ENTREPRENEURSHIP IN THE ENGINEERING CURRICULUM: SOME INITIAL RESULTS OF PUC-Rio's EXPERIMENT

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Abstract:*The ideal of the entrepreneurial spirit has played a key role in shaping the current reform of engineering education at the Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio). The previous paradigm of a science-based conceptual engineer has given place to what may be termed a science-based entrepreneurial engineer. This paper discusses this transition, focusing on the main concepts, strategies and tactics of change, as well as some important initial results achieved in the intended direction.*

Introducing the entrepreneurial dimension in the training of engineers is akin to venturing onto uncharted waters. While several business schools have achieved some experience in this field, the same cannot be said of engineering schools, most notably in Brazilian universities.

To engineering schools in the context of a research university, the focus on entrepreneurship has a special strategic significance. On the one hand, it reflects a growing perception that their new graduates need the technical and behavioral attributes and skills of the entrepreneur for a successful professional life. Such a perception can easily be inferred from the current demands and opportunities of the job market. On the other hand, such a focus also reflects schools' awareness of a much-needed change in their institutional culture.

This cultural change of research universities is needed to comply with growing social demands for more tangible benefits from university research. As universities meet this demand through a heightened entrepreneurial outlook, they will be in a better position to comply with students' and society's request that they practice what they teach.

This paper argues that, with proper guidance, the entrepreneurial vision leads to investment in a set of complementary assets that enhance universities' ability to respond to societal demands and, at the same time, to offer students vital elements for enduring professional and personal development.

At PUC-Rio, an experiment is underway for the introduction and dissemination of entrepreneurial culture through several institutional means, including the engineering curriculum. The driving force is the newly created Genesis Institute for Innovation and Entrepreneurship, which is also responsible for the production and management of the complementary assets required by this endeavor. This experiment is detailed in the paper, together with its initial results.

Key Words: engineering education, entrepreneurship training, entrepreneurial engineer, cultural change in the university, institutional cultural change.

The Science-Based Entrepreneurial Engineer

The ideal of a science-based entrepreneurial engineer is defined in [1], in compliance with the educational policy recommended by the REENGE program (Brazil) and the NSF (U.S.), and in response to the formidable challenge of socioeconomic change and changes in work processes at the turn of the century. These changes are the result of fast-paced technological advances, the new economic dynamics (increased value of market orientation, globalization, growing uncertainty, etc.), the new division of labor (standardization, automation, modularity, outsourcing, etc.), and the rise of new values, new problems, and new opportunities.

This ideal, which replaces that of the science-based conceptual engineer generated in the Fifties and Sixties, may be summed up as a set of skills seen as necessary to face the situation brought about by the above-mentioned changes:

- ability to generate one's own information flow: self-teaching capability, which requires an ample scientific and cultural basis, given the present state of technological development and the emergence of new problems;
- ability to create, design, and manage technological interventions: being a problem solver;
- communications skills;
- ability to work in multidisciplinary teams; leadership;
- ability to evaluate the social and environmental impact of one's interventions; perspective;
- market vision, business acumen;
- ethical behavior;
- last but not least, entrepreneurship.

Entrepreneurship means the ability to create new values through a reordering of reality. "The science-based entrepreneurial engineer aims, by means of a science-based technical intervention (discovery, invention, planning, management, organization), to exhibit and to produce new products, services, transactions, resources, technologies or markets which can be recognized as valuable by society" [1]. The entrepreneur must constantly relate to the world around him or her, not only to specify the problem that must

be solved but also to search for a solution, test it, and develop it. He or she must have perspective, taking in not only the technical aspects but also the economic, social, cultural, and ethical contexts. And he or she must realize that society today — whether or not he or she agrees with it — sees the engineer's activity in business terms, and accordingly be prepared to deal with this reality.

Introducing the entrepreneurial dimension in the training of engineers is akin to venturing onto uncharted waters. This article discusses the problems and the tentative solutions found at PUC-Rio in the attempt to create a suitable environment for the training of this new kind of engineer. Also discussed are the ensuing conceptions of university structure.

