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Repercussions of complex adaptive systems on product design management

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Abstract

Product design management is becoming an increasingly important concept. However, there is no generally accepted agreement as to exactly what activities this management involves. We therefore put forward the need to link design management with other convergent theoretical approaches that clarify and improve an understanding of the concept. In this study, we look at the implications of the ideas involved in complex adaptive systems, steeped in the new science of complexity, for product design management. Following on from this, we highlight four product design management activities: strengthening the relationships between firm members and the outside, fostering relationships between areas or people within the process of product design, increasing information flow to a maximum, and promoting a balanced heterogeneous participation in design decision making.

Keywords: Complex adaptive systems; Product design management; Product design

1. Introduction

Design is an essential aspect of the process of product innovation (Aubert, 1982; Walsh, 1996) and new product process (Cooper and Kleinschmidt, 1986), a fact that can be seen in the apparent importance it has in improving competitiveness and business performance (Potter et al., 1991; Gemser and Leenders, 2001). However, there seems to be a lack of understanding of its value and potential (Lorenz, 1995; Trueman, 1999), which, according to Lorenz (1995, p.74), is due to the fact that to present, nobody has been able to develop a clear way of characterizing design so as to achieve something like an equivalent of the fours P's in marketing.

Apart from the development process leading up to the creation of an artefact or product, the concept of design has traditionally, involved a series of organizational activities or practices that are required for this development to be achieved (Gorb and Dumas, 1987). These activities or practices have been considered by the literature as design management. This management heavily conditions product design efficiency, although very little is known about its problems and performance (Bruce and Cooper, 1997; p.3). Cooper and Press (1995, p.224) hold that there is a lack of agreement over its definition and the activities it involves, which, if taken together with its inherent interdisciplinary nature, make it a concept that is difficult to establish as a solid area of interest in management.

With the aim of examining product design management more deeply and following proposals put forward by other studies on different organizational concepts, i.e. strategic management (Stacey, 1993; Eisenhardt and Brown, 1998) or knowledge management (Boisot and Child, 1999), in this paper we will link this concept to the science of complexity and more specifically, to the ideas on complex adaptive systems.

The main reasons for basing our study of product design management on these systems are firstly, that both organizations and businesses are considered to be complex adaptive systems (Gell-Mann, 1994; Stacey, 1996); and secondly, that it is when these systems find themselves on the so-called edge of chaos that innovation and creativity arise (Stacey, 1995), which are concepts that are very much linked to design management or to design itself.

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2. Complex adaptive systems

The so-called complexity theory was born in the sixties, although its true upsurge was not seen until the mid-eighties. This theory was not, however, the first approach to complex systems in the twentieth century (Simon, 1996), but, in contrast to previous approaches, it sets out to devise mechanisms to create and maintain complexity, and to produce tools for its description and analysis (Simon, 1996; pp. 169−170). The concept of complexity theory covers many fields of scientific research (such as chaos theory, the study of fractals, etc.), amongst which the study of complex adaptive systems is of major importance.

Complex adaptive systems are systems made up of heterogeneous agents which inter-relate with each other and with their surroundings, and are unlimited in their capabilities to adapt their behaviour as a result of their experience. In each system, each agent is different from the others, and its performance depends on the other agents and the system itself, which influence its behaviour. The context therefore takes on a vitally important role.

Complex adaptive systems are capable of anticipating the results of their actions, for which they develop schemas or models (Anderson, 1999; Stacey, 1996). The existence of these, together with the agents' individual schemas, open up the possibility of changes to these rules, or in other words, evolution, learning or creativity. A schema can be defined as a set of rules that reflects regularities in experience or as a cognitive structure that determines what action the agent or the system will take, given its perception of the environment (Anderson, 1999; p. 219; Stacey, 1996; p. 289).

These systems are self-organized (Anderson, 1999; Stacey, 1995), in other words, new behaviour model patterns appear as a consequence of agent interaction. No single program or agent completely determines the system's behaviour, in spite of the fact that each one of the agents holds common heterogeneous patterns.

