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ORIGINAL PAPER

Experiences in implementing design heuristics for innovation in product design

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Abstract The aided decision processes are expected to improve the design tasks by the reduction of uncertainty, which is one of the principal aspects that interferes with designer choices. These methods can optimise the problem solution by the time reduction in the iterative decision-cycles that can be based on previous knowledge. This article is based in the utilisation of a knowledge based method in design heuristics, which are defined as a set of procedures that allows both, discovery and acquisition, of a solution for a particular problem by the implementation of a strategy, guided by knowledge derived from the experience. This is applied to design area by the extrapolation of technical or conceptual knowledge that has been previously applied and proven in similar problem-solving processes and providing reference points within designs processes as well. For this reason the research focuses on the development of a design case in order to evaluate the interaction between the user and the guided problem approach. The objective was the analysis between two different design processes by the comparison of the implementation of heuristics based method and conventional design techniques in a design case. The purpose was to compare the outcomes of both experiments, taking as a basis the following setup: The design case proposed was carried out by two different teams, where the first team was instructed to use conventional problem-solving approaches such as Pahl & Beitz and Ulrich & Eppinger and the second one was intended to use the heuristics based method. The design task given to both teams was the development of a methane production system by the use of organic waste with the incorporation of technologies to allow the variables control, in other words, an automated biodigester; this allows to have an outcome all teams easy to comparable between each other. Each team performed the task separately, in order to avoid external influence in the process. All of this to proof that with the aid of tools based on heuristic strategies might enhance the innovation and diversification in design alternatives and strengthens conceptual exploration by providing more detailed concepts in early stages of the process.

Keywords Heuristics · Decision support · Product design · Conceptualisation · Innovation

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1 Introduction

The design processes oriented towards product development can be analysed as a problem solving process [16]. In design particular case, the task demands the creation of artifacts or systems that satisfies a certain need with technical solutions. This process that focuses in the human needs solution with a technical and functional scope, is what defines design procedures as problem-solving tasks. During development process the designer has to deal with different situations of the problem approach. Each stage conduct designers towards making decisions that defines a strategy path unto the solution. These decisions can be assisted by methods that provide technical information to improve the development task.

These methods, whether logical or rational, involve systematic decomposition and analysis of the problem [14]. Specifically in a design task, the designer must extract the product requirements, for further analysis and feeding knowledge models in order to to feed the problem approaches. These processes are guided by methods that make use of science and engineering principles and/or catalogues of solutions or procedures to guide the design processes to a successful solution.

These aided decision processes are expected to improve the design tasks by the reduction of uncertainty, which is one of the principal aspects that interferes with designer choices [2]. Conjoint to uncertainty, many product development processes are affected by the iterative nature of the definition of its tasks. Even so, these methods can optimise the problem solution by the time reduction in the iterative decision-cycles that can be based on previous knowledge [13].

This article is based in the utilisation of a knowledge-based method in design heuristics[1] [3] that assist the product development processes within the implementation of two different strategies. The first strategy support the process with a problem solving approach that focuses in the characterisation of design tasks more effectively, providing existing knowledge in a structured method. The second strategy provides an approach for the capitalisation and hierarchy definition of knowledge derived from design processes, in order to make it available for future situations. This is the fundamental purpose of heuristics: to create a structure for the existing knowledge in order to ensure a logical route for its reuse in the future.

Finally, the article is centred in the validation of the method by its implementation in a conducted design processes to determine the possible benefits can be derived from the implementation of heuristics methods to support design processes.

2 State of the art

2.1 Creativity measurement

Before exploring creativity measurement, it is important to recall that a significant correlation between the percentage of designs and the quality of the product [6].

Regarding to creativity, four different models can be discriminated: combination, mutation, analogical thinking and first principles. Combination happens when a new idea is the result of combining different features. On the other hand, mutation occurs when a specific feature is modified looking to create a new one. Analogical thinking happens when an idea-solution is found in other domain of knowledge. Finally first principles is when a design is centred in functions that define the form of the product [4].

[1] Method for the implementation of heuristics in the design process presented by Arts et Métiers ParisTech from France and Universidad EAFIT from Colombia.

Regarding to metrics for measuring idea effectiveness, it is, some indicators based in results had been defined [15]. This indicators are centred in how to relate measures of design ideas with measures of methods of ideas generation. Two basic criteria are identified: for this purpose identified for this purpose: *How well does the method extend the design space? How well does the method explore the design space?*.

