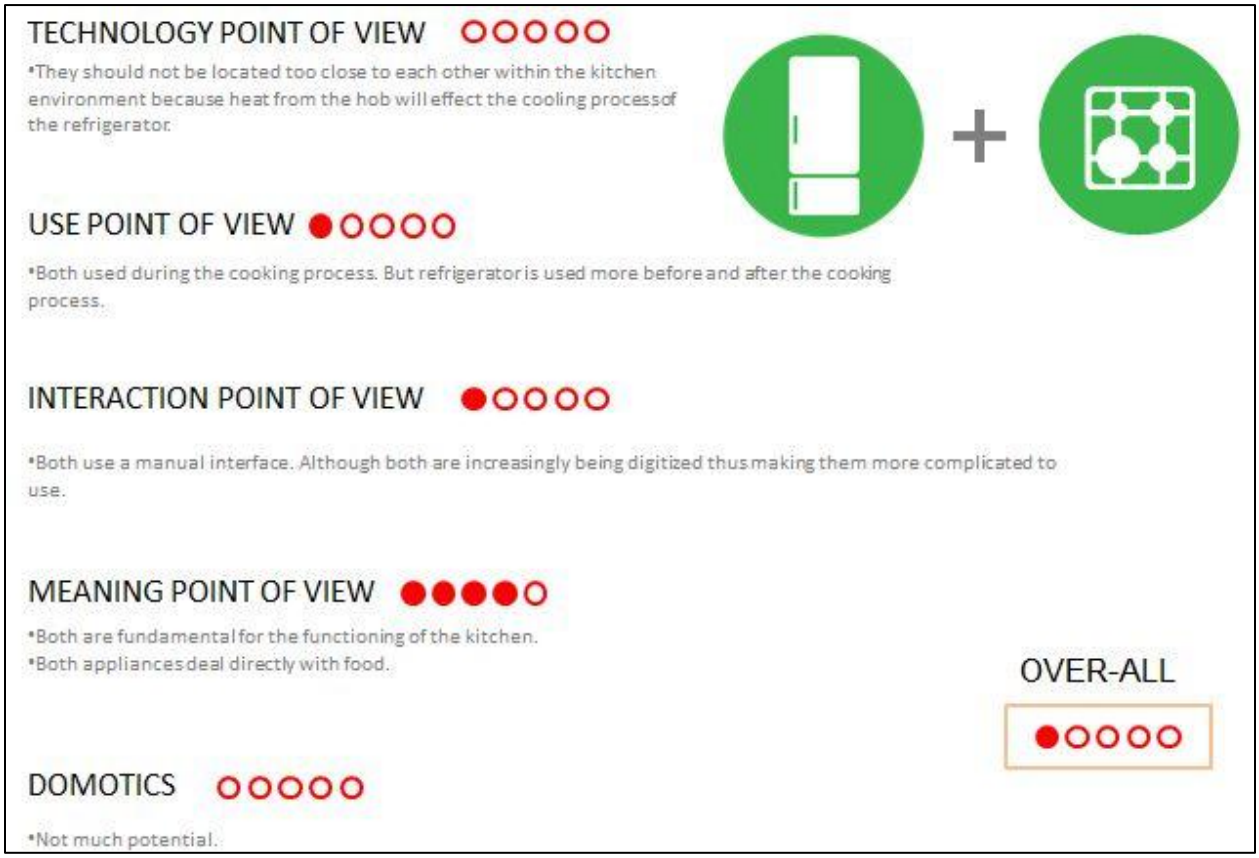
Oven + Refrigerator



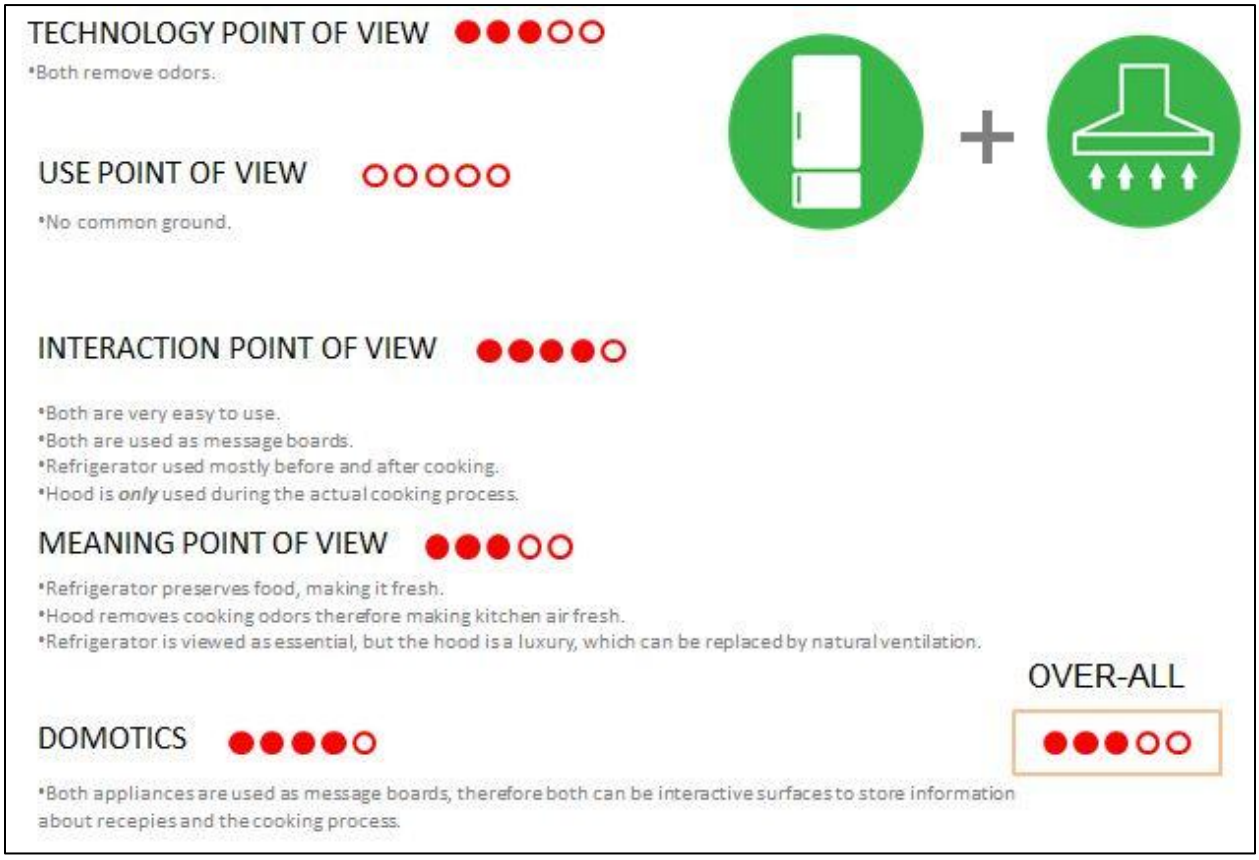
Oven+ washing machine



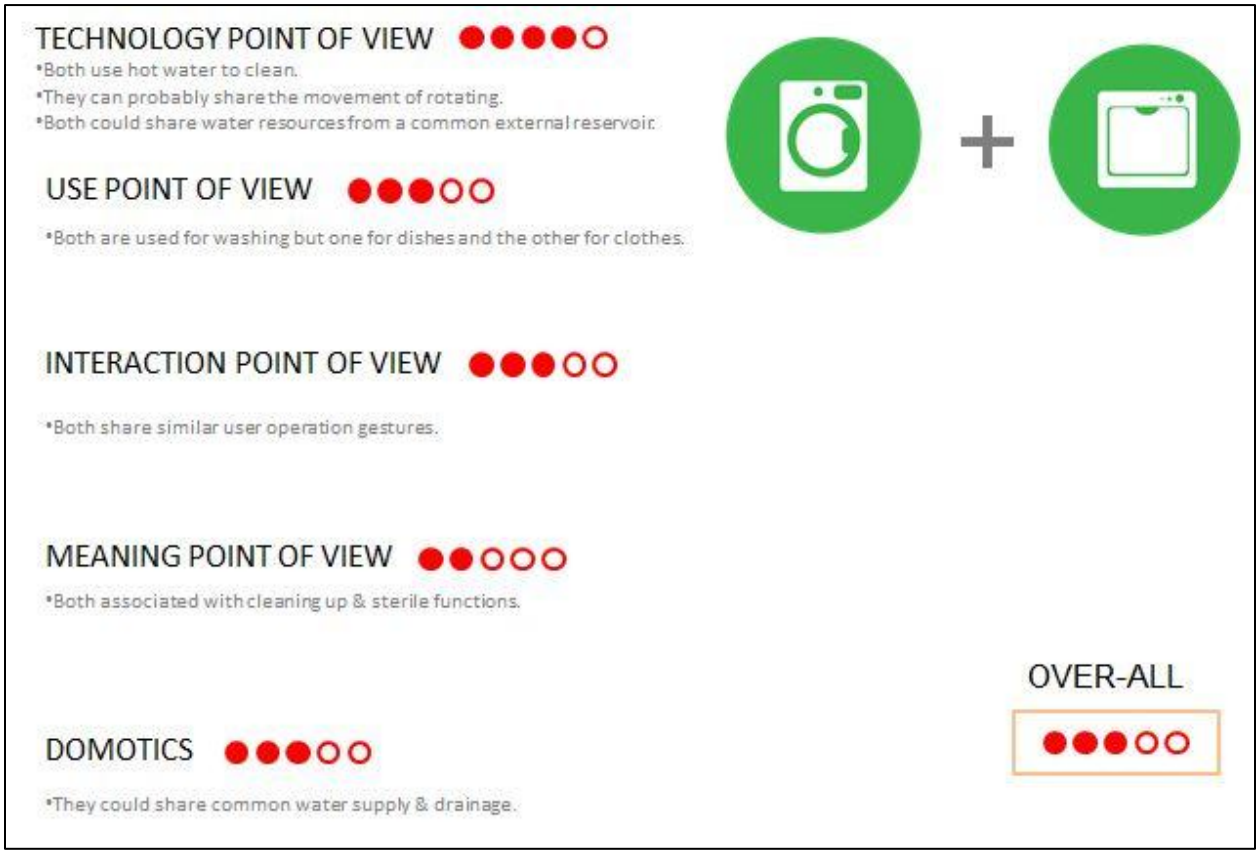
Refrigerator + Gas cooktop



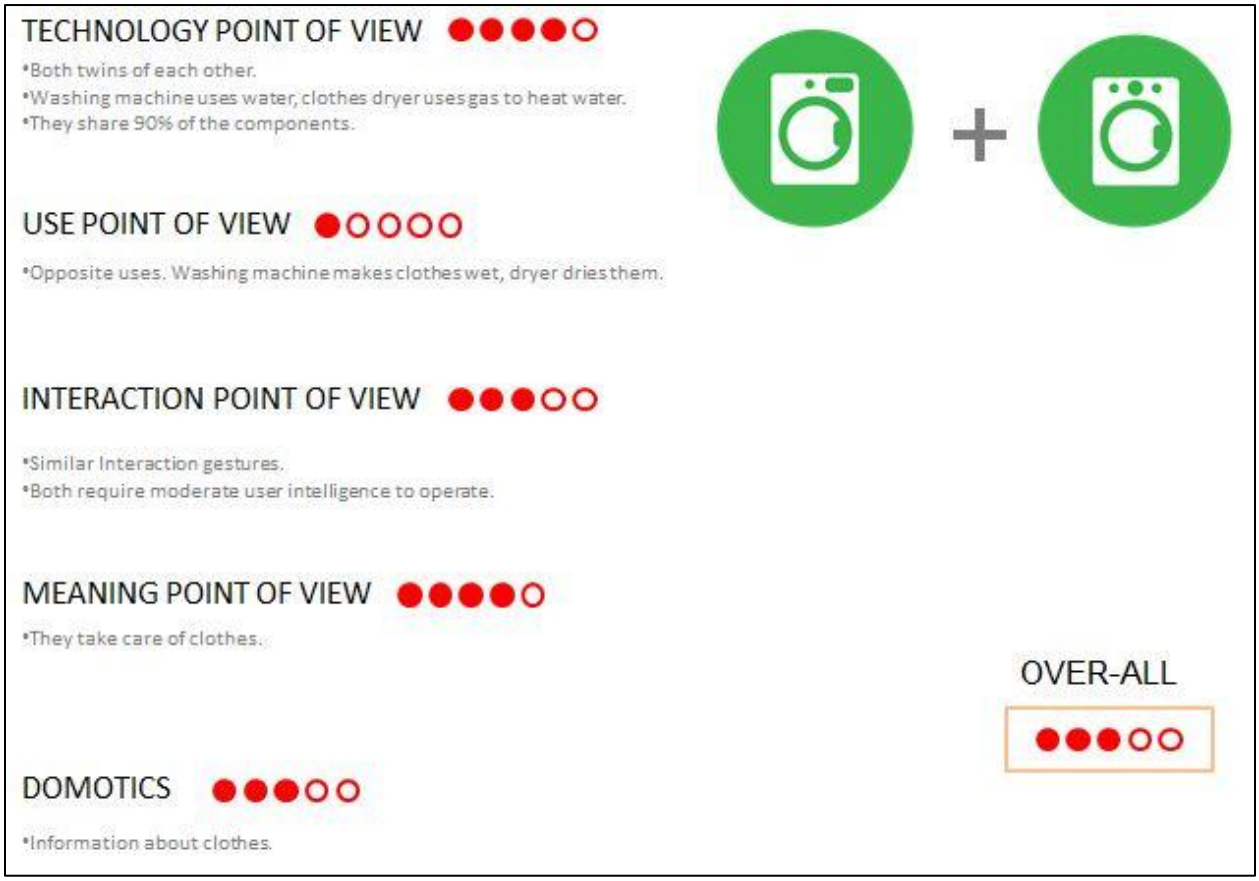
Refrigerator + Hood