Complex adaptive systems self-organize when they find themselves on the 'edge of chaos' or 'limited instability' (Anderson, 1999; Stacey, 1995, 1996). Complex adaptive systems can develop three types of behaviour: stable or controlled by negative feedback, unstable or controlled by positive feedback, and limited instability or tension between various forces which place it on the edge of chaos (Fig. 1). On the edge of chaos, the system is very complex, in the sense that the degree of the schema's extension required to define it is high (Gell-Mann, 1994), and an equilibrium between stability and chaos is produced. This stage sees the emergence of innovation, creativity and adaptation, as well as self-organization.

A process of creative destruction takes place at the edge of chaos, in which the general schema is modified, due to the continuous interactions between the agents and their environment, to the information flow and to the level of diversity between the agents' schemas. When these aspects or parameters become acute, the situation changes from that of stability to the edge of chaos (Stacey, 1996).

3. Product design management

Langdon and Rothwell (1985; p.12) argue that design is an activity based on problem solving and of a cognitive nature. The purpose behind design is to create or restructure a specific component, product or service in order to fulfil a social, organizational and engineering objective efficiently. Design is a creative process in which products and processes are conceptualised and specified, and which plays a vital role in enabling firms to successfully exploit their innovative research (Langdon and Rothwell, 1985).

Design activity involves the creative visualisation of concepts, plans and ideas, which are represented through the use of sketches, and it is aimed at providing instructions to create something that does not exist, or at least does not do so in that particular shape or way (Walsh, 1996; Bruce and Cooper, 1997).

Design is a broad, complex concept that takes in varied and distinct disciplines. It can be perceived and dealt with in different ways, but it is design as creativity that perhaps stands out most clearly. The act of designing requires a combination of logical and intuitive thought. One of the objectives of design management is to design within an environment that stimulates and fosters creativity (Cooper and Press, 1995).

Aubert (1982) understands design as being the essence of innovation — the moment in which a new object is thought up, put into material form and shaped into a prototype. Thus, design is closely linked with innovation, since the very act of designing itself always introduces something new (Felip and Gimmy, 1995; p.94). Design is crucial to innovation because it represents the creative aspect, where ideas are put into material form, and also because it involves the meeting or union of technical capabilities and consumer demands (Walsh, 1996; p.514).

Bruce and Cooper (1997; p.31) divide the product design process into four phases: planning (problem formulation and idea generation), evaluation (idea refinement and prototype development), implementation (transfer of design to production, launch and delivery) and monitoring (evaluation of outcome against objectives). However, Iváñez (2000, p. 142) understands product design as a more simplified two-phase process: the analytical–conceptual, and the technical–creative. The objective of the former is to assess and analyse the socio-economic context and the tendencies within the

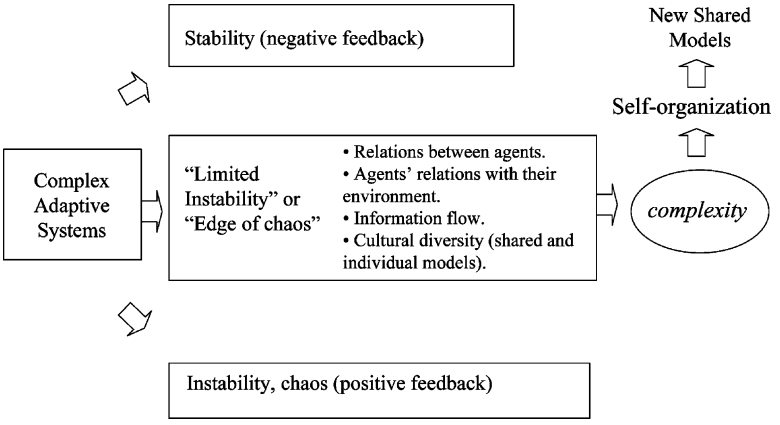

Fig. 1. Complex adaptive systems

target market, together with the commercial, strategic, productive, logistic and technological facets of the firm, and aspects dealing with image and communication. All this determines the characteristics of the product. On the other hand, the technical–creative phase involves a formal and creative interpretation of the above-mentioned characteristics, as well as the technical resolution required to determine the product.

