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New Methods in Design Education: The Systemic Methodology and the Use of Sketch in the Conceptual Design Stage

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This study describes the application of a new product concurrent design methodologies in the context in the education of industrial design. The use of the sketch has been utilized many times as a tool of creative expression especially in the conceptual design stage, in an intuitive way and a little out of the context of the reality needs that the design should be attended. This methodology systematizes and guides the process of sketching by means of a conceptual model and a geometric model toward a feasible solution, complementing the role of the sketch in the phase of a product conceptual design. The model describes its operating principles, as well as the phases of implementation in the context of teaching the industrial design illustrated with projects carried out in the workshop of conceptual design of the University Technical College of Valencia and University of the Bío-Bío, Chile. Finally, we discuss the implementation of the systemic models, their relation with the optimisation of the sketching process in the conceptual design stage, and their implications in the educational context.

Keywords: industrial design, methodology, model, sketch, conceptual design, systemic, education

Introduction

Nowadays, the design of new products must meet a series of demands that are imposed in different ways, such as the global market, consumers and production, which are only some of the factors that influence it. Nowadays, developing a product is a complex process that requires managing and trying a lot of information. Information technologies applied at developing products fix together new approaches in current and collaborative engineering (Aguayo & Soltero, 2002; Contero, Company, Vila, & Aleixos, 2002), and developing new products is assumed as a simultaneous and collaborative activity that contemplates aspects which are defined and resolved in back phases of the process.

This is the definition of a new paradigm in new product development, concentrating on the initial phases and different strategic decisions about the new product. The management of this information and the knowledge must be done in an efficient way, so that the creative process would cause real and innovating solutions (Awad & Ghaziri, 2003). In this context, the proposed focus using the systemic methodology (Hernandis, 2003) allows people to register information from the beginning of the creative thought throughout different design stages, and in this way, it can be part of the so-called knowledge management. This

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methodologies innovative focus is based on a model (the modelling phase) which establishes the dispersion of the fundamental design factors (Hernandis, et al., 2005).

Design and Systemic

In the context of industrial design, if people apply these considerations into the products design, they would observe how they are referring of a structure based on systems and multiple relations (see Figure 1).