How to Develop Entrepreneurial Engineering in the University

The ideal of the science-based entrepreneurial engineer implies curriculum changes in engineering courses, as to both the material to be taught and the methodology to be adopted (see [2]). In addition to this, two of the skills listed above are inner attitudes: being a problem solver and being entrepreneurial. To deliberately encourage an inner attitude in students, it is necessary to place them in an environment where the desired attitude is common currency, where the attitude in question is constantly required and exemplified.

In the case in point, entrepreneurial-engineers-to-be must be required to solve concrete problems, in contexts increasingly similar to those in which they are to work (hands-on methodology), and must be encouraged to start their own businesses, conceiving, planning, and simulating them, and whenever possible actualizing them.

But it is not enough to simulate interactions between students and society. The university will be unable to conduct such "exercises," and these will remain "academic," unless these interactions are concretely effected in the university environment. The education of science-based entrepreneurial engineers requires special conditions. Most importantly, the university itself must behave in an entrepreneurial way, particularly in its interactions with companies and the government agencies. These relationships must be based on exchange, rather than on charity. In addition, universities must see themselves in a market, where opportunities come and go, where decisions involve risks, where "product" and "business" are not foreign terms or dirty words. In this environment, faculty will be able to speak to students of their own experience, thus providing students with formative and concrete role models. Students will be required not only to engage in business simulations, but take part in real-life projects and business arrangements, involving social reality and the tangible presence of technological intervention and its consequences.

Nevertheless, a university is not a corporation involved with a specific kind of business, nor are university professors businesspeople. Their aims are different, and the different goals of business and academia tend to be seen as antithetical, for they are associated with contradictory ethos. Should engineering schools, increasingly similar to business schools, be detached from universities? Or should universities change their environment so as to include the contradictory ethos of the ivory-tower specialist and of the businessperson? The situation becomes even more complex in the case of research universities, in the Humboldtian sense, recently reorganized to emphasize research and graduate studies (as is the case of PUC-Rio). To deepen our understanding of the problem, a short digression is in order.

A Critical View of the Research University

Today's research universities were created on the basis of principles quite different from those appropriate for educating entrepreneurial engineers. To begin with, the academic institution is a world unto itself. This is a consequence of the separation of the "pursuit of truth" — its ultimate value — from "mankind's necessary cares," to quote from a famous speech by John Henry Cardinal Newman (the creator of Dublin's Catholic University). Cardinal Newman hoped his university would be dedicated to the pursuit of knowledge "for its own sake."

In this paradigm, the relationship between the university and the rest of society (and the world) takes place through two perfectly controlled channels. On the one hand, the universe takes the world as its object of study "academically," adopting for methodological purposes an aloofness that does not allow the institution to engage in "transitory matters." On the other hand, the university trains professionals who are prepared to apply to the real world the knowledge it generates and retains.

The research university is arrogant: it generates and retains knowledge and teaches the proper way to apply it to the world. Whatever entrepreneurial spirit is to be found in it is what is inherent to scientific research, and it serves essentially the purpose of training new academic researchers: the university is a world unto itself.

This paradigm neatly separates academia from the rest of the world, a separation of places, values, and attitudes. An opposition is established between two sets of values. On the one hand, the values of the past, represented by the classical texts, and the values of science and philosophy, generated inside the walls of academia — values associated with durable, stable truths. On the other hand, the values of a contingent and unstable external world, where pragmatism replaces the search for truth.

Until recently (with the notable exception of the MIT ideal, about which more will be said later), associations with businesses for consultancy or product development were seen as distortions of the true university spirit. Professors who developed ties with companies were perceived as involved with activities marginal to the real interests of the university, or even harmful to the institution. This is the

beginning of the protracted discussion over values between "pure scientists" and "applied scientists." Or should one say "pure" and "impure"?

The compartmentalization of knowledge in disciplines, together with the paradigm described above, has led to the division of the academic world into mutually incommunicable fiefs, each with its own specialized language and apparently independent problems. This amounts to the internalization of the break with the world, and it transforms the university into a set of specialists each in his or her own ivory tower.