Roy and Riedel (1997; p.538) define product design as "the choice and configurations of elements, materials and components that give the product particular attributes of appearance, performance, ease of use, method of manufacture, etc.". In sum, product design is understood to be the process by which a product is developed while taking into account any function, use, manufacture and communication requirements (Kotler and Rath, 1984; Ulrich and Eppinger, 1995; Walsh, 1996). This implies not only the creative effort, but also a whole series of technical, strategic and market aspects. These convergences and requirements entail a complexity within the process, which needs certain management activities to support and sustain it.

Definitions of design management can be either very specific or broad However, we understand that all of them emphasize the need for certain managerial activities to optimise design or its apparent effects (customer satisfaction, business performance etc.). Basing our definition on Gorb and Dumas (1987), we will consider it as a series of organizational and managerial activities or practices that are required to achieve the process of design.

In sum, product design management is understood in different ways, depending on the aspects or activities highlighted. The main activities included within this concept and mentioned in the literature may be classified into four groups.

The first consists of the activities linked to decisions on organizational aspects of design: the existence of an in-house design function, the use of external expertise, etc. (Dumas and Mintzberg, 1989; Bruce and Morris, 1994; Topalian, 1994).

The second activity consists of the transmission of information and knowledge about the company (objectives, priorities, competitors, design strategy, post-evaluation measurement and feedback) to the designers (Rothwell and Gardiner, 1989; Topalian, 1994; Dickson et al., 1995; Olson et al., 2000).

The third type includes activities associated with the creation of an organizational context that favours the design process, with special emphasis on communication, dialogue, creativity encouragement, participation and management support to raise its importance (Gorb and Dumas, 1987; Rothwell and Gardiner, 1989; Dickson et al., 1995).

Lastly, we come to the activities that form a part of the operational management of human and other resources within the actual product design process itself: stages, customers' and suppliers' involvement in the process, use of computer-aided design tools, assessment of manufacturability, cost estimation of new products, etc. (Topalian, 1994; Dickson et al., 1995).

4. Product design management and complex adaptive systems

Complexity theory perceives organizations as complex adaptive systems (Gell-Mann, 1994; p. 36). However, human complex adaptive systems, such as organizations and companies, have certain distinguishing characteristics (Stacey, 1996), amongst which the following should be stressed: the agents of these organizations are affected by emotions such as compassion and anxiety; they are capable of prioritizing their own mental objectives over those of the group; they are aware and capable of thinking systematically, unlike other animals such as birds or ants; and power differences exist between agents, which they are influenced by. As a

consequence, these complex human systems are still more complex, and we must therefore be very cautious when setting out analogies with the previously outlined characteristics.

According to Simon (1996; p.111), design is the building of processes with the aim of changing existing situations or objects for more preferable ones. This is the purpose of artificial science as opposed to natural science, which seeks to find out what things are like and how they work. For this author, the artificial world focuses on the relationship between the internal and external environment, as well as achieving objectives by adapting the former to the latter — a process in which design plays an essential role. This consideration links design with complex adaptive systems, which are characterised by their capacity to adapt to their environment and to learn. When they find themselves on the edge of chaos, these systems design new schemas that are defined in new products (product design), behaviours, policies, strategic positions, and so on. It is a stage that implies innovations and creativity.

As a result, the behaviour of complex adaptive systems can make certain contributions to how firms go about performing product design management.

Given the characteristics that allow complex adaptive systems to reach the edge of chaos and therefore to design new schemas and to innovate, in Fig. 2 we propose a theoretical model in which we highlight the factors that facilitate the product design process and which represent the activities carried out in the course of product design management.