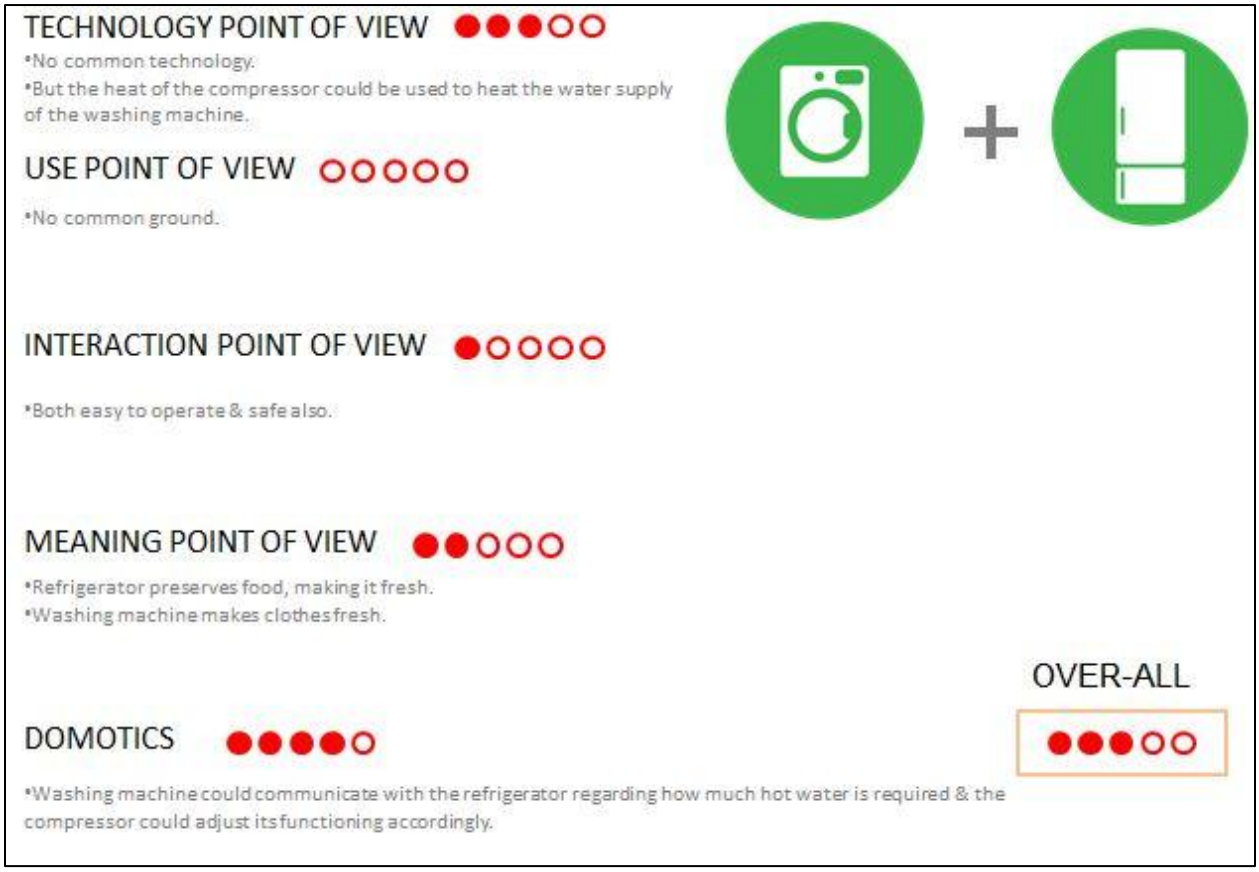
Washing machine+ Dishwasher



Washing machine + Dryer



Washing machine + Refrigerator

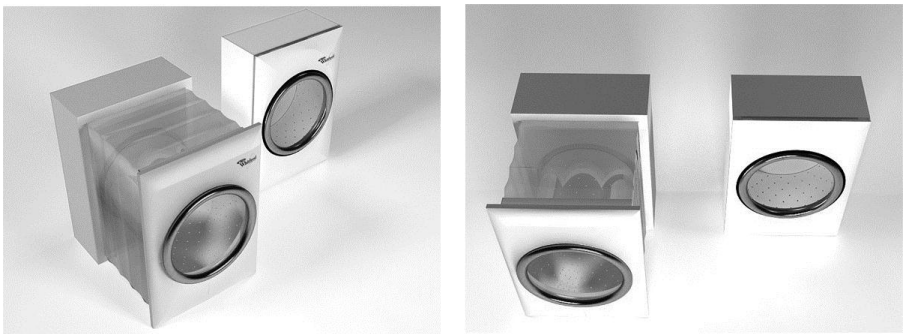


Appendix 3: Result images of Indian Institute of Technology, Guwahati workshop

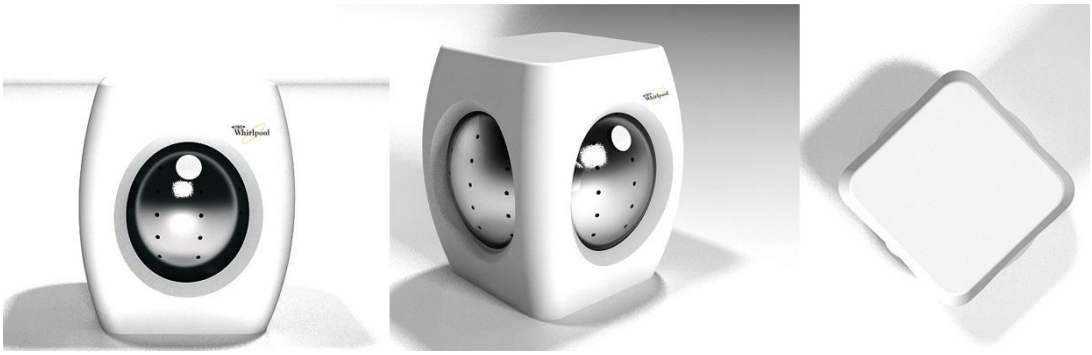