However, the real world out there disregards such constructs. New problems arise at every moment, and most of them are of a multidisciplinary or interdisciplinary nature. The very structure of science has changed as increasingly advanced research makes experiments ever more complex. In physics and biology, large number of authors, including scientists and engineers of different areas, often co-write articles. In engineering, every concrete problem is multidisciplinary and becomes unrecognizable to students after it is broken down into various academic areas.

The immense success of the natural sciences in our century[1] has called attention to universities, and their funding has increased tremendously. But financing has mostly been of a "pragmatic" sort, requiring social comfort as the return of investment. The phrases "applied research" and "induced research" have become increasingly common, to refer to those programs dedicated to topics dictated by government interests. This is nothing short of scandalous to those who espouse Cardinal Newman's view of what a quality university should be. The aristocratic view of the university — that is, an institution reserved to an aristocracy of the spirit — has given way to a democratic view according to which only the interests and comfort of all justify the allotment of funds to the few.

The tension arising from this clash between "absolute truth" and "pragmatic truth" is inherent in the history of the natural sciences, which are pragmatic by method and motivation [4]. The relations between industry and academia have been rather turbulent since the days of Galileo Galilei[2], and discussions about the funding of universities (provided mostly by government) only underscore the continuing disputes between "pure" and "applied" scientists. Unlike traditional academics, governments and taxpayers prefer patents and innovative companies to Nobel prizes.

A curious example of this dispute is the idealized model adopted by the Massachusetts Institute of Technology (MIT). It would be unnecessary to analyze here the actual functioning of the MIT, involving multiple partnerships with advanced-technology companies. Let us simply examine what is stated in ideal terms: an institution where industry finances the development of pure science and applied science, producing both papers and patents, where students found companies that hire professors as consultants. According to this ideal, the patents and the new companies implicitly justify investments in pure science. We refer to this as an ideal rather than a paradigm because the mechanism is never quite clear: is "pure science" the prime mover of the entire institution or is it induced by corporate demand? Which administrative mechanism allow the correct mix of incentives for all to interact in a mutually beneficial interchange? The implicit political issue remains unsolved, in terms of both principles and procedures. One need only point to the fact that, with the decrease in government funding of the weapons industry since the end of the Cold War, the MIT itself has been experiencing difficulties [3]. And, after all, the MIT is a rare phenomenon.

Another change affecting the university in this century is the growth of middle-class families, with its accompanying increase in the demand for university degrees for middle-class youths. This has increased many folds the number of college students, so that it has become impossible to finance courses for all in a classical research university. The university's role as a trainer of professionals has been tremendously reinforced, and costs have to be reconsidered. This has led to reorganization of university structure in many countries [3]. It was this context that generated the movement for reform in engineering courses, pioneered in the U.S. by the NSF and in Brazil by REENGE/Finep-CNPq-SESU-CAPES.

France is a particularly radical example: there, the different roles played by universities tend to be assigned to different institutions: there are laboratories for fundamental science (mostly funded by the government), applied-science laboratories (which are forced to sign contracts with companies), and engineering universities and schools (dedicated to professional training). But the system does not function smoothly. This may be observed by the CNRS's continuing efforts to bring these various branches closer together, in an attempt to solve problems such as unemployment among recent holders of graduate-school degrees. Industry feels that their training is inadequate, and they prefer to work in research laboratories, although France expects from them just the opposite [5].

The fallacy lies in the fact that the best way to train engineers is to involve them in scientific research at top-level laboratories. The example shows clearly that professionals trained in this way are more interested in scientific research associated with the world surrounding it: separation from the social and political context by the academic moat, smug and self-asserted values, aversion to the contingencies of the real world. This is the very opposite of the entrepreneurial engineer.

We believe it is impossible to train science-based entrepreneurial engineers without integrating professional training into the development of fundamental science and the development of innovations. The first kind of integration corresponds to the science-based conceptual engineer, a concept emphatically championed in the Sixties. The result

[1] Sciences that are pragmatic in its methodology.
[2] See also the work of Archimedes and the research in Alexandria.

of this model was the addition of scientific disciplines to engineering curricula without any essential change in the teaching and practice of engineering.