Shah [14], proposes one of the most accepted frameworks [9,10,17,18] for measure effectiveness: novelty, variety, quality and quantity which measure different aspects of the effectiveness of ideation.

In *novelty* it is make a comparison from the starts from the universe of ideas or generalisation between the ideas of the participants. The smaller the number of alternatives with this characteristic the greater the novelty.

For measuring *variety*, it is applied to an entire group of ideas. The ideas are grouped according to how two ideas behave to satisfy the same function. Ideas are arranged in order to differentiate physical principles used by each idea for satisfying the same function; In a lower level, the differences are based on different principles of work but share the same physical principle. In the third and fourth level the ideas have different mode of execution and different detail, respectively.

Quality is based on how the physical property (time, weight, energy, etc.) performs. At the conceptual stage, overall quality can be estimated and in the stage of completion it may be possible to perform a quantitative analysis.

Finally, *quantity* is based in the total number of ideas generated by a group or person in a given amount of time. It is necessary to validate that they are different ideas after a variability analysis.

2.2 Design methodology

Product design process can be defined as a decision-making process, and as a process of its nature it is important to recall that several approaches are used in order to assure that the developed product meets the initial goals. In this connection, several considerations appear in order to empower designers team to take the correct decision, especially because 70% of decision taken in early design stages affects dramatically the final performance of the product. Also, it is very important to recall the importance of having reference points in order to compare different concepts and prototypes. Having these references empowers the decision making accuracy [12].

The heuristics concept is defined as a set of procedures that allows both, discovery and acquisition, of a solution for a particular problem by the implementation of a strategy, guided by knowledge derived from the experience. This is applied to design area by the extrapolation of technical or conceptual knowledge that has been previously applied and proven in similar problem-solving processes and providing reference points within designs processes as well.

Multiple authors have proposed the implementation of structured approaches towards the incorporation of heuristics in the product design processes. Some of these approaches assist the design processes, supporting the decision making rather than providing clues. Those clues provided by other methods used by designers, guide the concept development with tools that are intended to envisioning solution strategies to particular problems, without the knowledge capitalisation. These approaches provide a convenient perspective to obtain several solutions to a same problem, but their specificity in the application on design cases is limited. In the other hand are derived from other contexts, and the precision in the application on design tasks is limited. This can be confuse, rather than productive.

One of the most important design methodologies (Pahl and Beitz) recommends for the concept generation phase to use several tools that empowers solution finding; tools such as morphological matrix which seeks information in well-known solutions, and other more creative tools like TRIZ and Heuristics [11].

Also, it is important to recall the important of interactive design methodologies, which are related to the use of new and more advanced technologies that allows a better overview of the possible solutions by assisting designer to obtain valuable information during ideation phases a then a most adequate solution regarding the design problem. This methodology supports the decision-making processes in design phases were designers must face to unknown knowledge fields. It is highlighted that the need to assist the unknown phases and the importance to provide specific information to designers. This type of processes reduce uncertainty and allow designers to focus on the creativity tasks and the finding of new application of existing knowledge [7,8].

2.3 Heuristics

In design heuristics context, Daly and Yilmaz propose a solution to unspecific information given by tools that not include knowledge and experience capitalisation. These approach is based in the analysis and comprehension of development cases by design experts. Knowledge capitalisation occurs when similarity between procedures emerges and it can be defined as a problem-solving strategy to be used in new design cases during the conceptualisation stage. The research concludes with the determination of 60 Design Heuristics, that are intended to facilitate the generation and diversification of concepts in design tasks [5]. This method only focuses on the first concept generation stage, excluding architectural definition and detail design.

TRIZ is a similar approach based on an extensive knowledge analysis and capitalisation from a representative number of patented technical products. The problem-solving process is guided by the application of the 40 inventive principles that act as a set of rules or strategies that helps designer to develop feasible technical solutions [1]. The implementation of TRIZ rules requires the analysis of the design problem from a technical perspective by its definition as a functional contradiction, which is not so easy when the solution definition is not complete. This task represents a major complication for not experimented designers. To conclude this chapter, there are several studies that include the implementation of heuristics in solving-problem processes, but its specific approximation to the field of product design is still incomplete.