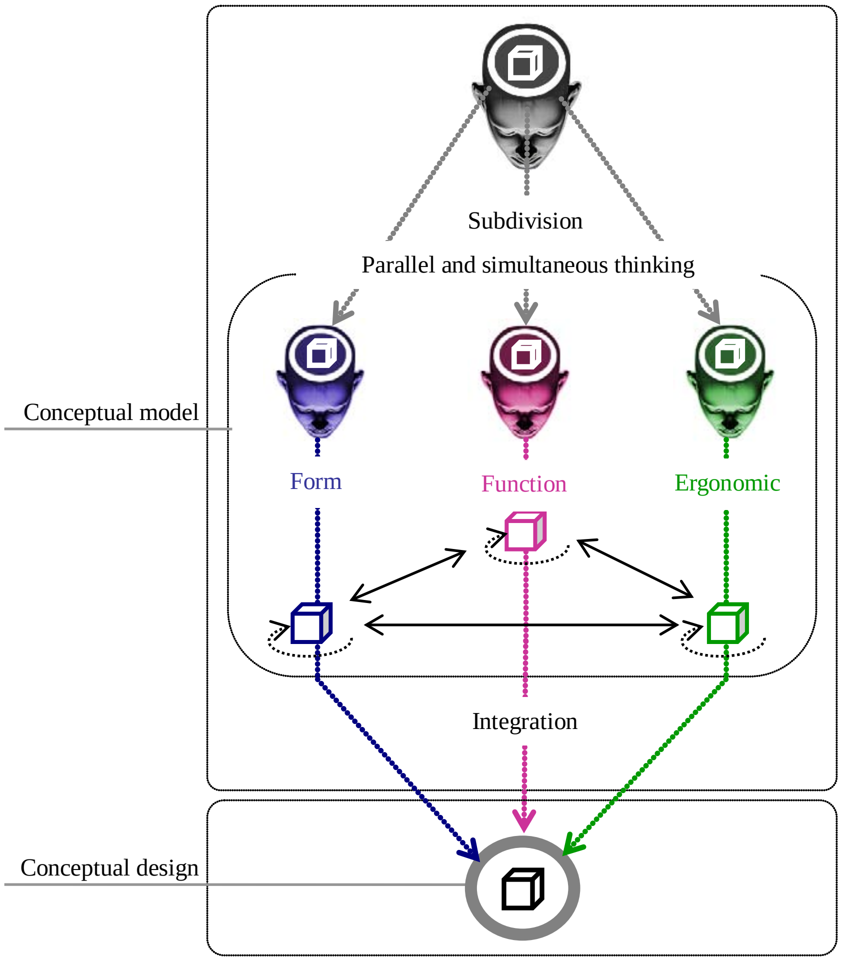

Figure 1. Systemic model for the innovation and new products design. (Hernandis, 2003)

The analysis of the influent factors in conceptual design, as well as their considered value according to the proposed objectives and how can people incorporate them in conceptual design, open new expectative for the designers. This new exposition can be broach with an adequate knowledge management from the beginning of the design problem to the final solution. Nowadays, one of the challenges that are posed is the pursuits of the different phases in the design and the control of the information, which is associated to the problems. We have to take into account that the majority of designs display complexity levels whose control of information demands a process with different alternatives.

Systemic methodologies allow considering these multiple factors and the effects caused by diverse alternatives according to the objectives.

At the moment, great parts of the investigations are based on the initial phases of the design process and the using of the information generates for successive works.

Our works are based on the modelled factors that integrate the design with the object of managing necessary information in an optional way, and at the same time, to shorten the time of products development, taking advantage of the accumulated experience in each development.

The analysis of sub-systems and common relationships between types of products demonstrates how from the abstract, initial definition of the design, common elements can be defined for a range of products independently of its shape characteristics.

Systemic Model

Many of the problems detected in recent decades regarding to the complexity of the management of data no longer exist, thanks to the evolution of information technology, which is able to control and resolve difficult problems, not only from the point of view of the mathematical models to be used, but also from the approximation to the processes and common tools used by the designers.

Product analysis, with the aim to determine its integrating factors, has been done in a rather intuitive way, from the appearance of its products from the first stage of conception, which mainly considers its use.

It is certain that Vitrubio made a characteristics division in 32 BC, in aesthetic, functionality and reuse. Perhaps this is the first factors' division that composes the design. In 20th century, Mintzberg (1991) commented on the field of forms, appreciating that the objective is to satisfy the aesthetic requirements of a product. In the same way, it is the functions' aim to proportionate technological aspects to a product and the ergonomics will adapt the formal and functional aspects to the user.

In an updated way, and as the result of a lot of models that have been done, people can infer recurrent patterns that foresee new work ways.

From this systemic perspective, we analyze the subsystems integrating the design, considering all the aspects and formulating an analysis proposal that we considerate appropriate for the conceptual models.

We proposed an analysis based on decomposition of fundamental subsystems of design: shape, function and ergonomics, in volumes, surfaces and contour limits, as a division which is able to incorporate all the values that integrate the design, making possible a conceptual model of formulation by objectives that could be generalized to any product analysis as it can be seen in Figure 2.

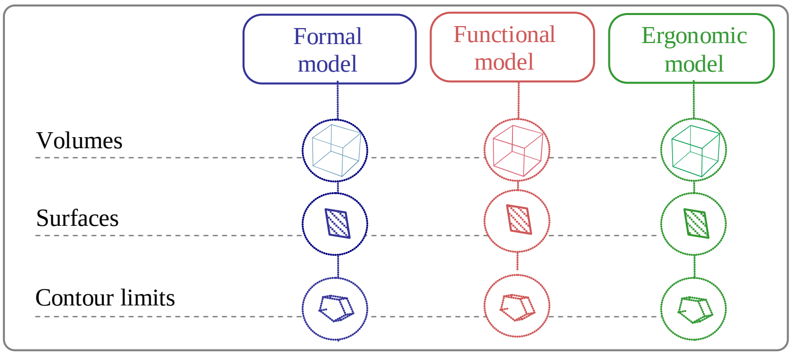

Figure 2. Model for geometrical disarrangement for each subsystem. (Hernandis, 2003)

Therefore, cases are analysed where the application is studied and appropriate definitions regarding volume, area and sketch in all the cases are observed.