The second kind of integration requires that the search for innovations with social and industrial relevance be represented in the university. This is contrary to Cardinal Newman's proposal in that it tends to bridge over the moat between the university and the real world out there; it implies accepting the interchange of information between society and business, blurring the boundary lines of the university. It implies bringing into the university the pragmatic values of the contingent and unstable outer world, the discussion of "mankind's necessary cares." It implies facing the political antagonism between "pure" and "applied" science, together with the pressure for innovation within the university itself. One of the issues that must be faced is the possibility of considering participation in industrial projects, creation of innovative products and patents, and development of new teaching techniques as criteria for professors' promotions, things that would have been unthinkable in a "quality" university only a few years ago.

Nowadays the boundary lines of the university are already blurred, as a consequence of social and economic pressures. Multiventures with university laboratories funded by corporations have become common[3], as well as consultancies and commissioned projects[4]. The sort of demand-oriented research funding[5] advocated by governments today amounts to outright encroachment on the autonomous will of the university. The resources that make distance learning possible, particularly since the advent of the Internet, coupled with the accelerating pace of technological change, that has increased industrial demand for refresher and extension courses, have put into question the desirability of classical training and have made the boundaries of universities permeable. Furthermore, through the Internet, the distance among researchers-professors has been definitely abolished, making multi-institutional teams a common reality.

The problem is more than just how to educate entrepreneurial engineers. How to organize the university so as to allow it to play its various roles, facing the inevitable political conflict? How to manage the university's blurred boundary lines so as to generate an environment conducive to innovation and interaction with business and society without detriment to scientific research and the autonomy of the university? How to reorganize courses so as to meet new demands? How to generate the heterogeneous and dynamic environment required for the education of science-based entrepreneurial engineers?

[3] As the Microsoft Laboratory in the University of Cambridge and the TecGraf and the Laboratory of Formal Methods in PUC-Rio.

[4] As the "Petroleum University"of PETROBRAS, in Brazil, funding research of its interest in many brazilian Universities.

[5] As the "actions thématiques programées" of CNRS/France and the funding programs of FINEP/Brasil, the PADCT/Brasil being an example.

Managing Institutional Cultural Change: A New Paradigm for the University

Perhaps the essence of the paradigmatic shift of the modern university consists in moving from a (nearly) closed system to an open one involving extensive and intensive interactions with its environment. Traditional research universities have championed this shift as a result of the intensity of their extramurally funded research and, to a lesser degree, of the commercial exploitation of research results.

The outstanding performance of these institutions has clarified, to both governments and companies, the significant role that advances in knowledge now play in the acquisition and maintenance of a differential position. As a result, the inherent dynamics of the (applied) research function of such universities have become part of the "value-chain" of many important firms and government agencies.

The forces that impel universities to become even more open have grown broader, affecting more than the research function of the university. As the cycle of knowledge moves ever faster and industry improves its ability to reap benefits from closer proximity with the university, pressures mount to involve other university functions in this interaction.

To this effect, there is a need to conceptualize the modern university in ways that will enhance its ability to interact, while preserving certain key and distinctive features responsible for its intellectual vitality, independence, ensured quality and foresight. There are different approaches to this conceptualization; what follows is a description of the one adopted at the Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio).

For simplicity's sake, let us consider the three main functions of the modern research university: teaching, basic research, and applied research & innovation. Figure 1 presents an interesting view of the distinction and complementarity between the second and third functions: research transforms financial resources into knowledge (basic or applied); innovation transforms knowledge back into financial gain, through some differential position. Universities are being expected to increasingly participate in the "innovation business" stemming from their research results, not only to enhance industrial competitiveness but also as a source of financial support.

In viewing these three university functions, it is most important to recognize that they entail different yet intertwined functional environments, with characteristic cultures and processes. This diversity is both essential and peculiar to the university environment, as is the fact that most of those involved in these processes are the same individuals (researchers-professores) who must change hats depending on the environment where they find themselves. This latter feature is one of the roots of the uniqueness and strength of the university setting, in so far as a single individual enacts such a multiplicity of synergistic functions.