Concept 1

Concept 2

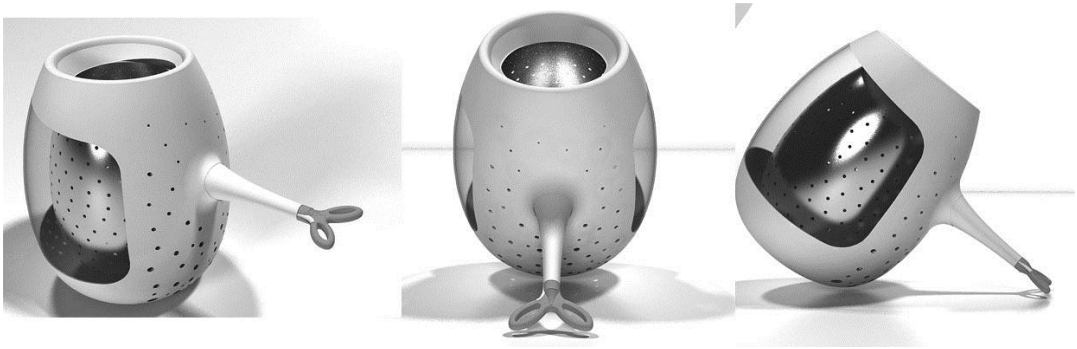
Concept 3



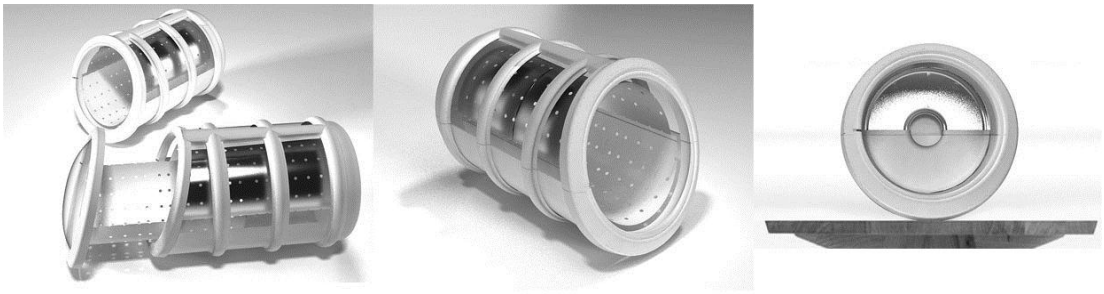
Concept 4



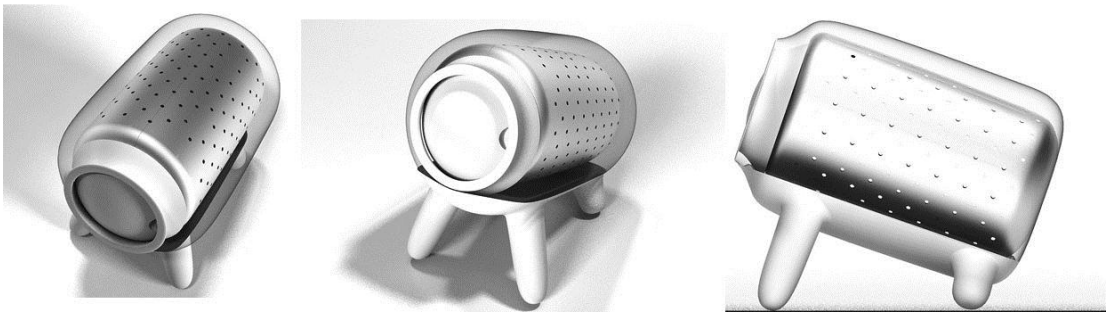
Concept 5



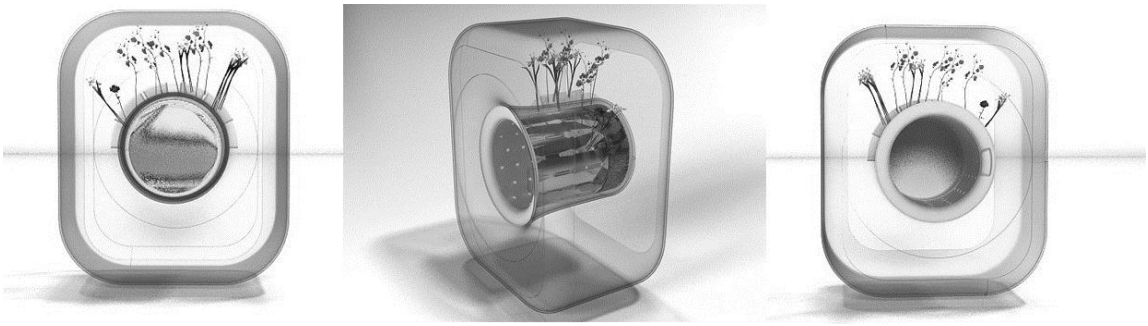
Concept 6



Concept 7



Concept 8



Appendix 4: Washing machine evaluation study-1

Age (Anni): _____

Sex (Sesso): _____

Part I

Instructions:

Below are 8 concepts for washing machines. Do not spend too much time looking at the images. Record the first **adjectives** which come to your mind upon seeing each concept.