3 Practical enquiry

3.1 Implementing heuristics in preliminary design

There are two types of ideas generation methods: intuitive and logical. Intuitive methods stimulates the unconscious processes and focuses on the creation of novel solutions, which is the reason that the outcome is rather unpredictable and undetailed. Logical methods are based on systematic analysis, functional decomposition and assessment of the problem. These methods make use of science and engineering principles and/or catalogues of solutions or procedures [14] .

This research focuses in the validation of one logical method based on 78 heuristic rules that has been previously extracted and categorised by the analysis of knowledge from several design cases. This method provides a problem solving approach as a decision making support tool. The designer is guided through progressive strategy creation by rules. Those rules are structured in the shape of problem solving strategies and incorporated in the method in a hierarchical treelike structure (see Fig. 1). Each branch of the structure provide segments of sentences that step by step configure the strat-

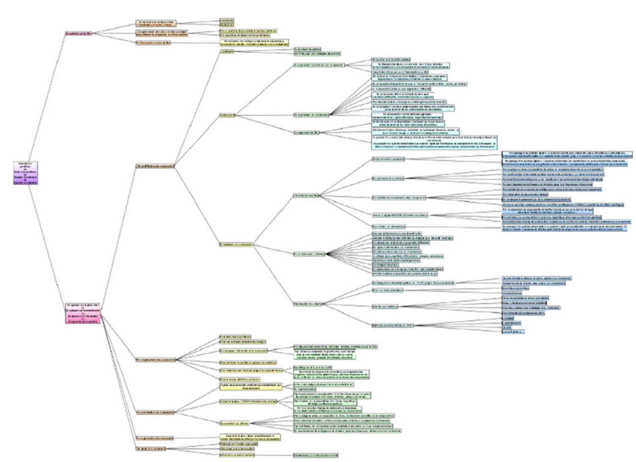

Fig. 1 Heuristics rules tree. Adapted [3]

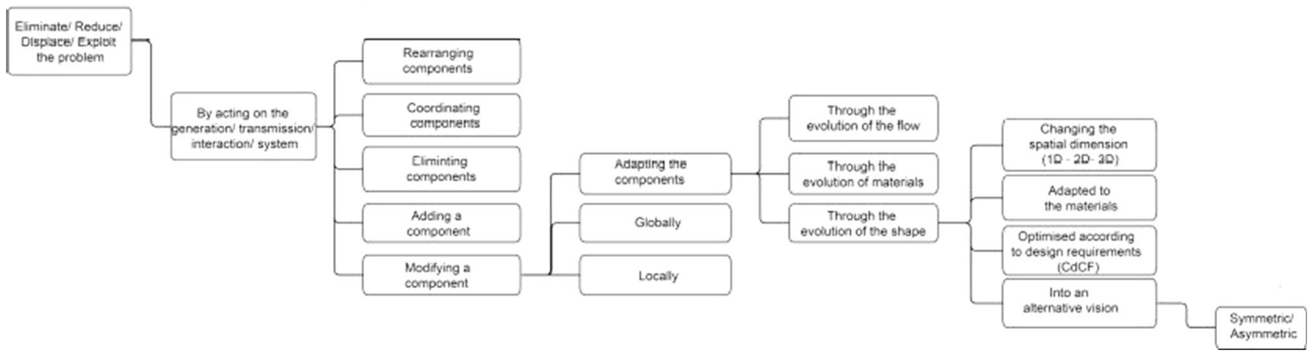

Fig. 2 Heuristics route example

egy unfold into several different strategies, thus allowing the designer to explore diverse possible solution principles for a single problem [3].

One of the advantages that result significant of the method, is the level of detail of the problem approach rules. The level of detail increases as the designer progresses throughout the structure of branches. The level of detail corresponds to a hierarchical organisation that assist designers in the decision-making process to define the type of approach is needed to analyse the problem and then determine the strategy to implement in the solution.

The first step in the problem solving process, based on heuristics method, is the analysis and comprehension of the problem. The designer is guided by a set of steps to understand all the components, factors and external elements that are related with the problem. This disaggregation of the problem provides a full perspective of each behaviour and the relation between elements. At the final step, a cause-effect diagram is presented to facilitate the analysis of the systems, flows and relationships that occur where the main problem is located. With this information the designer can decide where to locate the action to aboard the problem with a further analysis using the heuristics tree.

In this connection, it is also important to state that the rules have been constructed taking into account the semantic value of the words and verbs that describe the actions, so as to simplify the interaction between the designer and the tool, and still provide valuable output for the creative process.

