THE CONTRIBUTION OF THE NEW TECHNOLOGIES TO THE 21ST CENTURY DESIGN

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ABSTRACT

In the past the market economy was dominated by the local and regional design, characterized for strong links to the customs, traditions and natural resources from each region.

As the consequence of the technological advances and the growing needs of consumption, at present, products are manufactured based on economical, functional and marketing criterions, which means that their design is very offset from the regional and local signs.

Between the challenges that characterize the actual economy, one highlights the existence of more market niches, product variations and shorter life cycles. To survive in this economy, marked by the competition and the globalisation, one search to imply in product developing process, the design, engineering, marketing and production department, that composes a known industrial methodology called concurrent or simultaneous engineering.

In this article, one intends to exhibit the applications and advantages of the new technologies, like Rapid Prototyping (RP), that are valuable tools of the concurrent engineering and to analyse the specific implications in the design history and teaching.

RP is a family of modern technologies that generate three-dimensional solid objects under computer control. Besides its designation be reported to the first major application that is industrial prototyping, the RP equipments also allow the rapid tooling and the direct manufacture of small series or single products.

Nowadays, the commercialisation of RP equipments, termed concept modellers or 3D-printers is in great expansion. Although these machines use a very reduced class of cheap materials with poor mechanical characteristics, they allow the designers to verify and quickly test the ideas that they are developing during the creative process. The designer can realize in plenitude the iterative process of creation without the traditional economical and materials limitations, being enough to send the CAD file directly to the RP equipment placed in a office, like an usual inkjet printer. So it is possible to test new ideas with better accuracy before its concretisation, avoiding misunderstandings and delays and inciting the positive criticism through the involvement of the technical staff from all the related departments.

Particularity, faced to the challenges due to the globalisation, the traditional and regional industries will find in these technologies the means that they need to ensure its own future surviving.

This presentation is divided in the following sections:

- Innovation loop in the past and in the present. The iterative process.
- New technologies available to the design and the designers: Rapid Prototyping and Internet.
- Design Pedagogy: new challenges in the formation of future generations of designers.
- Conclusions and future trends.

Key Words: design, rapid prototyping, internet, design pedagogy

1. THE INNOVATION CYCLE IN THE PAST AND IN THE PRESENT. THE ITERATIVE PROCESS

With technological advances the human being has been released from the intensive physical efforts and repetitive monotone tasks, moving his strength and intelligence to the upstream process of the production cycle where the design concepts are highlighted.

This step of the development of new products is characterized by a high complex level that requires creativity, intelligence, practice planning and management, qualities and functions very hard to get through the use of machines. Meanwhile, growing technological capabilities of support that are emerging, make easy the complex tasks that designers are faced in their creative work.

In the past like in the present, the innovation process demand iteration (Fig. 1). The product development process begins with concepts or ideas. In the design stage, one must select materials and define configurations that must carry specific loads and perform specific tasks. The materialization of these configurations becomes a prototype, assuming physical or virtual nature. This prototype must be qualitative or quantitative assessed. In the beginning, the process starts from a crude configuration, and modifications and analysis are repeated in an iterative fashion, until all the design requirements are satisfied and an optimised configuration is obtained.

In this context the difference between analysis and design must be highlighted. Analysis is a deterministic process, that when applied to a specific configuration assesses his behaviour response [Jones (1998)]. On the other hand, design is not a deterministic process, being an iterative procedure of selecting a configuration in a wide set of alternatives.

An essential difference between an old process and an actual industrial process is related with the time spent during the conception and the design stage. In the past, a product with a successful design could take years or decades to get an optimal performance. Nowadays, the greatest time compression is demanded as well as reduced costs (Table 1). Frequently, the price of these iterations limits their number, so other means to speed up the process at a low cost are been investigated.