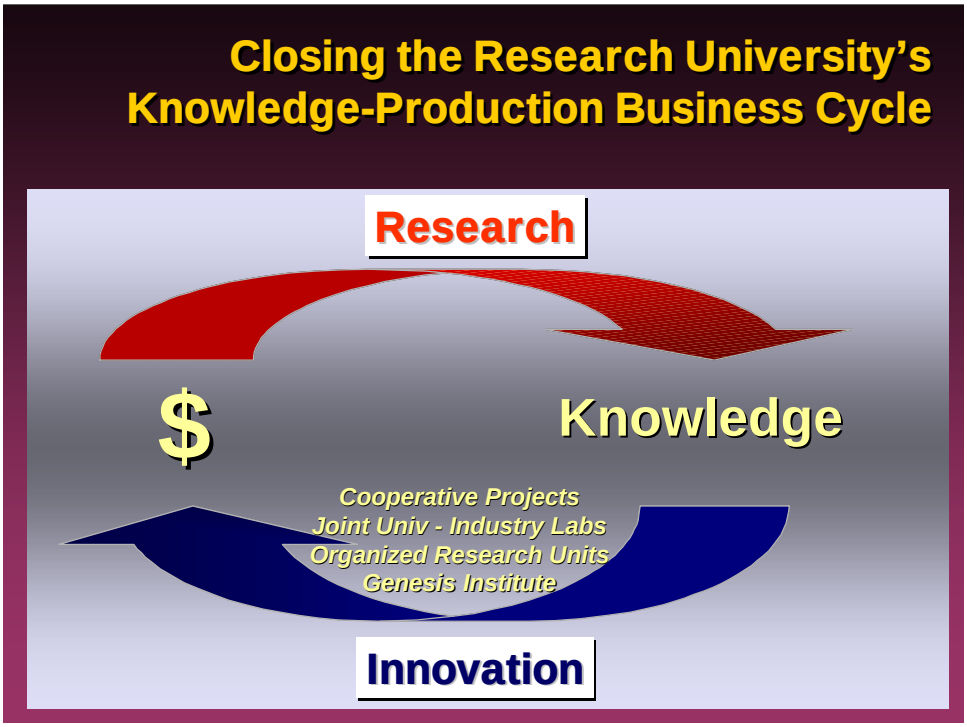
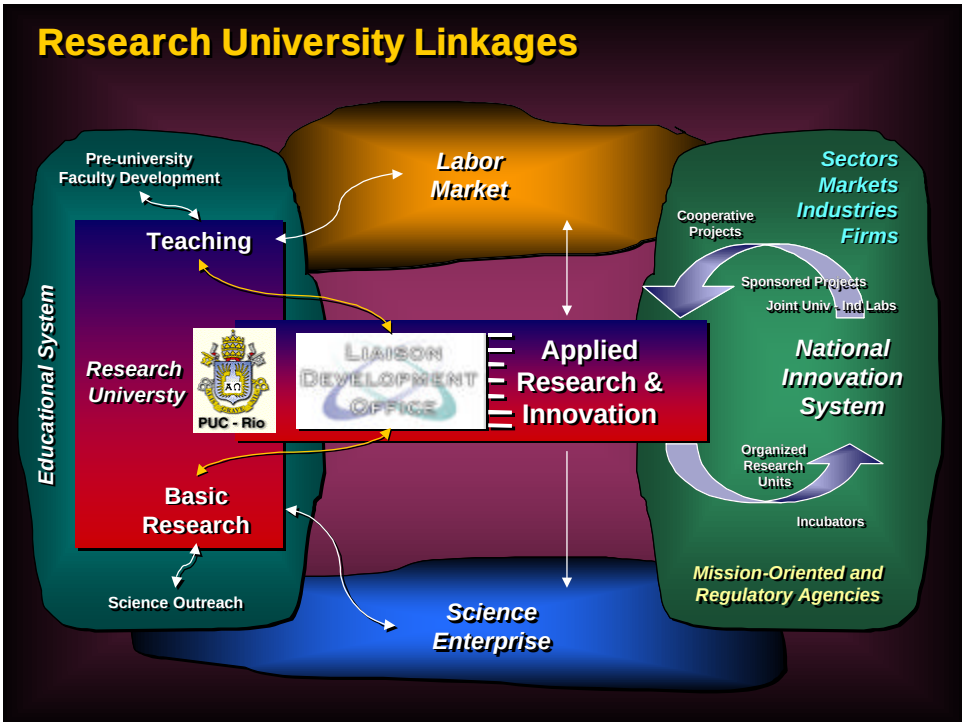


Figure 1 - The knowledge - production business cycle.