Some authors (Trueman, 1999; p.120) have highlighted the importance of the planning or conceptual–analytical phase of design, arguing that this is the stage that marks the difference between the success or failure of the product. Nevertheless, as this author has previously stated, this is not a very common company activity. The analytical phase, or design planning, attempts to assess different aspects in order to determine the attributes of the product, the most important of which is information about the firm, its market and technology

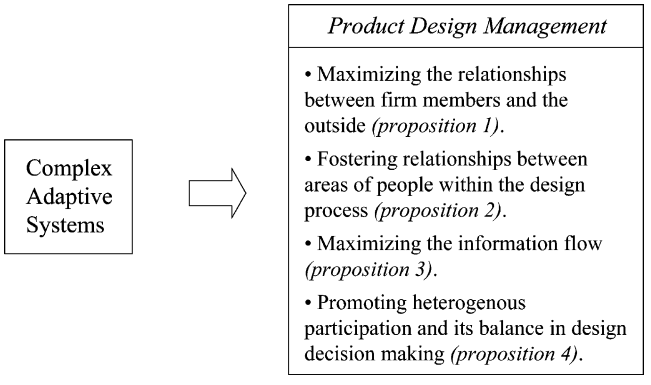

Fig. 2. Design management according to complex adaptive systems

(Rothwell and Gardiner, 1989; Walsh, 1996). Complex adaptive systems underline the importance of maximizing the relationships between the members of the organization and their external environment, which thus fosters the existence of a mechanism for obtaining information from the outside, either about markets, competitors or suppliers. Consequently, we can put forward the following proposition. *Proposition 1: The relationships between the members of an organization and the outside favour an efficient design process.*

Furthermore, these systems highlight the importance of the relationships between agents, which in a firm would be areas or people. This would allow both the smoother flow of information about the firm and about the outside gathered by agents, and greater collaboration in making decisions on design. This last aspect would involve the silent design set out in the literature (Gorb and Dumas, 1987), which refers to the participation of non-designing agents in the making of decisions on design, and the involvement of designers in other aspects of product development, such as in their communication or commercialisation. *Proposition 2: The relationships between the members of the organization favour an efficient design process.*

The flow of information — its quantity and quality — is one of the aspects that comes into play on the appearance of the edge of chaos. Maximizing this flow of information, which is transmitted in the relationships, will favour the determination of the characteristics of product design.*Proposition 3: The higher the quantity and quality of the flow of information that is transmitted in the relationships are, the more efficient the design process will be.*

According to complex adaptive systems, the diversity and tension of powers between agents (people or areas) favours the appearance of the edge of chaos. This highlights the importance of a heterogeneous participation of different people and areas in the design process, and the tension or balance of power, which is encouraged by balanced positions of power. For instance, if the commercial department were to enjoy a more powerful position than the design or production departments, then this heterogeneity would be in vain. *Proposition 4.: Heterogeneous participation and its balance of powers in making decisions about design favour an efficient design process.*

All these propositions put forward ways of achieving an efficient design process which embodies the activities performed by design management.

5. Discussion

In this study we have brought together the ideas from complex adaptive systems, steeped in the new science of complexity, which have the capacity to learn, in order

to apply them to the ideas on product design management. Although this is not the first time ideas from the world of natural sciences have been extrapolated to the social sciences, the literature on design management should, in our opinion and given its current theoretical confusion, listen to and take into account the ideas from systems that are capable of adapting and design schemas or models which will be reflected, in the case of firms, in product designs, organizational behaviours, human resources policies, and so on.

As a result of this extrapolation, in this paper we have pointed out particular activities that design management should consider in order to undertake the process of product design efficiently. While some of them had been taken into consideration tangentially by the literature, others had not been considered in the same way or had not had the same aspects highlighted (Proposition 4). Future work should confirm our propositions by analysing the effect of these activities on business performance.