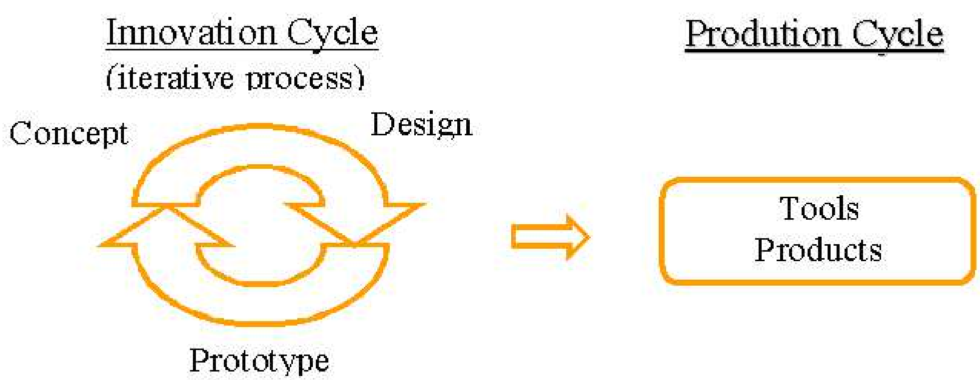


Figure 1. The innovation process demands iteration.

2. NEW TECHNOLOGIES AT THE DISPOSAL OF DESIGN AND DESIGNERS: RAPID PROTOTYPING AND INTERNET

Since Pre-history man uses 2D sketches and drawings to express and communicate ideas, concepts and messages. This establishes a natural resource of effective and fast communication and an economical and accessible tool that designers frequently use to materialize and support their proposals. The emerging of sophisticated and powerful computer resources has been changing the processes and methods of the development of new products in the conceptual and production design areas. The CAD programs that are in the basis of this change are more and more user friendly, delivering accessible and intuitive interfaces, simulating the manual sketching that designers perform during their creative research.

Table1. Innovation cycle in the past and in the present.

Past	Present
Old technological resources; quality dependent from the experience and operator skills	**Automation**
Conception and development performed by intuitive and experimental method	**Integrated solutions (design, prototyping, analysis and simulation, data management, tool manufacture, production)**
Inventor	**Multidisciplinar team; concurrent engineering**
Long iterative processes	**Fast and low cost iterative processes**
Regional and local markets	**Global Markets**

The traditional processes based in 2D technical drawings are being obsolete and replaced by CAD systems that are able to generate tri-dimensional solid models. The presentation with photo realistic images and computer animations allows to change the customers' attitude and sometimes, to avoid the manufacture of expensive prototypes.

Due to the advances of computer programs, the concept of Virtual Prototyping (VP) is emerging as an option to the physical prototyping. Virtual prototyping allowing analysis and simulations in early steps of the product development process, turned out to be an excellent design tool.

CAD software can be associated with other specialised applications, allowing the creation of a global approach to the product development and production (Fig.2). Modern technologies termed Rapid Prototyping, RP, are an example of such technologies and allow the manufacturing of prototypes and pre-series with a reduced time to market [Lino (2001b)], [Neto (2001)] . RP systems manufacture prototypes directly from a CAD drawing and so they can produce a physical model that present an unquestionable advantage compared to a virtual model. It may be said that if a picture is worth a thousand words, so a part is worth a thousand pictures.

In a broad sense, RP embraces a wide group of solid modelling technologies to quickly produce models and prototypes based in data from 3D CAD and other digital systems. In the pre-processing step, solid models are converted in STL representation, that is, in a superficial triangular mesh. Then, applying the RP equipment software, this model is sliced in parallel planes which distance is the depth of the layer to be deposited by the additive technique (Fig. 3). This digital format is the base of planning tasks to the machine processing.

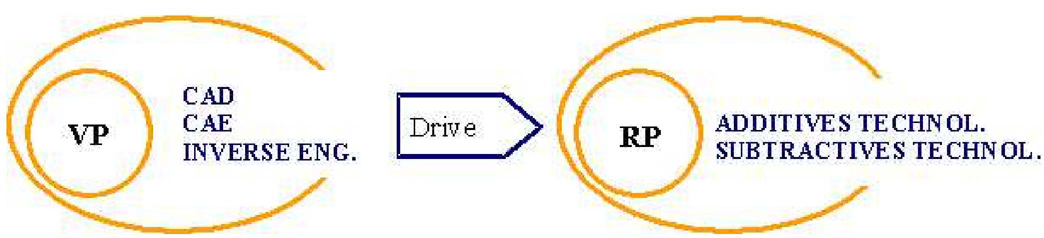


Figure 2. CAD systems that are part of the virtual prototyping systems are the basis of the new RP technologies, allowing the creation of a global approach to the product development and production.