The advantage of this division appears in its incorporation to systemic models which in turn establishes theoretical models, with the desired abstraction level. This proves that no excluding case for its application has been found.

With the development of systemic methods, in particular with that of the contributively design which tries to form the product, we are able to decide as far as the existing prescriptions and possibilities go when designing the product which is the best response to the proposed objectives. This requires an attribution of characteristics to the product from its formal, functional and ergonomic perspective. When looking at the fundamental subsystems, we aim to build concepts about the product.

To accurately look at volume, area and sketches, we need to differentiate between positive volumes which belong to the objects' geometry and negative volumes which define the geometrical considerations required, regarding normative restrictions, specifications or particular considerations. These correspond to the environment, and are just as important when designing, as the ones attributed to the products final physical state. They belong to an immaterial world and consider geometry of use. The sum of the positive and negative geometries equals to the "design space" or design polyhedron from a geometrical point of view. Both defining the external and internal considerations will optimise the design objectives.

The Sketch in the Conceptual Design

The idea of "conceptual" in the context of the design process has been understood as the design development principle, where abstract solutions aiming at solving those problems that arise while developing the design are found.

The conceptual design stage has become the first instance where the initial ideas are summarized, solution principles (Pahl & Beitz, 1996) as a whole (Pugh, 1991) and under high out-of-context abstraction levels regarding its technological mapping (Aguayo & Sotero, 2002).

Thus, the use of sketching as means for representing the conceptual design makes up an essential strategy with respect to the development of the new products, as it has been stated by Goldschmidt and Porter (2004, p. 222):

> No design activity can exist without representation. Ideas must be represented or illustrated in order to be shared with others, even when being shared with themselves. The various types of representations and strategies that have been discussed provide different options to read or change the design ideas.

Design uses representations or illustrations as a way by means of which ideas turn into something real or become somehow "physical and material" to be seen, assessed, shared, corrected, improved and changed.

The sketch under this context becomes a means of expressing the creative process. This tool's typical feature was already well known in the renascence, thus, referring to the sketch as "Pensiere". First thought (Olszweski, 1981), as a representation means that assists the cognitive process (Ullman, Wood, & Craig, 1990) is able to describe the product's characteristics at its early stages.

The sketch as the expression element in conceptual design provides this means of representation with a serviceable role in both the industrial design and product development field.

This is done by means of an interface able to cope with mental process speed in order to state, register and investigate possible solutions.

Such development strategy had already been stated by Cross (2000, p. 224) by saying: "Design by drawing", which means to design by drawing when developing a product. Due to the fact that it provides the possibility of generating alternatives and has them tested, theoretically speaking, before being pushed to spend huge amounts of money in operational models, drawing not only has the characteristic of showing objects' visual appearance, but also expresses the way they are made. Regarding the latter, most of the drawings that are related to industrial design refer to the shape, position and size-based structural features of all their elements.

So, sketches as a specific type of diagrammatic drawing have the following characteristics (Briede, 2008): (1) problems statement and visualization; (2) cognitive activity organization; (3) problems solution simplification and the creative effort; (4) representation of real world objects that are likely to be handled and think about them; and (5) ideas review and improvement.

Implementation of Concurrent Design Model in Design Education

The teaching of the systemic model was carried out within two instances in Spain.

Design teaching of the systemic model is delivered in 2 parallel courses in 2006-2007. The first course is entitled "Leisure and Auto-mechanics", which takes place in the school of Technical Design Engineering at The Technical University of Valencia. The second course is called "Design Methodology", given in the 8th version of the university master in design, management and development of new products.

And one in Chile: Conceptual design workshop was given at the School of Industrial Design at University of the Bío-Bío during the first term of 2008. The school typical methodological approach is based on observation as a means of detecting opportunities or problem-based issues. This more intuitive process, which is based on personal sensitivity and perception, makes it possible to take up the systemic proposal as a complementary means, with the purpose of having the project's idea developed in a more systematic manner.