References

Aubert, J.E., 1982. Innovation in Small and Medium Firms. Organisation for Economic Cooperation and Development, Paris.

Anderson, P., 1999. Complexity theory and organization science. Organization Science 10 (3), 216–232.

Boisot, M., Child, J., 1999. Organizations as adaptative systems in complex environments: the case of China. Organization Science 10 (3), 237–252.

Bruce, M., Cooper, R., 1997. Marketing and Design Management. International Thomson, London.

Bruce, M., Morris, B., 1994. Managing external design professionals in the product development process. Technovation 14 (9), 585–600.

Cooper, R., Press, M., 1995. The Design Agenda. John Wiley and Sons, Chichester.

Cooper, R.G., Kleinschmidt, E.J., 1986. An investigation into the new product process: Steps, deficiencies and impact. Journal of Product Innovation Management 3, 71–85.

Dickson, P., Schneider, W., Lawrence, P., Hytry, R., 1995. Managing design in small high growth companies. The Journal of Product Innovation Management 12 (5), 406–415.

Dumas, A., Mintzberg, H., 1989. Managing design, designing management. Design Management Journal 1 (1), 37–43.

Eisenhardt, K.M., Brown, S.L., 1998. Competing on the edge: Strategy as structured chaos. Long Range Planning 31 (5), 786–789.

Felip, M., Gimmy, G., 1995. El papel del diseño en el proceso de innovación. Economía Industrial 301, 93–104.

Gell-Mann, M., 1994. The Quark and the Jaguar. Adventures in the Simple and the Complex. WH Freeman, New York.

Gemser, G., Leenders, M.A.A.M., 2001. How integrating industrial design in the product development process impacts on company performance. Journal of Product Innovation Management 18, 28–38.

Gorb, P., Dumas, A., 1987. Silent design. Design studies 8 (3), 150–156.

Iváñez, J.M., 2000. La Gestión del Diseño en la Empresa. McGraw-Hill Management, Madrid.

Kotler, P., Rath, G.A., 1984. Design, a powerful but neglected strategic tool. The Journal of Business Strategy, Autumn, 16–21.

Langdon, R., Rothwell, R., 1985. Design and innovation, policy and management (introduction of the editors). The Design Council, London.

Lorenz, C., 1995. Harnessing design as a strategic resource. Long Range Planning 27 (5), 73–84.

Olson, E.M., Slater, S.F., Cooper, R.D., 2000. Managing design for competitive advantage: a process approach. Design Management Journal 11 (4), 10–17.

Potter, S., Roy, R., Capon, C., Bruce, M., Walsh, V., Lewis, J., 1991. The benefits an costs of investment in design: using professional design expertise in Product, engineering and graphic projects. Design Innovation Group, Manchester.

Rothwell, R., Gardiner, J.P., 1989. The strategic management of reinnovation. R&D Management 19 (2), 147–160.

Roy, R., Riedel, J.C., 1997. Design and innovation in successful product competition. Technovation 17 (10), 537–549.

Simon, H.A., 1996. The Sciences of the Artificial. Institute of Technology, Mass.

Stacey, R.D., 1993. Strategy as order emerging from chaos. Long Range Planning 26 (1), 10–17.

Stacey, R.D., 1995. The science of complexity: an alternative perspective for strategic change processes. Strategic Management Journal 16, 477–495.

Stacey, R.D., 1996. Complexity and Creativity in Organizations. Berret-Koehler Publishers, San Francisco.

Topalian, A., 1994. Best practice benchmarking of design management practices and performance. The Alto Design Management Workbook, Alto.

Trueman, M., 1999. Innovation by design. In: Zairi, M (Ed.), Process Innovation Management. BH, Woburn, Mass, pp. 104–138.

Ulrich, K.T., Eppinger, S.D., 1995. Product Design and Development. McGraw Hill, Singapore.

Walsh, V., 1996. Design, innovation and the boundaries of the firm. Research Policy 25, 509–529.

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