As there is no intention to describe or analyse, in depth, the actual RP systems, one can classify them in two main classes:

- Concept modellers, commonly known as 3D printers;
- Functional and technical prototype modelers, properly called RP systems.

The RP systems currently available commercially can be grouped, based on their layer creation method, in three categories [Thomas (1997)] (Fig. 4):

- Selective cure
- Extrusion / droplet deposition
- Sheet form fabricators

Selective Cure Layered Systems use a laser either to selectively solidify portions of a layer, curing a liquid photopolymer resin (SLA – Stereolithography) or to sinter a fine thermoplastic powder layer into a solid one (SLS – Selective Laser Sintering).

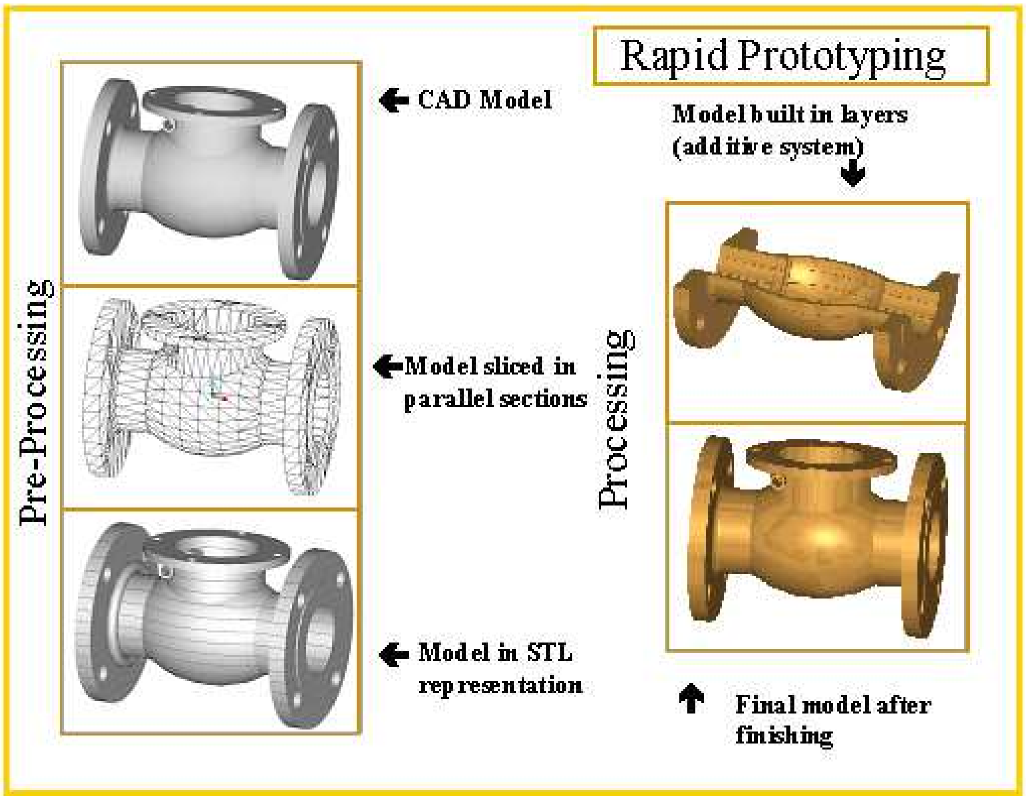


Figure 3. Additive pre-processing and processing steps of the RP devices [Vasconcelos (2001)]

In the droplet deposition process, a multi inkjet printing head deposits a liquid binder that links a powder layer (3DP – 3D Printing). Other alternative technologies use an extruder head that deposits polymer droplets that solidify to form the prototype (FDM – Fused Deposition Modelling).

In the processes based in sheet form materials, the layers are cut from these sheets, stacked and bonded together (ex. LOM – Laminated Object Manufacturing).