A standard washing machine: **[850mm x 550mm x 595mm]** Use this as a reference image to understand the size of the images below.

Concept 1 *(Below are 3 views of the same product concept)*

[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

1) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

Concept 2 *(Below are 2views of the same product concept)*

[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

2) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

Concept 3 *(Below are 3 views of the same product concept)*

[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

3) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

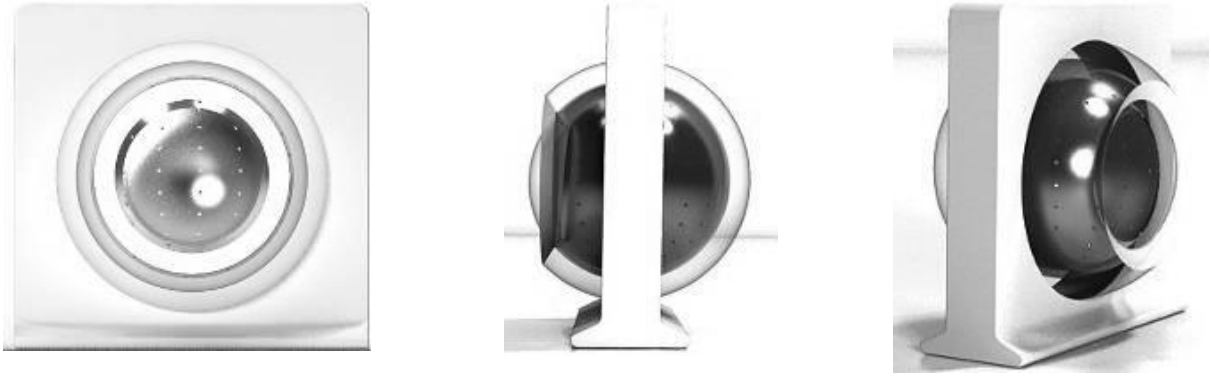
Concept 4 *(Below are 3 views of the same product concept)*

[Describe the above concept in ***3 adjective (descriptive words)*** which come to your mind.]

4) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

Concept 5 *(Below are 3 views of the same product concept)*



[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

5) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

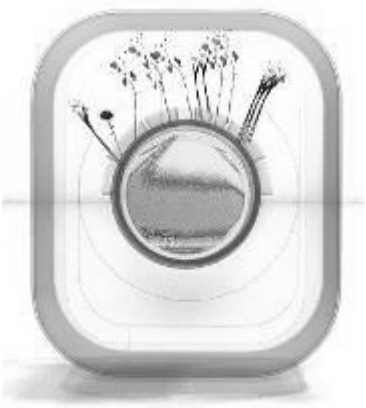
Concept 6 *(Below are 3 views of the same product concept)*

[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

6) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

Concept 7 *(Below are 3 views of the same product concept)*

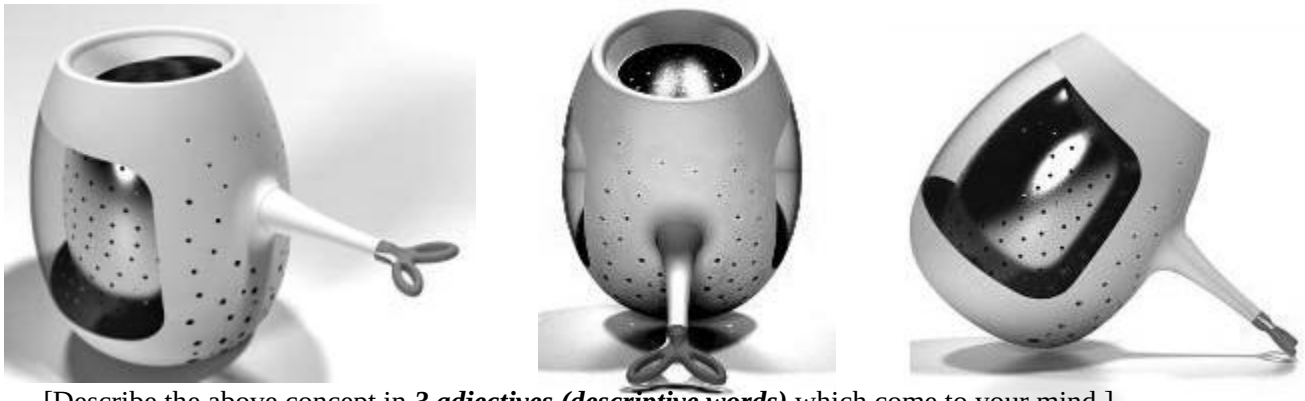


[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

7) _____

a. [Answer A]
b. [Answer B]
c. [Answer C]

Concept 8 *(Below are 3 views of the same product concept)*



[Describe the above concept in ***3 adjectives (descriptive words)*** which come to your mind.]

8) _____

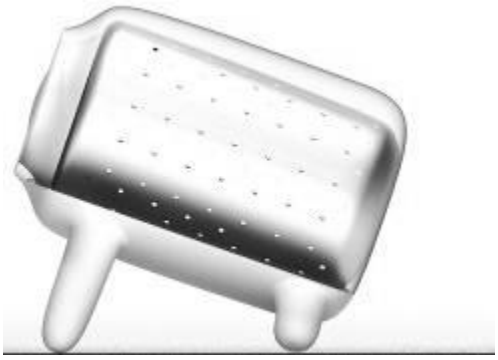
a. [Answer A]
b. [Answer B]
c. [Answer C]

Part II

Which of these washing machines appeared '**eco-efficient**' to you'?