The model implementation stages were completed up until the theoretical model was able to do the conceptual design. The degree of separation and depth in the implementation of the model was created in a low difficult level, in relation to the students' experience. However, free choice was given to keep on setting up and deepening its use, thus increasing the number of variables, and therefore, the product complexity and other issues were to be taken into consideration. The task was to design a product and develop it in an individual way.

We will show the application of the model up until the conceptual design phase. This model has been set up at University of the Bío-Bío conceptual design workshop. The implementation of the model was adapted according to the availability and the experience of the students. These criteria resulted in a process developed in the 6 stages (see Figure 3).

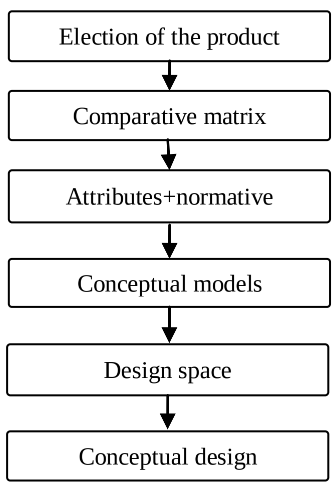

Figure 3. The 6 stages of the methodological model.

To put into action concurrent design corresponding phase, each of which shall include examples of data information about projects that have been developed in the above-mentioned workshop, the following has been done.

Choice of a Product

To determine what kind of product is going to be designed, it contemplated different fonts of information as: opinion polls (user necessities), previous knowledge of the designer (experiences and tastes), and necessity or opportunity detection, customer order (requirements). Also, the objectives the product must carry out have to be defined. This is fundamental, because it is the guide in rear process. In other way, none of these facts inside the different phases are immovable; it means that they are capable of improving and changing, by analysis and feed-back. During the project developed by Liza (2008), a study work for a given topic was conducted: shelter for protection-type dogs, which in turn, lead to a particular case: rain insulation and control for patrol dogs.

Comparative Matrix

In this market study, it looked for grouping all the products that have got similar characteristics for the elected product. Analyze the different characteristics of the product in a released way must be done. Also it has to establish A (advantages) and D (disadvantage) from the different points of view: formal, functional and ergonomic (see Figure 4).