The Fig. 2 illustrates an entire heuristic rule with all the branches that gives shape to the strategy. The way to conduct each heuristic rule is the following:

1. Determinate the action that outbreaks the design problem: suppress, reduce, displace or exploit.
2. Decide where the action will take place: act on the ow of the system or act on the system [this option include subcomponents of the system and its interaction (generation, transmission,interaction)].
3. Define the rule to the particular action that helps to solve the problem.

For the example in Fig. 2, with the selections made, the complete heuristic route is: *Eliminate/ Reduce/ Displace/ Exploit the problem by acting on the generation/ transmission/ interaction of the system modifying a component with the adaptation of the components through the evolution of the shape - into an alternative vision of asymmetric and symmetric shapes.*

Once the designer has a full perspective on the strategies provided by a particular heuristic rule, a creative process can be performed to facilitate the concept generation. That is the manner the heuristic rule assists the process, providing and locating a desired action to aboard a particular problem as a solution strategy.

Under the approach there is a tool that explains the heuristic rules by the application examples in contexts from engineering, industrial design and biomimicry. The perspective from these fields facilitate the comprehension of the functional principle behind the strategy and the integration of the strategy in the development process.

This heuristics method works as a web platform where designers can enter to explore the heuristic tree and all the exemplification information for each strategy. In the same way, the website was created to facilitate strategy comprehension by the use of inspirational images with physical explanation for each example. An example file of an heuristics can be seen in Fig. 3.

4 Case study

4.1 Validation method

The objective was the analysis between two different processes by the comparison of the implementation of heuristics based method and conventional design techniques in a design

Fig. 3 Heuristics file example [3]

case. The purpose was to compare the outcomes of both experiments, taking as a basis the following setup:

– The design case proposed would be carried out by two different teams, each team were formed by 3 students from 5th year of Product Design Engineering at Universidad EAFIT. The first team was instructed to use conventional problem-solving approaches such as Pahl & Beitz and Ulrich & Eppinger and the second one was intended to use the heuristics based method.
– This first team was defined as a *benchmark team*.
– The design task given to both teams was the development of a methane production system by the use of organic waste with the incorporation of technologies to allow the variables control, in other words, an automated biodigester.[2] This in order to make the outcomes from all teams easily comparable between each other. Each team performed the task separately, in order to avoid external influence in the process. The product is intended to be used by farmers in Colombia.

The case was defined to be approached from the early stage of the design process: the problem analysis and the brief definition. All of this to ensure the entire problem comprehension by the teams. The benchmark team, was oriented to choose its desired development methodology, in order to create a real and common product development situation. In the other hand, the test team was focused in the implementation of the heuristics methodology. The next sub-sections of this article expose a description of the process followed by the design teams.

[2] Reactor where the digestion of organic waste matter takes place by the use of anaerobic bacterias.

4.2 Experiment 1: Benchmark team

This experiment has been developed by a team that did follow an unstructured approach based in conventional methodologies. The process followed by the benchmark team is described in the following activities:

– Problem analysis by the theoretical and literature review.
– Context analysis by field exploration.
– Product requirements detection through the execution of a brainstorming process
– Functional analysis and product architecture definition.
– Concepts generation and evaluation for a further integration.

The output of this experiment is a set of concepts that focuses in a formal integration of different components to satisfy the solution requirements.The technical detailing of the concepts was superficial and the number of concepts was based in the product architecture variation.

Since the decision making process was performed without any assistance, all the choices in the process were inherent to designers criteria. This increased the level of subjectivity of the final solutions.

4.3 Experiment 2: Heuristic team

The second team was instructed in the implementation of heuristic rules in the design process, and use this method to empower the understanding of the problem. The instruction was given to the team by the guided development of some examples with the method, this to assure the assimilation of the approach. At the beginning the process followed by the heuristic team was similar to the performed by benchmark team. The data acquisition was developed with the same activities by both teams. The differences appeared at problem comprehension stages when the method was implemented. The following activities describe the development process of the heuristic team.

– Problem analysis by the theoretical and literature review.
– Context analysis by field exploration.
– Product requirements detection through the execution of the problem disaggregation process (included in Heuristics method).
– Functional blocks definition and hierarchical organisation.
– Functional blocks interaction definition and classification.
– Functional solution assessment by the implementation of a cause effect model.
– Functional solution definition by the implementation of heuristic strategies.

- Concepts generation and evaluation for a further integration.