Figure 2 - Example of Linkages of a Research University



The cultural differences arise both from the peculiarities of each function and from the nature of the surrounding environments. Figure 2 presents a useful starting point for viewing the main functions of a research university, its more immediate external environments and examples of linkage mechanisms. It also depicts the important role that Industrial Liaison Offices can play in strengthening linkages in other university functions, thereby acting more generally as Liaison Development Offices.

One of the functional environments is that of basic research, the fundamental object of the Research University in the Humboldtian sense. Organized in disciplinary lines of research, it transcends each particular university, forming what is known as "scientific enterprise." A basic-research team in a given institution tends to have stronger links with teams researching the same topic in other institutions than with teams in closer geographical proximity[6]. Thus, communication and cooperation is intra-disciplinary.

In actual practice, this is also where research-oriented training fits in: graduate studies culminating in a doctorate. Its object is to train a new generation of researchers, for work within disciplinary boundaries. The organizational structure and pattern of funding of governmental agencies, which also follow disciplinary lines, have reinforced this mechanism of renewal. Furthermore, one of the key arguments for research support in this context is the recognition that good research training is impossible outside of a research environment.

The teaching environment has been undergoing profound change over the past decade. Originally its raw material was made up of high-school graduates, and its object was to train them as professionals ready to go into action immediately after graduation. This conception was a viable one at a time when technological stability gave an engineer a useful life of 20 to 30 years. Today, assuming an up-to-the-minute undergraduate course — a utopian assumption — this useful life is of less than 5 years (in the most active areas); after this period there is a need for refresher and extension courses and the like.

For this, classical graduate-school courses are clearly not adequate. The engineer in need of a refresher has well-defined objectives and cannot afford to stop producing for two or three years, submitting to academic curricula geared to the interests of the research group in closest proximity. Hence the growing importance of extension courses, continuous education, and distance learning, and the rise of engineering doctorate (Eng. D.) degrees (UMIST) and refresher courses geared to the needs of specific companies. The new paradigm requires the creation of new instances and specific university units, dedicated to the development and coordination of these activities, in particular the offer of new degrees and courses.

[6] This phenomenon was described as the substitution of "universities" by "multiversities".

The current success of Production Engineering may be put down not only to the administration training it includes but also to the fact that these are undergraduate courses of a general nature, which provide a more pragmatic and rounded culture by combining technological, administrative, economic, and financial aspects. Specialization is sought only as needed and as required by company interest.

Two of the various consequences of this new situation are the scarcity of good applicants for traditional graduate-school programs and the almost complete disappearance of the ultra-specialized student. The traditional type of student, that majors in a specific area and then gets a master's and a doctor's degree in it, is now being replaced. The new student stresses breadth rather than depth, and a broad contextual perspective that relates knowledge to application[7].

It is up to the university, together with the business world, to redesign education taking into consideration these new trends.

The applied research & innovation environment has a heightened dynamism due to the external (social and industrial) pressure arising from its close links with the National Innovation System. In this environment, various distinct organizational forms arise to develop relationships with the external milieu, shaped by a hybrid culture. Examples are corporate-funded R & D laboratories[8], research programs and projects. Another important examples are the business and technology incubators. All of these have been considered valid initiatives by a large part of the academic world, but still meet with resistance in its traditional core.

Such initiatives have the effect of opening the university to society, allowing interchange of experiences (which means the research university must give up its arrogance), the rendering of services, and the creation of an entrepreneurial environment in which innovations can be developed. To return to the main topic of this paper, these initiatives are essential for the creation of an environment suitable to the training of entrepreneurial engineers, as long as they engage faculty and students in the appropriate way.