Concept modellers use the same manufacturing layered principles based in CAD solid modelling. In general, in these equipments, an inkjet head deposits a binder, wax or other thermoplastic material onto a powder material.

What distinguishes concept modelers from other RP systems is the use of low cost materials that don't match the final product properties. As geometric and dimensional accuracy is reduced (Table 2), they are not adequate for functional tests or to apply mechanical tests. Meanwhile, the price of a concept modeler that can vary from 50,000 to 75,00 euros is about an order of magnitude lower than the price of a conventional RP system. In addition, the cost of concept modeler's materials and maintenance are much more reduced.

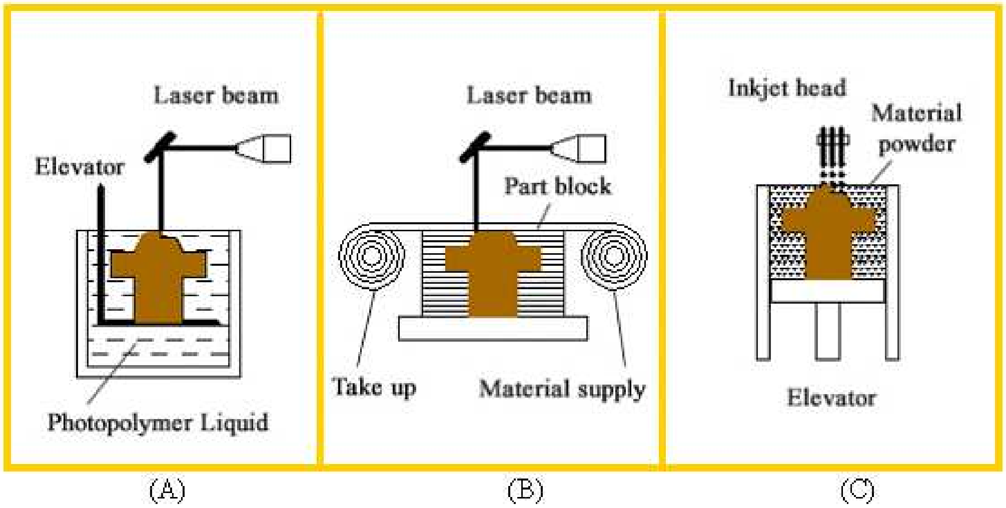


Figure 4. RP Systems: (A) Selective Cure Layered Process (SL); (B) Sheet cut process (LOM); (C) Droplet Deposition Process (3DP).

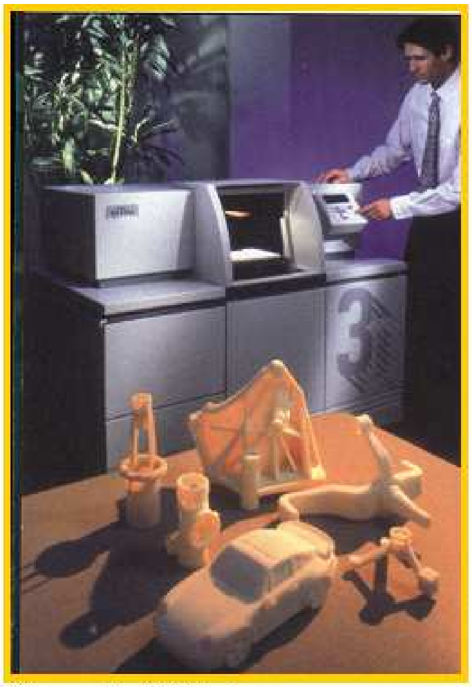
Concept modelers are powerful design tools [Smith (2001)], so they ensure to check design, to detect mistakes and to improve communication. They can work in an office environment like 2D printers. Low cost and easy function of geometric models are the best solution for a designer, so it offers the ability to perform multiple iterations in reduced time, that necessarily drive to a better design. They allow to test new ideas with more accuracy before its materialization, to avoid mismatches interpretations and to incentive a constructive criticism. They contribute to join technicians and staff from related departments to provide as much design information as early as possible to providers and tool makers and to reduce the need of information in the 2D drawing form. Great systems manufacturers are 3D Systems (Thermojet), Stratasys (Genisys) and Z Corporation (Z 402) (Fig. 5).

