Conceptual design: on multiple tools to assist complex cognitive tasks

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Abstract: This article approaches the problem of methods' inadequacy to assist complex cognitive tasks in information technology systems projects. Authors like MARMARAS and PAVARD (1999), among others, introduce these methods and present proposals for an approach to the problem recognizing the need of assisting complex cognitive tasks. Using the Curve–S metaphor as learning curve, this article discusses the need to identify the limit imposed by technological apprenticeship, as well as the search, in other sciences, for substitutive technology, before reaching the final limit in the Research and Development process, P&D. From the conceptual design on, it points to the action of multiple tools as a priority. It also highlights the fact that, in this field, isolated tools are not enough to achieve complete assistance: multiple tools are demanded to be employed in each stage of the design.

Key words: Product development, conceptual design, curve - S method.

1. Introduction

Authors like MARMARAS and PAVARD (1999), who are interested in the inadequacy of some methods to assist complex cognitive tasks in information technology systems designs, have presented a problem–oriented approach, recognising the need to assist these tasks. Their approach allows for completing the method by adding an auxiliary supporting tool for complex cognitive tasks in information systems designs. The validity of this approach lies in the fact that no tool in isolation can account for the problem. Thus, aiming at offering support to complex cognitive tasks, there are technological information systems with several denominations and fields. Each denomination indicates the sort of support offered (Table 1):

Table 1 – Technological information systems.

Technological information system	Function
CAD	Computer-aided design
CAM	Computer aided manufacturing
DSS	Decision support systems

2. Gaps in supporting technological systems

Several reasons may contribute to the inadequacy of technological information systems as regards support to complex cognitive tasks during the conceptual design (BARROS & FIOD, 2001). Most technological information systems, when being elaborated, received a technology-based approach. In these cases, the systems design is oriented by technological progress and by theoretical, technical and formal models within the application. Thus, these supporting tools are not based on difficulties faced by technicians who solve problems using these systems. On the other hand, as MARMARAS & PAVARD (1999), among others, have pointed out, a number of these systems have been developed having the prosthesis paradigm as a basis. The main scope of this paradigm is to apply computer science technology onto the development of specialized autonomous machines (stand-alone/ unique) which may offer some sort of problems resolution (ROTH et al., 1987). Moreover, cognitive aspects of human specialists, to whom these systems are directed, and by whom they are regarded as inadequate, should be taken into account. This is due to the fact that both the semantics used by a given specialist in a certain domain, and the way he/she actually solves complex problems – and makes decisions within limits and demands imposed by his/her working environment – are rejected (MARMARAS et al., 1992; ROTH et al., 1987). Another fact might be taken into account: simplified models and normative theories, mostly developed within laboratory environment, have been used for the systems design (WOODS, 1992). Participation and collaboration in real-life situations, aspects which do not receive due consideration nowadays, as well as their articulation with individual work, must be considered (BANNON, 1997). Finally, tacit knowledge achieved by specialists in a given domain, and which depends upon demands and impositions of his/her working environment, as well as upon his/her pedagogical history and specific training (NONAKA & TAKEUCHI, 1985), cannot be applied when these system are used, as they might lead to erroneous actions. Besides, the environment in which the work is developed is regarded as inadequate, since when a simplified view on the working environment is adopted, the importance of elements' complexity is denied. These are cases of simplification of complex systems, one example being in the domain of processes control: in this domain, a number of systems presuppose static components with unique flaws, which reveal extreme simplification of diagnosis situations in which people who solve problems deal with multiple-flaws possibilities, erroneous understanding of signs and interaction problems (WOODS, 1992). It is important, thus, to decide how to deal with cognitive difficulties faced by potential users in the execution of complex problem-solving tasks, when assisted by technological information systems. Within this scope, the present discussion focuses on the need for establishing a tool according to a general ergonomic model for the analysis of working situations for which the technological information system has been proposed.

2.1. Product position in the developing cycle

When carrying out research to identify one or more tools – or even a set of techniques – to provide the researcher of products with support, the following possibilities are taken into account:

a) the product, object of study, already exists and innovative attributes are aimed at;

b) the product does not exist, but there are solutions provided by a set of products;

c) the product does not exist and it is necessary to develop it.

In the first case, the product is in whatever point of the Curve-S, which represents its life cycle, being indifferent to the localization of its developing stage. In the second case, a set of products is grouped to solve the problem, characterizing convergence of technologies. In the third case, the product does not exist yet. As technologies advance, discontinuities become frequent. Companies cannot foresee or manage discontinuity, since products A and B usually appropriate distinct technologies, which result from the development of other sciences, allowing for the creation of a product which will replace the existing one with additional advantage. The figure 1 shows these discontinuities.