(Eco-Efficiency** in an appliance means environment friendliness and to consume very less water, detergent, and electricity for functioning.**)

Please rate as: **A:** Very Eco-efficient **B:** Some What Eco-Efficient **C:** Not Eco-Efficient



[How eco-efficient does this machine appear to you? **Answer as A,B, or C**]

Answer:

[How eco-efficient does this machine appear to you? **Answer as A,B, or C**]

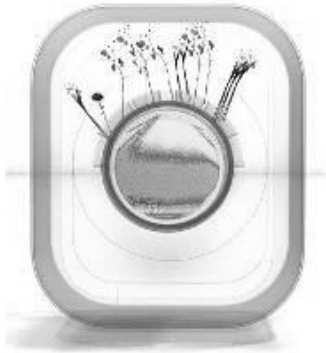
Answer:

[How eco-efficient does this machine appear to you? **Answer as A,B, or C**]

Answer:

[How eco-efficient does this machine appear to you? **Answer as A,B, or C**]

Answer:



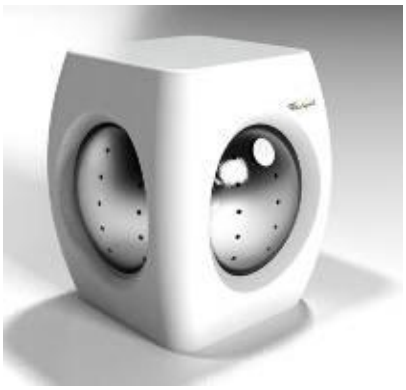
[How eco-efficient does this machine appear to you?

Answer as A,B, or C]

Answer:

[How eco-efficient does this machine appear to you? **Answer as A,B, or C**]

Answer:



[How eco-efficient does this machine appear to you?

Answer as A,B, or C]

Answer:

[How eco-efficient does this machine appear to you?

Answer as A,B, or C]

Answer:

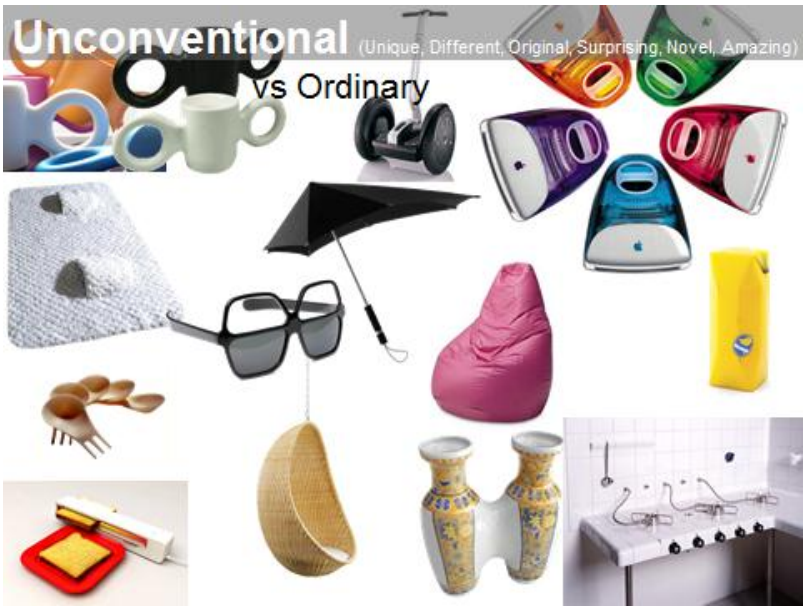
Appendix 5: Moodboards

1) Intended character: *Futuristic (modern)*

Character to be avoided: *Traditional*

2) Intended character: *Unconventional (unique, different, original, surprising, novel, amazing)*

Character to be avoided: *Ordinary*



3) Intended character: *Feminine (light, slender, delicate)*

Character to be avoided: *Masculine*

4) Intended character: *Smart (brilliant, genius, clever)*

Character to be avoided: *Naive*

5) Intended character: *Simple (easy)*

Character to be avoided: *Complex*

6) Intended character: *Practical (convenient, utilitarian)*

Character to be avoided: *Unpractical*

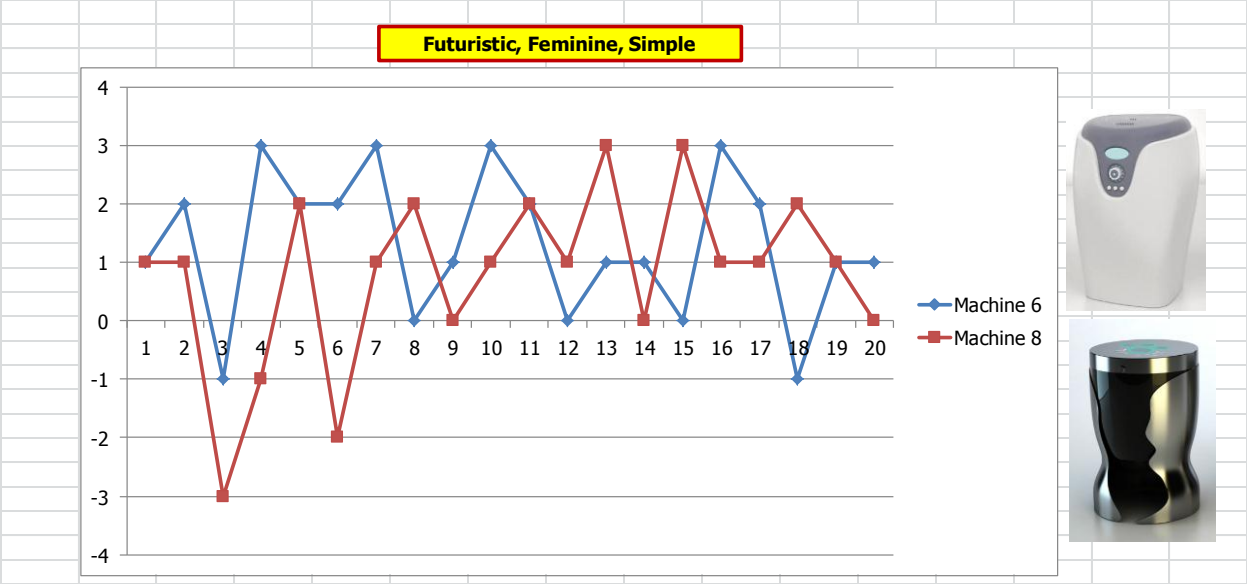
Appendix 6:

Questionnaire results of PoliDesign workshop

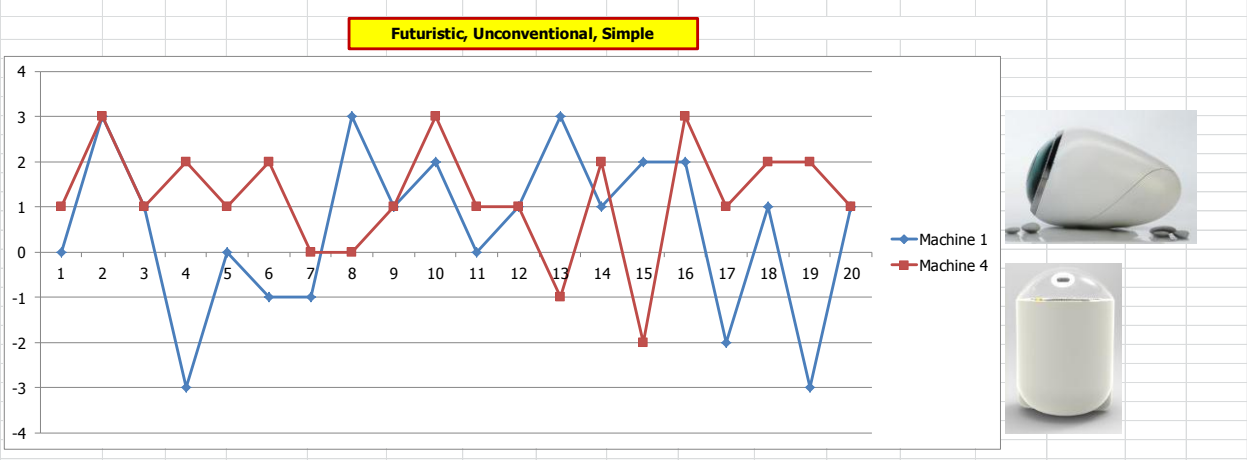
Name	**Age**	**Sex**	**Machine 1**	**Machine 2**	**Machine 3**	**Machine 4**	**Machine 5**	**Machine 6**	**Machine 7**	**Machine 8**	**Machine 9**	**Machine 10**	**Machine 11**	**Machine 12**
Chananya	29	**F**	0	1	1	1	1	1	1	1	1	1	1	1
Rujirat Wattanaapisit	29	**F**	3	0	3	3	1	2	1	1	1	1	1	1
Allison	21	**F**	1	2	-2	1	-2	-1	-2	-3	-3	0	0	2
Takorn	29	**M**	-3	2	1	2	1	3	1	-1	1	3	-2	3
Authaphol	28	**M**	0	2	1	1	0	2	0	2	-1	1	0	2
Shane	27	**M**	-1	2	-1	2	1	2	-2	-2	-2	1	1	1
Narin	36	**F**	-1	1	1	0	1	3	2	1	2	3	2	0
Nicha	32	**F**	3	1	0	0	-1	0	-1	2	2	1	1	0
Anand	29	**M**	1	1	1	1	2	1	-1	0	2	1	0	1
Sadhana	49	**F**	2	2	1	3	2	3	-3	1	1	2	-2	-1
Tarun	34	**M**	0	-1	0	1	1	2	1	2	1	0	2	2
AnnaLisa	25	**F**	1	1	1	1	2	0	-1	1	1	1	1	0
Apu	19	**M**	3	2	2	-1	2	1	0	3	2	1	1	1
Aloke	28	**F**	1	0	0	2	1	1	-2	0	-1	0	1	-1
Madhu	47	**F**	2	-1	1	-2	1	0	0	3	1	2	1	-2
Tapati	54	**F**	2	1	1	3	1	3	0	1	2	2	0	0
Salman	28	**M**	-2	0	-2	1	1	2	1	1	1	0	0	0
Tanusree	29	**F**	1	3	3	2	3	-1	-2	2	3	3	-1	1
Jasmeet	34	**M**	-3	-2	-1	2	-3	1	-3	1	-3	0	-2	-1
Sonal	28	**F**	1	1	-1	1	0	1	0	0	-1	0	0	0
Total Score			**11**	**18**	**10**	**24**	**15**	**26**	**-10**	**16**	**10**	**23**	**5**	**10**
Percentage (%)			**58**	**65**	**58**	**70**	**62.5**	**72**	**42**	**63**	**58**	**69**	**54**	**58**

Appendix 7: Data analysis of PoliDesign workshop results

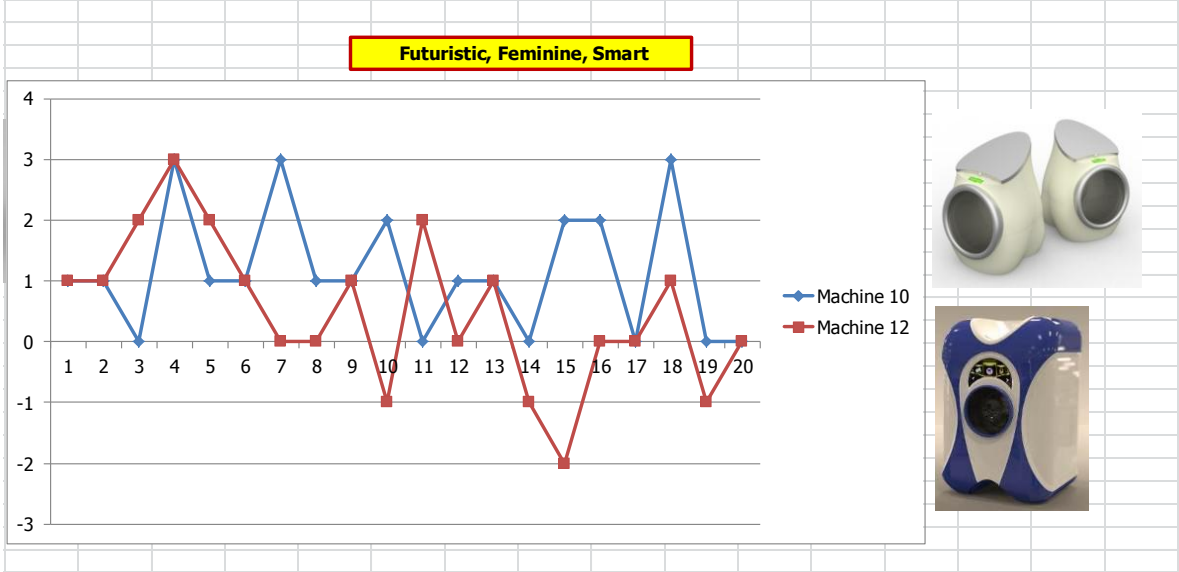
1. Character set- *futuristic, feminine, simple*