Nombre producto	Descripción	Atributos y/o características		Formal		Funcional		Ergonómico	
		Ventajas	Inconvenientes	Ventajas	Inconvenientes	Ventajas	Inconvenientes	Ventajas	Inconvenientes
3. Collar grandes razas. 	**Collares de cuero para razas grandes.** Con doble cuero para una mayor resistencia. Adorno con remaches y costuras reforzadas. Diferentes medidas.	-Ajustable y adaptable al grosor del cuello - Anatómico - Resistente a los tirones. -Material Semi rigido. -Gran capacidad de control. -Fácil y rápido de poner. -Liviano y de textura suave. -Simple en su forma.	-No lavable. -Su uso diario puede producir alergias y alopecia. -Los tirones pueden cortar el aire al perro y rasgar el collar. - Aprieta mucho el cuello del perro con los tirones.	-Diseño bicolor. -Huincha semi rigida con Costuras reforzadas, resistentes a tirones y permite copiar la geometría del cuello. -Su forma simple comunica y facilita el modo de uso (poner y sacar) - Apariencia	- Los remaches hacen que el cuero se rasgue más rápido. -No es lavable. - Cuero de buena alidad.	- Mantiene bien sujeto al animal apretando su cuello. -Material resistente, semi rigido que ayuda a su propósito de rodear el cuello para dominar. - Puede mantener controlados a perros de razas grandes, gracias a sus medidas (tallas)	-Aprieta mucho el cuello del perro, causándole daños.	-Ajustable a la medida (talla) del cuello. -Anatómico. - Liviano, fácil de portar. -No incomoda. -Suave al tacto, su textura no produce dolor	- El roce continuo produce alergias y alopecia. - Al apretar dificulta la respiración normal del perro.
4. Collar de Nylon Antialérgico. 	**Collar de nylon antialérgico con costuras reforzadas y uniones termo soldadas.** Repelente al agua. Diferentes medidas	- No produce alergias. - Repele el agua -Ajustable y grosor del cuello -Anatómico. -Fácil y rápido de poner. -Liviano. -Diseño simple y pulcro. - Enganchable a cualquier correa para perro. -Diferentes tallas.	-Puede producir alopecia con el uso diario. -Puede cortar el aire al perro al tirar de la correa. -Aprieta mucho el cuello. -- Material fácilmente desgastable y rasgable	- Cinta ancha para distribuir mejor la resistencia a la fuerza de un tirón. -Diseño simple, una pieza - acabado fino - Su forma simple comunica y facilita el modo de uso. - Repelente al agua.	- Por su anchura, cuando se dobla el cuello, se dobla el collar. - Material fácilmente desgastable y rasgable.	- Controla a perros de diferentes tamaños. - Sujeta al perro eficientemente, con uniones termo soldadas y costuras reforzadas. - No produce alergias que impidan su uso diario. - Conector para correas como vinculo de control	-Aprieta mucho el cuello del perro, causándole daños.	- Anatómico - Ajustable a la medida del cuello de diferentes perros (tallas) -Liviano, no molesta al andar.	-Puede producir alopecia con su uso diario (roce) - Al apretar el cuello, impide la respiración normal del perro.
Nombre producto	Descripción	Atributos y/o características		Formal		Funcional		Ergonómico	
		Ventajas	Inconvenientes	Ventajas	Inconvenientes	Ventajas	Inconvenientes	Ventajas	Inconvenientes
9. Vestimenta para perros de carabineros 	**Capa de tela que lleva estampado el símbolo de Carabineros de Chile.**	-Capa anatómica, -Deja el cuello descubierto para poner el collar. -No produce alergias. -Cómoda y liviana. - Fácil de poner. -Identificación de la Institución.	-Sólo cubre el lomo del animal, - no es impermeable a la lluvia ni el frío. -Capa sólo de función distintiva. -Sólo para perros de la Institución.	- Tela delgada, suave y ligera - Su forma indica como se pone. -Fácil de poner y sacar. - Acceso inmediato.	- Su liviandad hace que se suba con el viento y se doble.	- Resalta que pertenece a la institución de Carabineros de Chile. - Intimidante.	- No protege de la lluvia ni el frío. - Cubre solo el lomo. - El perro se moja y enfría.	- Anatómico. Se adapta a la forma del lomo - Ligera. - No dificulta sus movimientos. - Cómoda. -Tela suave , no molesta el roce.	-No se vincula de ninguna forma con la persona

Figure 4. Section of a comparative matrix. (Liza, 2008, Shelter for protection-type, rain insulation and control for patrol dogs)

Attributes+Normative

Once the attributes of the product to be design have been defined, other attributes that are not in the competence matrix have been considered as some kinds of valid normative which can condition or limit the proposal.

Conceptual Models

Once the attributes that must carry out each sub-system have been incorporated, it will pass to the conceptual models implementation. Managing the function, ergonomic and the form is the first attempt of translation of the theoretical concepts to geometry. It is done by a theoretic diagram for each subsystem that is represented by an isometric cube, where it simulated a space in which it should incorporate different conceptual aspects, in terms of volume, surfaces and contour limits. This is a mental abstraction exercise, which is not easy, and it requires an analysis and a good relation capacity. It demands an effort not exempt of difficulties (see Figure 5).