"Sagrada Familia" in Barcelona is an example of how these modelers can be useful to compress time and costs [(3D Systems (2001)]. About the acquisition of a Thermojet printer to support the construction processes of Sagrada Familia, Jordi Bonet coordinator architect says: "Thermojet printer is a key system in Sagrada Familia project. Specifically, in aspects related to the design validation, allows to build in a fast and simple way more prototypes by part. Earlier we needed longer periods to validate the news designs. Now we can get a validated part in a day, approximately". Nearly two years was the time necessary to recover the investment.

CAD model is the common starting point of these new additive technologies. That is why they can operate in three different levels: Rapid Prototyping (RP), Rapid Tooling (RT) and Rapid Manufacturing (RM), which gives great flexibility to these technologies when compared with traditional ones (Fig. 6).

RT technologies based on RP produce prototype and production tools in an early step of product development.

It is possible to advance that RM, avoiding the need of tools, will be the future evolution of these technologies [Wholers (1999)]. These technologies supported by Internet will allow to compete successful in different market niches, in a short and medium term, with traditional technologies and production and commercial circuits. Indeed, the growing competitiveness and the new performances allow to reduce the price of equipment and to move towards wider applications.



Thermojet - 3D Systems

Z Corporation modeller settled in Massachusetts Institute of Technology (MIT)

Figure 5. Some concept modellers commercially available (courtesy of 3D Systems and Z Corporation)

Table 2. Comparative analysis between RP systems and concept modellers.

RP Systems	Concept Modellers
Expensive investment	**Price an order of magnitude lower (50,000 – 75,000 euros)**
Expensive materials	**Low cost materials**
High maintenance costs (complex mechanisms, e.g. lasers)	**Economic maintenance**
Functional, technical prototypes and preseries	**Models for design visualization and verification**
Industrial equipment	**Office equipment**
Rapid Tooling **Rapid Manufacturing**	

For expensive products with long life cycles, single products or short run series, RM systems already compete with traditional manufacturing technologies. For instance, biomedical applications like: surgical planning through anatomic models based on digital data from computed topography (CT) and magnetic resonance imaging (MRI); customize manufacture of implants and soft-tissues structures; cartilage and tendon repairs. Strong appointments are fast answer speed, the elimination of the tool and the ability to accommodate changes in the product design during the production cycle (it will be only necessary to change the STL file).

All these technologies avoid mistakes and costs, decrease time to market and improve the chances to get a successful design, which permits to say that RP, RT and RM technologies emerge as optimal tools in concurrent engineering.