The decision making process was carried out with an entire functional comprehension assisted by the heuristics method, due to that, the direction of the process is oriented at most by the designer comprehension of the heuristic strategies.

5 Analysis of the results

5.1 Benchmark team

The process developed by the benchmark team was guided by an unstructured process that takes activities from different conventional methodologies to analyse a problem for its further solution. In the problem analysis, the first team focused to solve the design task with the integration of existing technologies that satisfied the product requirements, due to that, the solution it is not a novel solution, and its differences with the existing biodigester is minimum. The solution principle used was the implementation of does not differ with the existing simplified biodigesters were the organic waste is contained and mixed with a rotational actuator. The variable control technology was implemented by the addition of a set of sensors and a resistor to control the inner temperature of the system.

The solution generation process result in six concepts that merely varies in the shape of the resistor and the mixing method. The depth of detail in this type of approach is superficial in all functional aspects, it concentrate the designer efforts in the number of concepts by varying the architecture most than exploring new functional solutions. That is the reason of why the functional concept of the known biodigester did not change. In Fig. 4 the solution concept achieved by this team can be observed.

5.2 Heuristics team

The design process developed by the second team was guided in each stage by the use of the Heuristics method. This assistance cover from the problem analysis to concept generation, due to that, the depth of the detail in the heuristics team concept is superior in comparison with the benchmark team.

The exhaustive functional analysis guided by the heuristics methodology result in an alternative point of view of the design case. The second team concluded the problem analysis stage, proposing a system that can be adapted to any existing biodigester or container, allowing variable control and execution of the needed functions in a digestion chamber.

The Heuristic strategies were implemented during the development of the final concepts. The team carried out the conceptualisation, assisted by the heuristic tree and its application examples. The decision making in this part of the process was determined by the functional analysis rather than the designer desire.

The idea generation process concluded with just one concept that merges all the functional solutions in a modular system that can be integrated with the existing technology because it is attached to the most important element in the biodigester: the organic waste. The proposed solution is a buoy that floats over the organic waste dilution and is provided with two pumps that recirculate the fluid in order to avoid the solidification of the superficial layer. The heuristics solution file associated to this principle can be observed in Fig. 5.

In the other hand, the solution considers three input sensors: temperature, humidity and pH, which allow the inner environment control to optimise the bio-methane production. In the same way, the buoy contains a resistor that transfer heat to the fluid. The modular architecture allows the installation of a solar panel to provide the necessary energy when the connection to the electric grid is unavailable.The electronic concept based on a generic processor allows the evolution to an advanced system that could enable the data storage, remote monitoring and control. The solution concept achieved by heuristics team can be observed in Fig. 6.

In order to improve the buoyancy of the system, the team included a counterweight in its design that keeps the buoy in