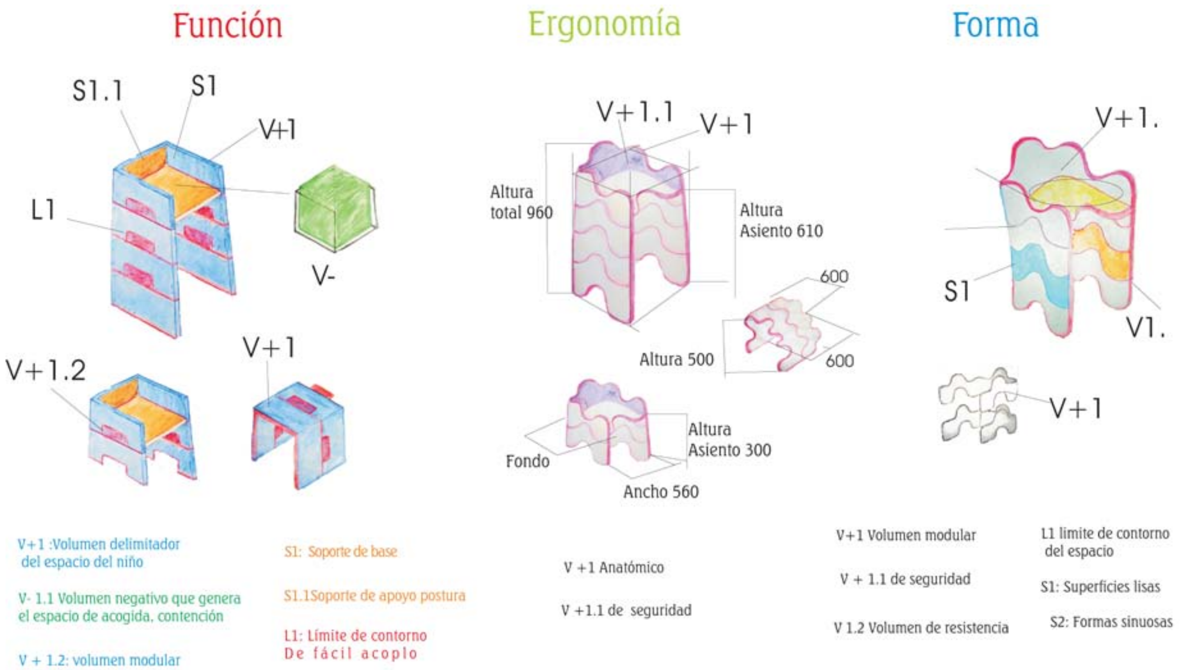

Figure 5. Develop of conceptual models. (Cisterna, 2008)

Integration

This is the moment where the different models, that were generated in an independent way (formal, functional and ergonomic), have to be integrated. Every attribute and its consequences must be analyzed and valued (for example, the case where two objectives are contraries), ranking the attributes in each case and taking a unitary agreement (see Figure 6).

It is important to highlight that due to reasons mentioned above regarding to the experience and the abstraction ability of the students, we chose a particular work flow in the modelling stage, which had already interrelated the characteristics of each subsystem to the next, suggesting a formal, functional and ergonomically implementation order. This made creating the model much easier, because the variables included in a model should be transferred to the next. This helped the integration, as each individual model began with the proposal made in the previous model.