Besides leading to the disappearance of products, technological transitions result in the productive exclusion of whole sectors. These transitions are identified in the product development, particularly when they are assisted by a supporting tool which provides support to complex cognitive tasks in information systems designs.

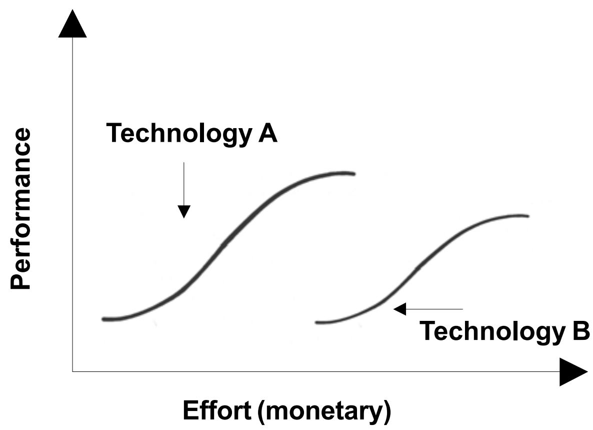

Figure 1 – Discontinuities in products development.

Thus, current technology leaders hardly ever survive to become leaders of the new technology. Discontinuity may allow leaders to keep their leading role in the market, but their participation is reduced.

Once the new technology – which will discontinue the product–obtaining process – is detected, it becomes hard to avoid the advance of old technologies by cancelling resources when some progress might still be achieved in the product's cycle. In the fifties, for instance, vacuum valves dominated the market, the transistor occupying only a little section of it. The passing of vacuum valves and their replacement by transistors characterizes a technological discontinuity. This transition had implications for entrants as regards the material to be used. The first material used was germanium, by Bell laboratories. This material reached the market via Hughes and Sylvania's products and generated high rejection rates

Table 2 – Ins and outs of companies (1955–1982).

1955	1955	1960	1965	1970	1975	1980	1982	1999 - 2000
Vaccum valves	Transistor	Semi-condcutor	Semi-conductor	Semi-conductor	Integrated Circuit CI	Large Scale Integrations LSI	Very Large Scale Integration VLSI	TECHNOLOGICAL CONVERGENC
RCA	Hughes	Texas Instruments	Texas Instruments	Texas Instruments	Texas Instruments	Texas Instruments	Motorola	
Sylvania	Transitron	Transitron	Fairchild	Motorola	Fairchild	Motorola	Texas Instruments	
GE	Philco	Philco	Motorola	Fairchild	National	National	NEC	
Raytheon	Sylvania	GE	GI	RCA	Intel	Intel	Hitachi	
Westing-House	TI	RCA	GE	GE	Motorola	NEC	Toshiba	
Amperex	GE	Motorola	RCA	National	Rockwell	Fairchild	Intel	
National Vídeo	RCA	Geclevite	Sprague	GI	GI	Hitachi	Philips	
Rawland	Westing-house	Fairchild	Philco/Ford	Copming	RCA	Signetics	Fujitsu	
Eimac	Motorola	Hughes	Transitron	Westing-house	Philips	Mostek	Fairchild	
Lansdale Tube	Clevite	Sylvania	Raytheon	American Micro	American Micro	Toshiba	American Micro	

Fonte: Adaptado de McKinsey & Co. Inc. Innovation – The Attacker's advantage FOSTER (1986)

and, consequently, increased costs. However, Texas Instruments and Motorola appropriated another technology: silicon, with a larger energy lacuna band[1], but with higher reliability. The following table illustrates what happened from 1955 to 1882.

The list above presents companies which are producers of electronic components, that is, those which produce for others, not for their own use. The table shows the downpayments of Japanese companies NEC, Fujitsu, Toshiba and Hitachi in the early eighties (FOSTER, 1986). The four leaders in the production and selling of vacuum valves - National Vídeo, Rawland, Eimac e Landsdale Tube – did not join the field of solid state and disappeared due to the leadership of the new technology. Other companies reached 1960 manufacturing vacuum valves: Westinghouse (which left this market in 1960), Sylvania (which sold its assets in 1965) and GE, which ended this activity in 1965. Let us see how discontinuity took place: the companies which left the market, with no exception, were stuck to matters of design – in the sense of a whole technological improvement of the project – and were taken aback by discontinuity. These companies were oriented towards a specific problem, but this problem was erroneously defined. In this example, there are four possibilities, which are observed between continuity and discontinuity:

a) Not investing: deciding to not invest in the new technology, notably National Vídeo, Rawlan, Eimac and Lansdale, which left the market;

b) Mistaken choice: choosing the wrong technology when deciding to invest, following financial pressures to shorten