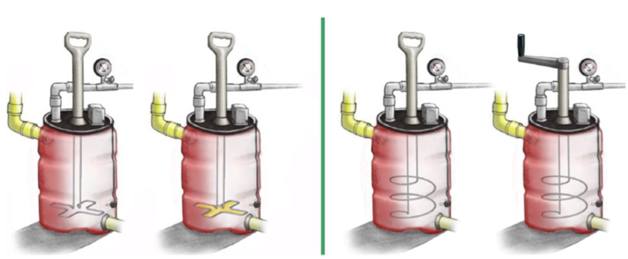

Fig. 4 Benchmark team concept

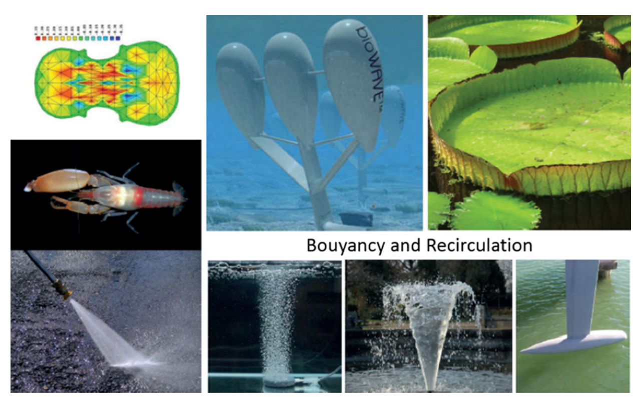

Fig. 5 Heuristics file used

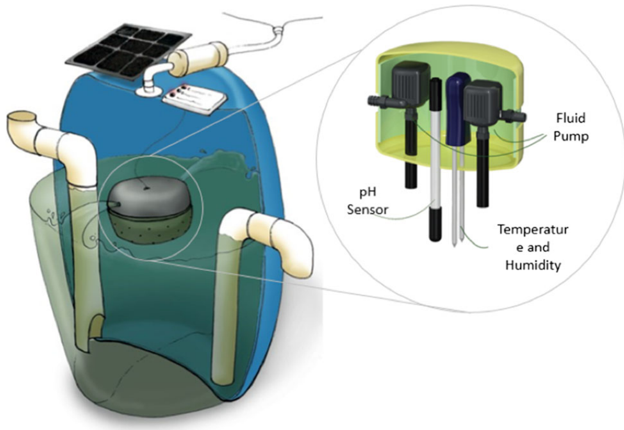

Fig. 6 Heuristics team concept

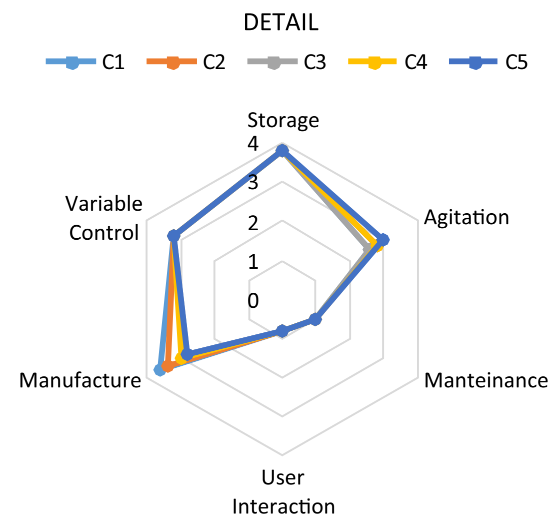

Fig. 7 Detail comparison

the desired position. This function allows the installation of a set of buoys in a bigger container.

5.3 Analisys

The differences between the design processes of the experimental teams are significant, also, both outcomes are comparable to determine the consequences of the heuristics implementation in a design task. The evaluation metrics were based on the conceptual design effectiveness metrics proposed by Shah [14]. Other metrics were added in order to analyse other satisfy the requirements given to designers in the design task. The evaluation criteria are described as following:

- Quantity: Is the total number of ideas generated by a team.
- Variety: Is determined by the difference between each ideas generated by the group.
- Detail: Is the depth of detail of the solution proposed.
- Novelty: Is the measure of how unusual is an idea compared with the existing solutions.
- Feasibility: Is the measure of how achievable is an idea.

The evaluation of the concepts under these metrics was performed by design experts with different background (Mechanics, Ergonomics, Product Marketing, Aesthetics). In order to parametrise the evaluation, a functional disaggregation was performed in order to define product characteristics that must be satisfied by each concept from each evaluation criteria (Quantity, Variety, Detail, Novelty, Feasibility). Functional disaggregation resulted in the following parameters:

- Storage: Represent the ability of the proposed system to storage the Bio-Mass to produce methane.
- Agitation: Represent the ability of the proposed system to agitate the the fluid to avoid solidification.
- Maintenance: Represent the facility in the system maintenance.
- User Interaction: Is determined by the interface designed to interact with users.
- Manufacture: Is determined by manufacturability of the product with local processes.
- Variable Control: Represent the level of automation to control the variables.

The evaluation was carried out by the qualification of each parameter under each metric, with a rank from 0 to 5, were 0 was the lower level and 5 the higher level of accomplishment of the required specification.

The results obtained from the quantity and variety evaluation can be analysed together because, even when the benchmark team exceeds the number of concepts per parameter (quantity) in comparison with the heuristics team, the differences between each design proposals are merely superficial (variety). Due to that, the qualification of both teams is similar and is not so representative.

In the other hand the detail evaluation was resulted in a superior qualification for the heuristics team which design has satisfied integrally all the functional parameters. Even when the benchmark team has developed several proposals, the depth of detail does not satisfies the product requirement in at least 3 parameters. The comparison of detail can be watched in Fig. 7, where team 1 is Benchmark team, and team 2 is Heuristics team.