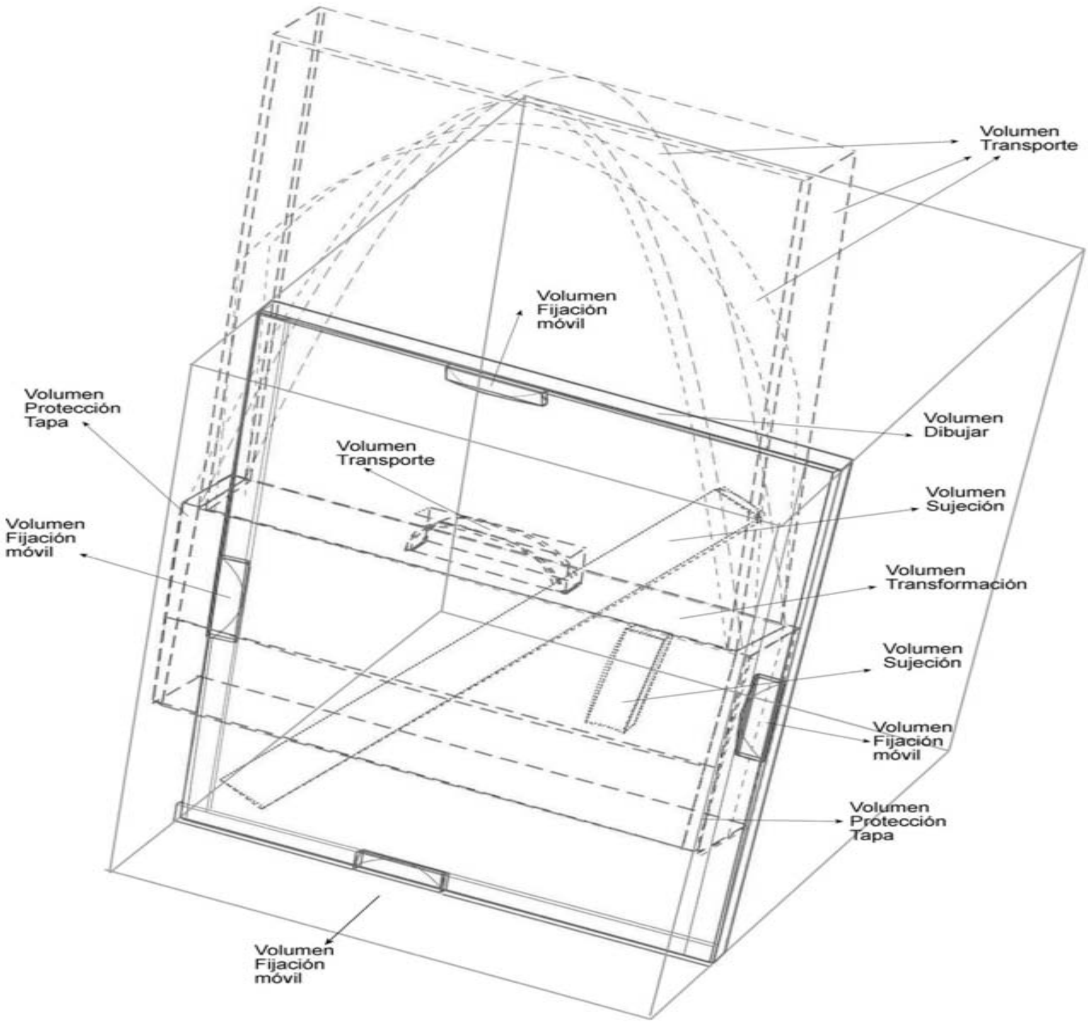

Figure 6. Conceptual model integration for a sketching transport and support system. (R. Gómez, J. Gómez, Pastor, & Sanz, 2007)

Design Space

It is the definition of a theoretic space including different factors that composes the process as a new design has to be modelled and studied. It is in the space where the designer has got all the decisions have to be carried out and any proposal has to be coherent.

Conceptual Design

In this proposal of conceptual design (see Figure 7), it must evaluate the different design architectures that were included in the space of design to develop alternative solutions (see Figure 8). It can use matrix methods based on theory, or other methods the designer decides. It is advised to use a process capable of valuing complex solutions; it must not forget that the complexity in any design requires levels of decision that are not acceptable from the intuition in the majority of cases.

Summarizing, a sequence providing a structure is given, as well as the acts as guideline for the conceptual design solution.

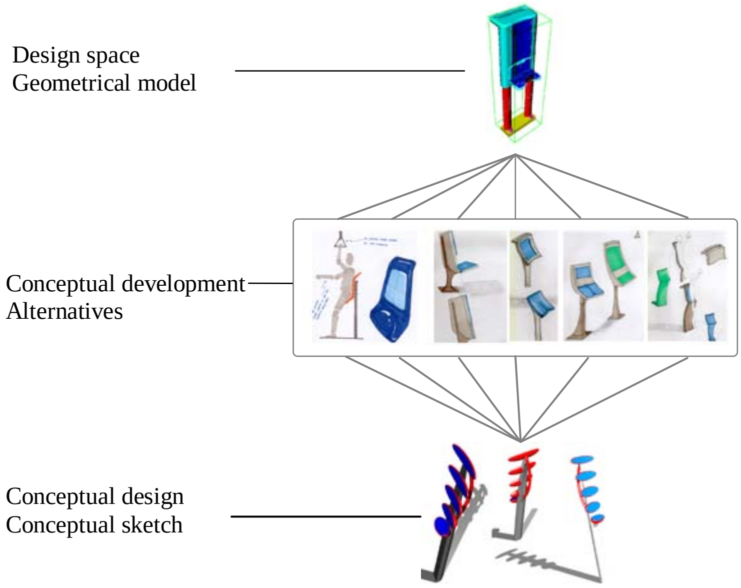

Figure 7. Conceptual design based on the design space defined by the geometrical model. (Briede, 2008)