On the other hand, opposition to the contact with the business world has reasons other than a refusal of the new values entailed. Working for companies implies the production of knowledge that must remain confidential for contractual reasons and because of economic interests. This is contrary to the principle of open information that is inherent to science: information must be easily accessible, both because of its social interest and because results must be criticized so they can be improved and verified.

The ensuing problems of intellectual property are serious and remain unsolved, particularly issues related to

[7] Which is a problem for the specialized professor wishing a student specialized essentially in his or her research subject.

[8] See note 3. These laboratories are not obliged to work only on the corporation interests.

patents and the use of classified information. Applied research related to specific products operates under contractual provisions establishing clear deadlines, well-defined stages, and rigid budgets, unlike basic research. The discrepancy in pay and in chances of securing contract awards may lead to relative neglect of basic research and of the pursuit of truth in favor of issues of fleeting and merely commercial interest that are the exclusive concern of a small section of society[9].

Thus new ethos arise, generated by different habits, motivations, and values, in accordance with the intrinsic logic and requirements of each environment. Hence the crucial need for an internal organization of the university that will integrate, harmonize, and preserve the three environments, each with its own appropriate characteristics. This is one of the key roles of the Liaison Development Office, which also include:

- fostering applied research (seeking out companies and organizing incentives to applied research within and outside the university, for instance) and the development of an entrepreneurial environment;
- presenting what the university has to offer in such a way as to make it easy to understand for companies (organizing thematic groups and preparing catalogs, for instance);
- regulating relations with companies so as to validate applied research only if there is enough external interest and internal overlap with basic research and/or teaching, so that the earnings are spread throughout the university;
- managing relations with companies so that faculty need not concern themselves with such matters, attending to such troublesome issues as intellectual property, research deadlines, and budgets, as well as the use of different kinds of fiscal incentives to R & D.

To carry out these tasks, PUC-Rio has created the Liaison Development Office, shown in Figure 2, as an agent of the applied research & innovation environment, having strong relations to the other two environments. See also http://www.ed.puc-rio.br.

On the basis of PUC-Rio's experience, external pressures and internal leadership seem to play a key role in change. In the case of Brazil, and of PUC-Rio in particular, there were then sufficient external pressures on universities to change their performance in the direction of increased extrinsic relevance. These pressures manifested themselves through both financial instability (as traditional public financial support diminished) and threats to institutional prestige. Thus, the essential role of leadership was to steer these pressures in fruitful and internally acceptable directions, generating proper demonstration effects.

At PUC-Rio's CTC, once awareness of the problem was attained, a major campaign was started to promote the new paradigm, even as the administration actively sought new sources of funding, contracts, and various kinds of incentives, trying to revive dreams that had been repressed by the earlier paradigm. It was necessary to generate examples that would demonstrate the possibility of entrepreneurial initiatives in a university environment, and these examples were at the same time trials of the ideas and methods. The examples involved the application of new teaching methodologies [6], new disciplines [7], new programs (see discussion of the Genesis Institute, below), and new kinds of contract.

The new paradigm is gradually earning its legitimacy as innovative examples achieve success, by means of internal propaganda, and through internal and external pressures that have the force of reality. Only after this legitimacy is won will it be possible to change the internal awards system (promotions and prizes) so as to take into consideration the activities in the three fields illustrated in Figure 1.

How to move the university towards this new paradigm? This is a crucial and necessarily a separate topic in itself. Yet some aspects of PUC-Rio's experience may be illuminating. Clearly, external pressure and internal leadership seem to play a key role. In the case of Brazil, and of PUC-Rio in particular, there was sufficient external pressure on universities to prod their performance toward more extrinsic relevance. Thus the essential role of leadership was to steer this pressure in fruitful and internally acceptable directions, generating proper demonstration effects that built momentum for change.

It is true that PUC-Rio boasts a history of pioneering major efforts of institutional change. Back in the sixties, it was used by the government as a laboratory for the early implementation and testing of the University Reform Law. Nonetheless, after thirty years consolidating its institutional model of a private (classic) research university, the element of internal resistance could not be underestimated. Thus great effort was placed on changing the mind-set of faculty as a whole and of key opinion-makers in particular.