Finally the experts evaluation resulted in a higher qualification for the heuristics team in Novelty (comparison in Fig. 8), due to that, the qualification for feasibility (Fig. 9) was lower because a novel solution could represent a complexity

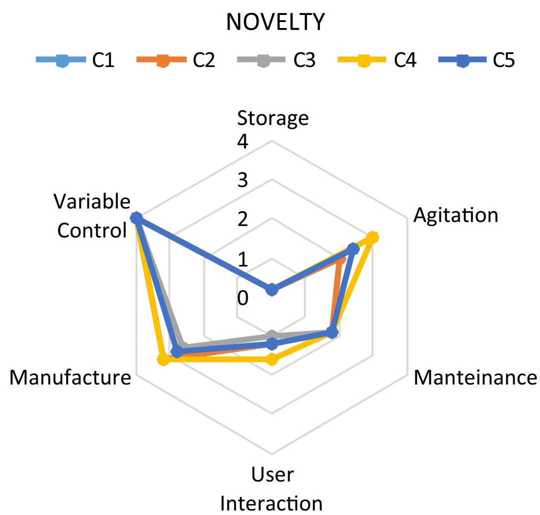

Fig. 8 Novelty comparison

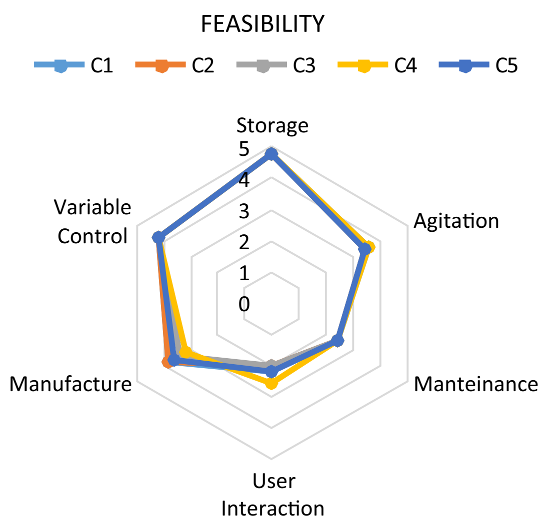

Fig. 9 Feasibility comparison

in comparison with an integration of existing technologies like the proposal of the benchmark team.

5.4 Manufacture and operation comparison

As a complement, a comparison out of design boundaries is analysed. It is intended to consider the following scenarios: (i) manufacture cost, (ii) operational cost, (iii) performance.

In terms of manufacture, both concepts were built using standard parts in order to keep prices low. Also workforce is not included because in both scenarios the students designed and built the concept. In term of cost, it is found that Heuristics team concept had a final value of 460,000 COP[3] (circa 140 EUR) while Benchmark team concept had a final value between 620.000 and 700.000 (190 EUR - 220 EUR). It is important to recall that the variation of the resistance size.

In order to calculate operational cost, an explanation of how each solution operates its expanded:

- The Benchmark team concept was designed with using a colour based intuitive interface to communicate the biodigester status to the user: red represented that the reactor was hot and it was necessary to cool it down; blue represented that the reactor was cold and it was necessary to warm it up; green indicates that the temperature is ok. Also the concept includes a led that flashes when it its necessary to stir. All of this considerations were defined in order to reduce the operational cost, avoiding the extra expenses on automation of the system.
- The Heuristics team concept was designed in order to develop an automatic system that can handle the operation of the stirring process. It also included a system for communicating the status of the biodigester to the user via sms messages.

Even when the Benchmark team concept seems to have lower operation costs, the system interfere with the user daily routine because of the extra attention required in order to set the temperature at level and the stirring process. In the opposite case, the Heuristics team system facilitate the operation of the biodigester with the automation of the stirring process. In the other hand the sms communication system, allows user to stay idle from the product.

Taking into account the proper operation of the system and the interference that it might have in the daily routine of a Colombian farmer, it can be concluded that the performance of the Heuristics team concept is higher than the Benchmark team. This is asserted by the absence of a human operator, which not only decreases the costs of operation but also facilitates the user to be able to develop other activities even while they have have biodigestor operation information.

6 Conclusions and further research

The analysis concluded with an indication of advantage in the use of heuristics in design processes, oriented to the detail specification in concept creation. The level of detail reached by the heuristics team was significantly superior. The method assist the designers in the decision making activities to ensure the inclusion of conceptual and functional analysis in each design choices. Those conscious decisions improved the final concept proposed by the heuristics team with a high level of detail in all the functional parameters, and is in that choices, were the greater difference between two teams resides.

[3] 1 EUR = 3200 COP.