Figure 8. Conceptual development. (Urban transport chairs. Contreras, 2006, 2007)

Results

Implementation of concurrent design model inside the education and as a methodology shows advantages, not only because it represents a work guide with specific steps at the time of designing, but also because it shortens the time of conceptual design development. Implementation model was planned as a work in 6 different phases. These were divided as well in activities with specific objectives. The application in various university settings (Spain and Chile) proved the method's versatility. It also showed that after an initial induction process, setting-up and tracking allow students to have guidelines and references to seek coherence and optimization of the suggested product, based on the initial theoretical conceptual structure.

Discussion

Implementation the model as a work tool in design teaching could be stated as a guide according to the obtained results. The majority of students had got experience in product design. There is no doubt that the use of the model has supposed advantages opposite the traditional procedure, when offering a different approaching that manages the knowledge on a separated way, and that not only uses the drawing as an immediate tool looking for a solution, but also the implementation of the model implies these solutions reply in a specific way to the objectives, and it is guarantee that the solution adopted is not the result of the first solution. Many methods automatically assumed that the result is based on the designer experience, without reflecting the analysis and depth level that concurrent design allows in its minimal conceptual expression.

Understanding process of that new tool is not immediate; it needs a period of time. It could be said that there is a period of absorption (+) without doubts. Then it comes a critical period (-) in order to have a clearly and completely understanding of the model (+).

Education must pay attention to new changes and new approaching. In a world where everything is resolved and the culture turns around the image, it is a difficult task to take the students into deeper states of reflection, where they can find an abstract level that allows them inhibit from the reality and let them reflect on, in a coherent way, establishing meaning is not only mere an answer.

Conclusion

Conceptual design, from the systemic point of view, is applied from the concurrent approach. With respect to this, the amount of information to be handled is larger regarding number and complexity when compared to usual methods, which in turn affects the number of factors and relationships to be taken into account.

It also allows, opposite traditional design methods proposals, looking for alternative and innovating designs, optimizing customers' or own designers' requirements, since the beginning by means of fixing and fulfilment objectives.

This proposal is not free of disadvantages regarding to traditional method, since it implies a particular work opposite the intuitive method to find the happy idea. Therefore, it displays main work dedication its initial phase brings in a half and lengthy term bases of the future knowledge.

It has been verified that after the first application, students begin to acquire experience and it is useful in later developments, because as a guide, it fixes the work's guidelines. That represents a double advantage, because it guides the students and also is an organized way to take structured information, providing the later problem presentation and reasoning.

Conceptual design definition by using representations or illustrations turns out to be essential, thus making up the conceptual sketch as a means of stored information is the first step of resulting representation from the conceptual design, where proposals are generated. Such visual record makes the study, assessment and evidence of those design factors involved in the product possible. Likewise, the identification of the use of construction variables from the sketch as a visual message for its suitable perception also applies.

Conceptual design definition through the sketch based on conceptual and geometrical models, helped and eased proof and coherence for the solution of those topics stated in theoretical ways. By doing so, a process featuring high degree of convergence is achieved and so, the use of the sketch as a complete tool can be strengthened. This means that the resulting image is the consequence of a feasible and consensual decision process.

The application of the systemic and convergence model, with respect to sketch processing, brought about time reduction in the definition and specification of those variables to be taken into consideration in the conceptual design, as well as in its representation when sketches being used, thus becoming a device capable of generating an outline with product specification, and beyond the mere artistic expression that is related to the hand-made sketch.

Development timing for both application contexts, both in Spain and Chile, got increased during the final stage.

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