[1] A way of characterizing semiconductors is classifying them by their lacuna band (technology gaps) – by the facility with which they trigger the electron of an atom. Because germanium has a small lacuna band, it was used by Bell. Lacuna band is the amount of energy, which must be added to an atom in order to trigger an electron. In the process of manufacturing, the facility for triggering electrons makes it easier for non-desired impurities to damage the components' performance in the final product.

the cycle, as Hughes, Transitron and Clevite, which chose the germanium and then had to leave the market;

c) Delay: delay in abandoning the old–fashioned technology and appropriating the new one, as in the case of Westinghouse, Sylvania, GE, RCA and Philips whose delay did not allow for sustaining their position in the market;

d) Erroneous definition of the problem.

It is not enough to know that the technological vigilance points to changes and shows discontinuity in the appropriation of technology. New technological contribution demands organizational changes as well as flexibility for breaking up with previous expectations – something which is not always obtained. Pressures to continue in the curve and find a differential for the product –in relation to the competitors' products – come from several areas in the organization. Conventional financial theories do not present a practical way of accounting for the opportunity cost of investing in new technology.

3. Continuity–focused training

Traditional academic training focuses on matters of continuity. From the particular viewpoint of classical knowledge, contradiction makes absurd the thought on which it is inscribed. Discontinuity sets researchers astonished. The contradiction considered here is not the one which appears in non–coherent reasoning or which results form lack of rationality, but that which results from rational thinking, that contradiction which "appears after a correct deduction based on consistent premises" (WALTZLAWICK, 1978, p. 188). Physicians in the beginning of the century, carrying out research in quantum microphysics, faced this sort of contradiction. This contradiction initially affected the very foundations of empirical reality and logical coherence, when verifying that, according to experimental conditions, the particle behaves either as a wave, or as a corpuscule. One example was provided by Heisemberg and shed some light onto the contradiction found: "in quantum theory, an alternative does not necessarily ask for "yes"or "no" answers, since there are other answers" (HEISEMBERG, 1962, p. 320). The existing dilemma only found a solution when Niels Bohr understood that the contradiction existing between the complementary terms wave and corpuscule was only one of the contradictions and antinomies of the same sort already found in other places, but disregarded for the benefit of one of the three opposing terms: (I) continuous/discontinuous; (II) species/individual; (III) society/individual. From Bohr on, a new antinomy came up from quantum physics itself: separate things/ inseparable reality (WHITEHEAD, 1978).

It is not only a matter of associating two opposing truths in order to have access to a deeper or more complete one. It is a matter of observing that truth might be found in a vacuum, impenetrable, in the logical gap open up by a contradiction, by discontinuity.

For MORIN (1985), contradiction may present itself as a threat to reasoning (paradox), as a conflict between two propositions equally demonstrable (antinomies), as a confrontation between two incompatible solutions (aporias) and, more generally, as a jointing of two terms which are self-exclusive.

Thus, the emergence of quantum indeterminacy, of Heisemberg's principle of uncertainty, and the recognition of an insuperable contradiction in the notion of particle put at stake, at the same time, the idea of mechanical determinism and the principles of identity, of contradiction and of the third excluded from the mathematics.

Lastly, it is important to be aware that logic is part of intelligibility and that going beyond logic is part of the problem in order to completely understand the matter. Logic is at the service of observation, experience, and imagination. It expands a new idea in its consequences, without giving rise to it. Technological perspectives search for whatever is new, not for what is logical. Before devising the adequate tool for the problem, one needs to question the problem itself: is it adequately defined or are previous studies and pieces of research just being given continuity? Have anomalies been investigated or abandoned for not being part of the problem?

3.1. Anomalies identified in research

Nothing is totally ready or perfect; the world is permanently in the making. Discontinuity is far from a comfortable state for it demands being constantly alert, always researching, analyzing, studying. For those who believe in magic paths, things become harder due to the fact that a great number of scientists have reached discoveries and conclusions by means of identifying anomalies in discontinuity. In this case, scientists are led to abandon their basic research, since an anomaly affects methodological steps directing them towards results which are far from the continuity under study.