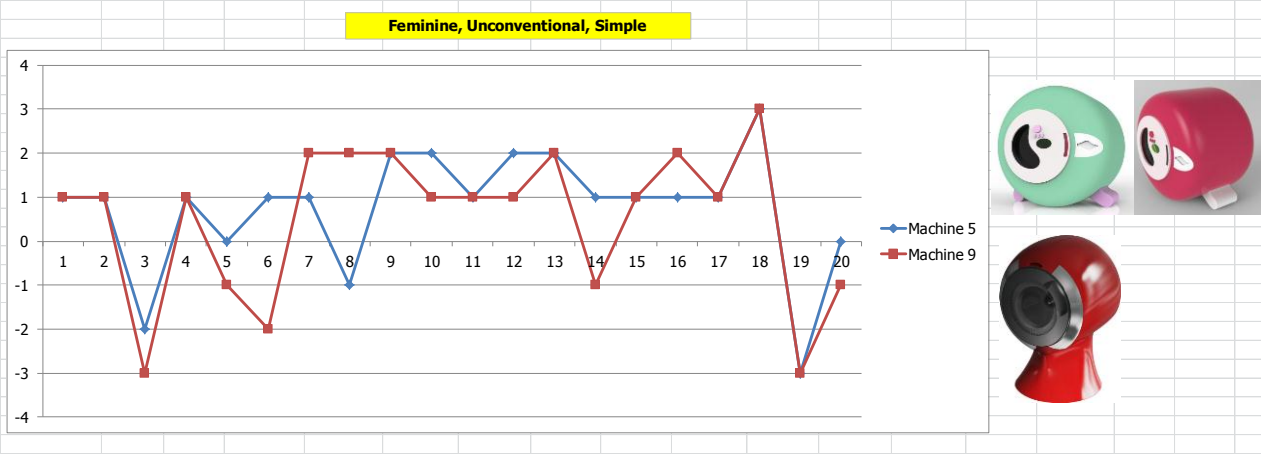
2. Character set- *futuristic, unconventional, simple*



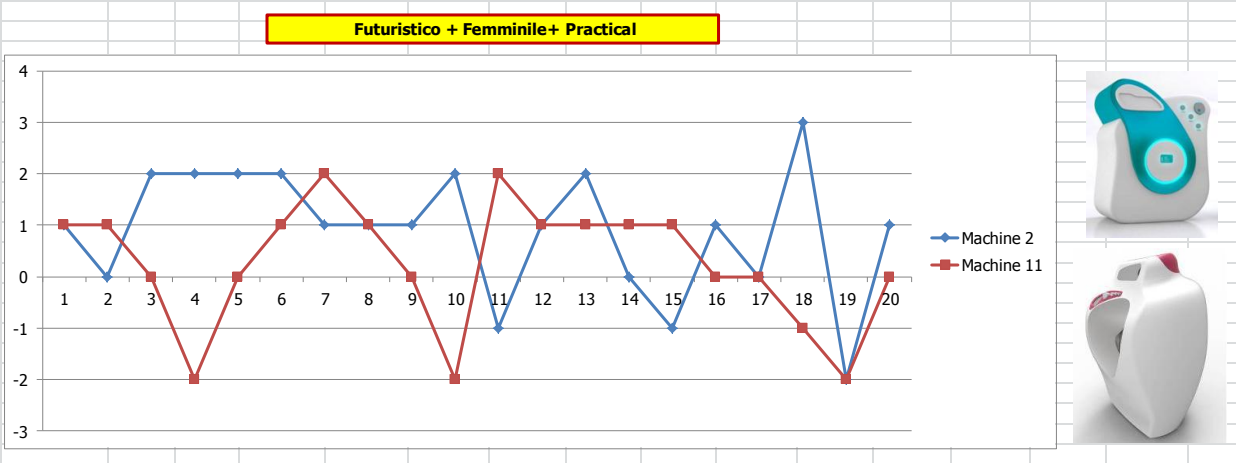
3. Character set- *futuristic, feminine, smart*



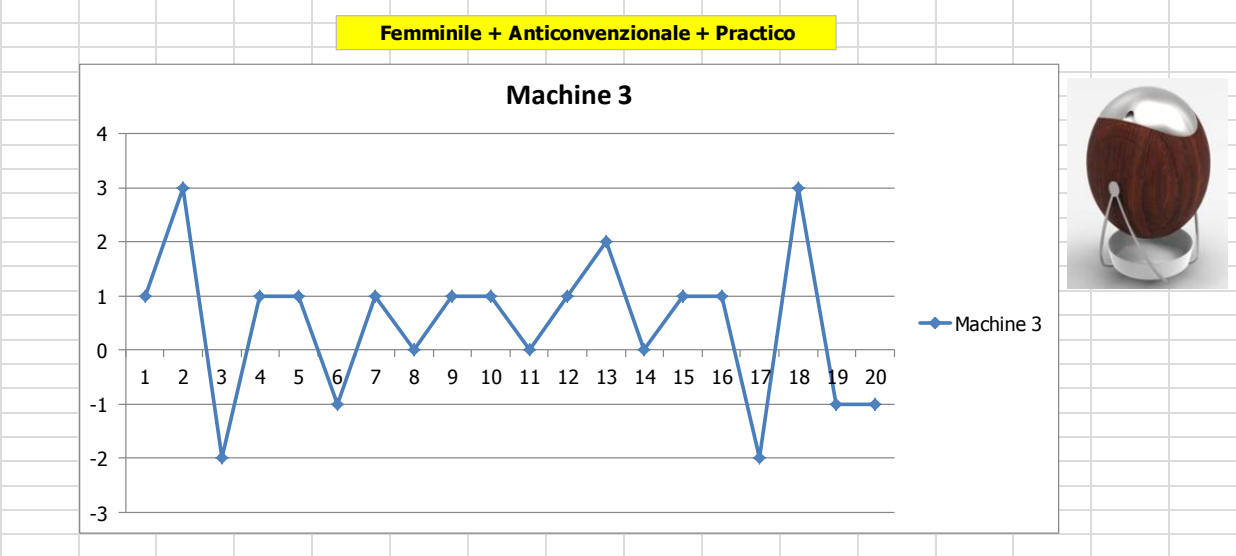
4. Character set- *feminine, unconventional, simple*



5. Character set- *futuristic, feminine, practical*



6. Character set- *feminine, unconventional, practical*



7. Character set- *futuristic, unconventional, smart*