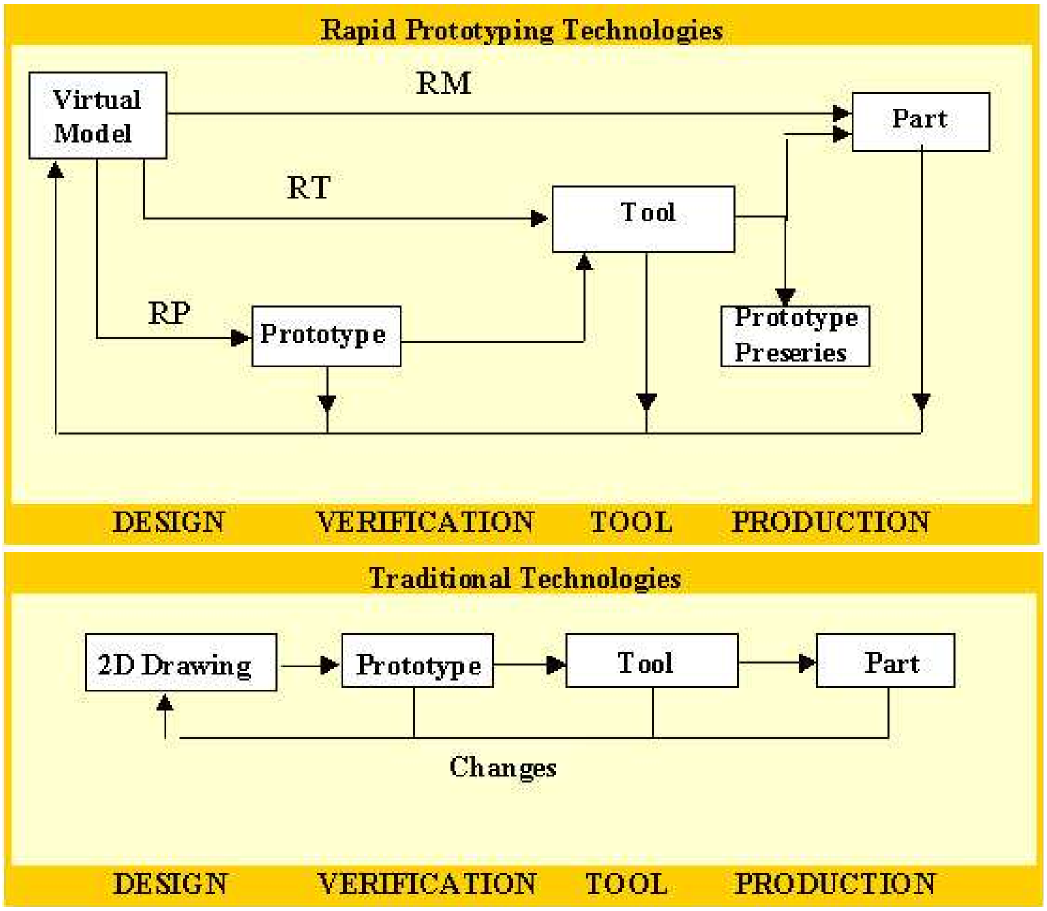


Figure 6. Versatility and capabilities of RP technologies when compared with traditional ones. [Vasconcelos (2001)]

Internet is a noticeable partner of RP technologies. In industrial countries it is usual that companies that don't have RP equipment, send CAD files through Internet to Service Bureaus. After receiving the files, these bureaus can immediately work in processing and converting them in prototypes that send to their clients by mail or other means of transport (Fig. 7).

Other multinational companies use Internet to e-mail CAD files to sister companies placed in different continents. That's a new 3D fax that can quickly link a design company in Europe or USA to other company in Asia, for instance. Nowadays, Adidas project department e-mail files with new designs of shoe soles to sister companies placed in different parts of the world, that have RP equipment to produce physical models.

In the future, probably, it will be possible the delivery of physical products by "downloading" on the Internet and manufacturing directly in customer's homes and offices, like 3D faxes. In this context 3D printers could be called "fabber" that means "a factory in a box" [Burns (2001)]. The possibility of designers, artisans and creative people to become independent from traditional production and distribution circuits will be a noticeable consequence aimed by the introduction of these revolutionary technologies. This new relationship, joining producers and customers, shortens the distance of concept from the final product, avoiding intermediate stages (Fig. 8). The contribution for a potential better design and quality and the personalized product manufacturing must be highlighted. These new performances will perform great significance in the traditional production and distribution circuits that now drive the introduction of new products in the marketplace and are the result of the easy manufacturer/customer circuit, the possibility of multiple iterations and changes without significant increased costs.