Several inventions were either reached by chance or resulted from a possible anomaly. But does the researcher's mind develop freely within this complex net of simple elements? How is this potential net updated, whose elements one wishes to investigate? Are there not any goals, guides or any sort of orientation in these ramified nets? To sum up, what are the utilization progresses of these nets? These questions need to be approached so that we can understand the role of technological vigilance in the realm of sciences, before directing our concern towards changes in the product itself. The researcher is affected by the same conditions as the common man as far as beliefs, conception of the world, habitus and social conditionals are concerned. For MOLES (1971, p. 208), "At least in its origins, there is no transcendental condition in the researcher in comparison to common men; the former is recruited among the others and his/her elementary intellectual processes derive from the common ground of thought: formal rationalism only interferes in the final and refined stage of scientific research".

3.2. Metaphors and manuals: between the abstract and the concrete

Every conceptual chain needs to be translated into evidences or into an experience. Matters of realization may impose constraints onto the development of the latter, which might differentiate, in a pragmatic way, imagination and invention. For MOLES (1971, p. 215), one of the first stages of creation is usually imagination: "this tendency we all share, concerning a given problem, to build in our spirit a design which is more or less feasible, to refine it, to enrich it, to adorn it with experiences which are somehow complicated etc.".

It is a tendency that, to a certain degree, all researchers share: "to produce ideas, construct theories, project devices, imagine tests" (MOLES, 1971, p. 215). This is the moment when the researcher searches for his/her manuals, didactic books, notes, articles, conferences annals, scientific periodicals in order to start testing, in a totally personal manner, and thus attempt to answer questions such as: would this be possible? Does it go against any

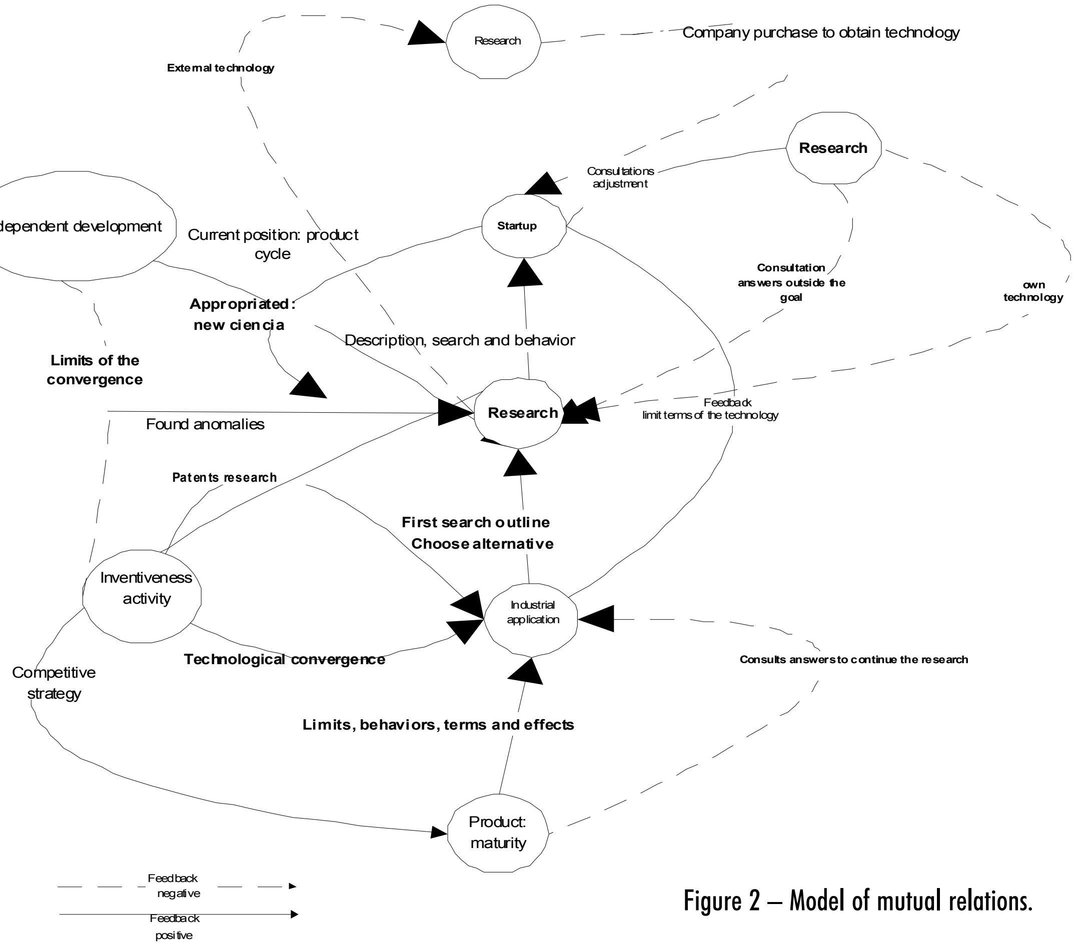

Figure 2 – Model of mutual relations.