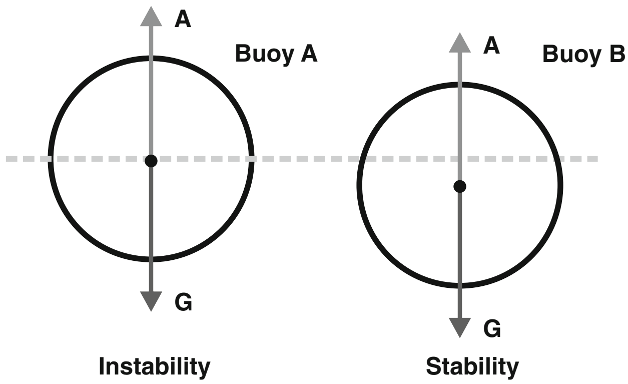

Fig. 10 Buoy stability

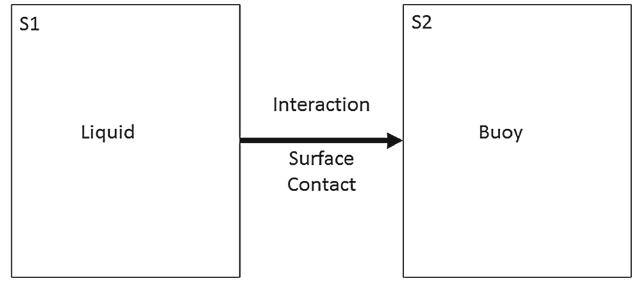

Fig. 11 Buoy stability analysis

The heuristics team has decided each aspect of the design, with the assistance of the systematic problem assessment of the proposed method. The functional disaggregation and the problem approach by the heuristic tree, provides the designer with proven information that defines in a higher level the concepts. The exemplification of the heuristics tree drives the idea generation process including information of similar solutions from different contexts, this type of support rise the possibility of a novel solution creation. In the case of the present experiment, the biomimicry examples were the most used by designers, whom said that preferred those examples because make them feel more inspired and provides the most simplified functional concept.

For the heuristics team situation, the decisions that defined the final concepts were inspired by analogue solutions, selected by designers, whom unconsciously implemented a set of functional solutions that not only assure the performance of the design proposal but improved the level of novelty.

One example of this unintentionally analysis is the counterweight of the buoy, that was defined by the team, using the following heuristic strategy: *Act on the system by adding a component to divert an undesired action*. That heuristic guided the designers to add the counterweight to avoid the instability of the buoy floating on the fluid . Unconsciously the designers analysed the undesired action and included the Archimedes principle to displace the centre of mass under the floating line to generate stability (Fig. 10).

As a final conclusion regarding to design, the method facilitates the creation of detailed concepts when is implemented in design processes providing a guided problem analysis and a decision support although the functionality definition seems to obey merely to designers capability. Even when the method proposes a problem functional analysis (Fig. 11) and the experimental team reached a correct solution for the problem in a unconsciously manner, is needed to instruct designers in an appropriate and conscious problem analysis that allows designers to understand requirements from a basic functionality perspective.

It is also found that the implementation of the method not only allows to come up with more creative solutions, but it also empowers to designers to create solutions more centred in the user needs allowing to generate cheaper and more effective solutions.

Another general conclusion of the use of heuristics is the inclusion of lateral thinking. These processes began to appear in early ideation stages, empowering the designer to be inspired by solutions out of functional domain, such as architecture and biology.

Moreover, design engineers are not limited to the generation of concepts in the functional domain, nor, the of rules of ideas. As a matter of fact, rules often grant engineers to discover ideas not directly connected with the function, but somehow related to them, allowing them to generate more diverse concepts.

Regarding to the use of the tool, it is important to recall that some differences can be considered regarding to the original proposal, the approach followed in this implementation was slightly different. The original method was created to be used exclusively by engineers familiar with MALIN methodology, that is to say, engineers with competences in functional analysis and physics understanding. In the other hand, during the present implementation, the methodology was modified in order yo allow that the tool could be also people from other domains. This modification allowed a more multidisciplinary approach, granting that engineers can work with industrial designers, marketing and management in early ideation stages.

For a further research is recommended to implement concepts of usability in the heuristics tree website, in order to minimise the distraction of the users from the problem assessment. In the other hand an structured validation with a higher number of participants is needed to prove through statistical analysis the efficacy and effectiveness of the implementation of heuristics.

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