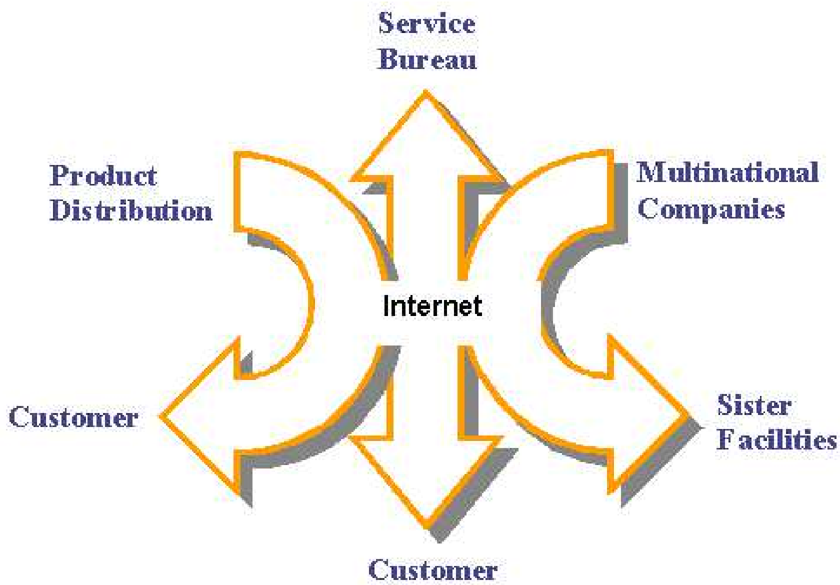


Figure 7. Potential applications derived from the combination of RP systems with Internet

RP technologies are not restricted to modern design products and, when judiciously used, will make viable the economics of the traditional and local production. The surviving of these industries will depend on their necessary restructuring faced to these new challenges and technological resources.

Traditional Production Circuit					
Project	Prototype	Tool	Production	Distribution	Customer
Fabber-Web Production Circuit					
Project	Fabber + Web	Customer			

Figure 8. Noticeable steps reduction between the CAD project, the final product and the customer due the association of "Fabber" equipments with Internet.

A typical example comes from the regional ceramic industry. Actually, this industry is interested in restructuring its project departments, to speed up the conception and design step. The productivity of the ceramic industry in this matter is expected to be only one third of the productivity of mechanical industry. CAD systems and the manufacturing of prototypes and silicone master models based in RP systems, will allow these industries to become more competitive in the future, providing, in this way, their survival (Fig. 9).

RP systems are contributing to that capabilities and human resources to product conception and manufacturing get closer to each other. Most of the product development process could be focalized in the designer or in a multidisciplinary team, depending on the ease of equipment interfaces and the complexity of the product (Fig. 10).

Burns [Burns (1995)] believes that RP will become an emancipating technology for the 21st century, offering to mankind the freedom to create, in the same way as the book was in the 15th century or the automobile was in the 20th century to the freedom to learn and the freedom to travel, respectively. He sees in advance that computers with 2D display will be replaced by 3D displays' computers with digital and voice input, that permit the designer to sculpt the desired geometry in the air with its fingers. Hinzmann [Hinzmann (1996)] suggests diverse potential scenarios relatively the expansion and future use of these technologies.

3. DESIGN PEDAGOGY: TEACHING FUTURE DESIGNERS

Unlike graphical designers, product designers must test their concepts against technological and functional constraints [Dolenc (1998)] that, frequently, mismatch the expected parameters and visual and aesthetics levels. Product design teaching is, at present, a potential challenge that demands in the educational process cross link development pedagogies of creative and expressive skills and technological and engineering knowledge. Students have some difficulty in harmonizing or adjusting their natural skills with these two scientific domains, which traditionally have been apart from each other.

Based in the future potential of these technologies, it is imperative, at least in a first step, to inform students about these tools and, later, to add experiences in the teaching activity that allow future designers to get closer to these new support means of conception work [Grote (1997)].