well–known law? Has it been done already? Why have answers for this problem not been found yet? Science fiction works, most certainly, are not to be taken into account, as they are apocryphal documents for a scientist. At this moment, the paradigm generates evidences by hiding itself. Once the paradigm is invisible, those who are submitted to it believe to follow facts, experience, and logic. MORIN, (1985) calls researchers' attention to the paradigmatic trap: a paradigm is the co-generator of the feeling of reality, as the conceptual and logical framing of what is perceived as real derives from paradigmatic determination. Thus, those who follow the Supreme Order believe that all deterministic phenomena are real facts, whereas casual phenomena would be just appearances (MOURIN, 1985).

In this sense, science is being taken here as: knowledge which includes, in whatever form or to whatever degree, some guarantee of its own validity. The limitation expressed by the terms "in whatever form or to whatever degree" is included here so that the definition may be applied to contemporaneous science, which does not aim at the absolute (ABBAGNANO, 1998). According to traditional concepts, science includes absolute guarantee of validity, being, therefore, the maximum degree of certainty as far as knowledge is concerned. The opposite extreme is the sort of opinion characterized by a lack of guarantee of its validity. The various conceptions of science may be distinguished according to the guarantee of validity attributed to them. Such a guarantee may consist, firstly, of demonstration; secondly, of description; and, finally, of correctness.

4. Mutual causality processes

There is no complete developed theory or tool to exhaust the matter. Some aspects make it impossible to devise a complete prospective model which is able to exhaust the matter: the great amount of parameters, environment conditions – which vary from one moment to another – some uncertainty, and a strong degree of subjectivity in decisions concerning which technology to adopt and which science to apply as support. In the last years, specialized literature has shown some concern with the establishment of bases for explanations concerning technological development. The root of this concern lies on the Theory of Complexity, according to which, just as in physical processes, it is impossible to identify the final stage of a system – a system able to analize subjective conditions in an environment of uncertainty and untouchable aspects.

The sort of analysis proposed aims at reasoning about the problem, revealing the model of relations which sets the product development apart from the technological realm as well as from the science which provides support for continuity. The figure 2 shows this process in abstract way. A net of positive and negative feedback makes up the set of relations. The positive feedback is highlighted as relations point at discontinuity. Most techniques for this sort of perspective falls into the trap of linear thought, in a search for simple causes supposedly present at the root of the problem. Linear thoughts of this kind end up establishing bases for linear solutions. The theory of autopsies (MATURANA, 1997) generated a new sort of comprehension. It presents a contextual analysis of some of the innumerable relations which contribute to abandon continuity (in the development of a product) in order to appropriate available technology from another area of scientific knowledge. As it has already been pointed out, when focusing on matters of discontinuity during a product development, continuity is pervaded by linear thought, whereas discontinuity is pervaded by circularity. This circularity involves variables and establishes mutual–cause relations. MARUYAMA (1963) focuses on the role of positive and negative feedback in the study of systems dynamics. Maruyama shows the importance of negative feedback processes, in which a change in a variable sets up a change towards the opposite direction, in order to explain systems stability. Processes are characterized by positive feedback in which "more leads to more" and "less leads to less". These concepts are important for explaining systems changes. Relations illustrated in the net establish the mutual causality existing between variables. Interventions are likely to influence the whole, so they need to be adjusted so that the sort of systemic transformation expected can be obtained.

5. Concluding remarks

MARMARAS and PAVARD'S (1999) proposal about the approach directed to the problem recognizes the need for assisting complex cognitive tasks. The problem of correcting supporting tools inadequacies finds no solution as long as the proposed method is not based on the realm of a conceptual project. Any tool only provides assistance when used during the "creativity" stage. In this case, being directed towards the problem is the initial step for generating new supporting tools which assist complex cognitive tasks in information systems projects. However, it is important to highlight the fact that, in this field, isolated tools are not enough for complete assistance: multiple tools are needed to be applied in each stage of the design. Within this scope, several works may be cited starting from the association of the Theory of Inventive Problem Solving (TIPS) and the DELPHI Method as multiple tools in product development (BARROS & FIOD, 2001). It must be added that a great number of authors who are interested in the matter have published proposals to use coordinated tools to assist products development. Those who are interested may follow the path.

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