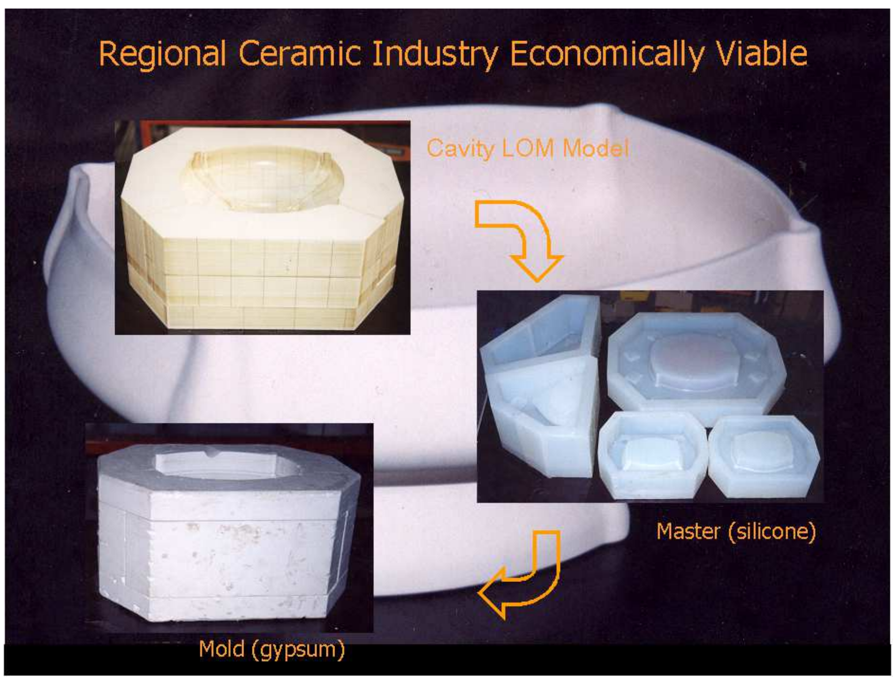


Figure 9. Ceramic Project RP based developed in INEGI - porcelain terrine to a ceramic company

In this context it has been developed, in the North of Portugal, a healthy partnership between teaching institutions and INEGI (Institute of Innovation and Technology Transfer). This unite possesses RP equipment and RT technologies and has allowed to develop different activities in the design area with the participation of students from related courses [Lino (2001a)]. This collaboration has performed different forms:

- Promoting sensitization seminars;
- Participation in post-graduate courses;
- Manufacture of functional and no functional prototypes related to projects from academic activity;
- Professional and academic work placements with design and engineer students;

Several universities and other advanced educational institutes from Portugal are planning or have already acquired RP equipments wishing to properly adjust in an update knowledge society.

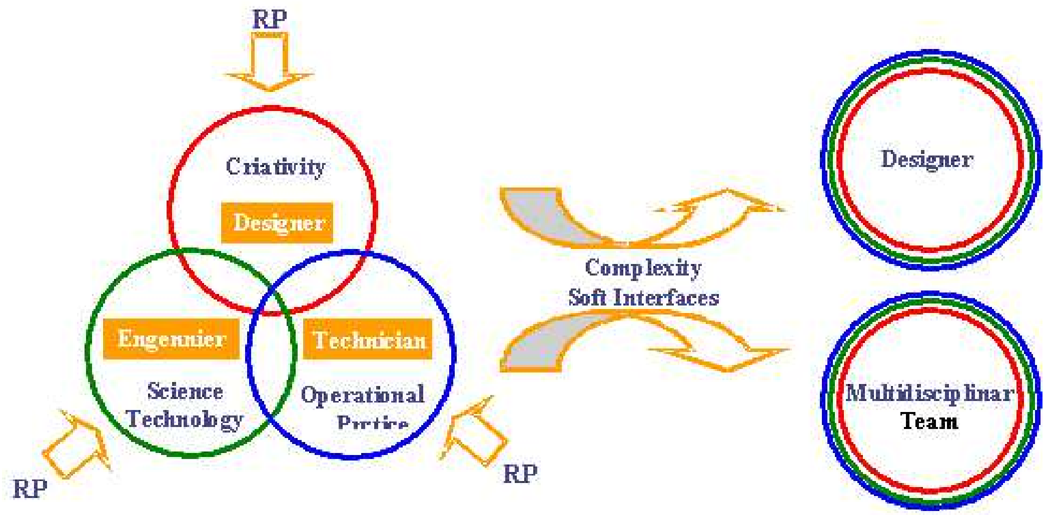


Figure 10. Contribution of RP systems to approach human skills and resources that participate in the product conception and manufacturing

4. CONCLUSIONS

Rapid Prototyping, Rapid Tooling and Rapid Manufacturing are different levels of rapid technologies which must be integrated into the workflows of product development processes to perform higher efficiency. This may provide the key to ensure better innovation, quality, flexibility, lower costs and reduced time to market.

RP supported by Internet besides offering great potentialities as a tool for designers and companies, promises to become a freedom tool to human creativity, revolutionizing manufacturing and trading principles. In the teaching area it will contribute to a technological knowledge, assisted and tailored to adjust to the individual needs of students (just-for-you pedagogy).

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