In addition to the above considerations, four other elements appear to have lessened resistance and generated internal momentum:

1. External visibility: great effort was placed on showing external agents that PUC-Rio was embracing the new paradigm with full vigor, so as reinforce both its internal and its external image as a pioneering institution. The imperatives for change were clearly presented, so that the commitment to change was perceived as irreversible.

2. Change to enhance: great effort was also placed on developing a shared vision of the essential elements of change and of the process of change. Most important was the continuous reinforcement of the position that the valuable elements of the existing institutional model were to be preserved and that the new elements to be introduced would enhance the ones to be preserved. In this respect, it was most important to emphasize that the new "applied

[9] See [8].

research & innovation" environment should be seen as an "add-on" and not as a substitute for the basic research environment. Complementarity between the two research environments was continuously emphasized, rather than interference.

3. Professionalism: as the new "applied research & innovation" environment demanded expanded interactions with industry, faculty would be assisted by a corps of full-time professionals (liaison personnel) under the leadership of a faculty member in the field of Technology Management. This gave rise to the establishment of the Liaison Development Office with the characteristics mentioned earlier.

4. Entrepreneurship: as the new research environment was crucially dependent on the establishment of an entrepreneurial culture in the institution, a new unit was created to approach entrepreneurship from both an academic and a practical standpoint. This unit — the Genesis Institute for Innovation and Entrepreneurship — and its role as an agent of change will be described below.

It was necessary to generate examples that would demonstrate the possibilities of entrepreneurial initiatives in the university environment, examples that were also tests of ideas and methods. Examples of applications of new teaching methodologies [6], new disciplines [7], new programs (see discussion of Genesis Institute, below), and new types of agreements were developed.

The legitimacy of the new paradigm is being achieved gradually, through successful innovative examples, internal advertising, and internal and external pressure, which bring to bear the force of reality. Only after this legitimacy is fully vindicated will it be possible to change the institutional rewards system (promotions and prizes) so as to take into account activities in the three fields illustrated in Figure 2.

The Genesis Institute for Innovation and Entrepreneurship: An Internal Agent of Change

This section describes one of the key institutional initiatives conceived and implemented in order to perform a role as an internal agent of change in PUC-Rio and as a visible sign of the leadership's commitment to the pursuit of the desired new paradigm.

The initiative capitalized on developmental efforts made by a technological services unit (ITUC) of the University's Academic Center for Science and Technology. With keen foresight, this unit started, in 1989, a technological incubation program, designed to attract engineering students towards entrepreneurial ventures, under the name of Genesis Project. It also laid the groundwork for a new building to house the incubator, finally opened in 1997, with partial sponsorship from a financial institution and governmental agencies.

Under the influence of the new leadership of the Center for Science and Technology, the concept of the Genesis Project was further enhanced, so as to perform the role envisioned in the move towards the new open-system paradigm of the university. The Project's fundamental role was to actively support change in the institution's culture, from one that originated in heavy dependence on governmental block grant support to one that could rely more on exploiting competitive opportunities, mostly from the market and residually from governmental agencies. This implied the introduction and dissemination of entrepreneurial culture, particularly among faculty, graduate students and administration officials.

This approach to change was in line with university policy directives, governmental guidelines and social expectations. These were:

- To reduce the university's excessive dependence on governmental support for research and consequently to diversify sources of its support;
- To lay more emphasis on bringing tangible benefits to society, as a direct consequence of intense research activity.

Along with other major initiatives directed by the leadership aiming at the same ends, the Genesis Initiative was perceived as meriting special attention. It was a unique opportunity to implement institutional change in a broad sense: cultural and academic change, a new organizational structure and a new atmosphere, changes in modes and outputs of production and in the nature of relations with the outside world, to name a few dimensions.

To this end, the original concept of the Genesis Project was to be redressed in its vision, mission, objective and operating lines so as to make it stand as a representative symbol for the intended direction of change.

Thus emerged the concept of the ***Genesis Institute for Innovation and Entrepreneurship***, as a hybrid unit developing a comprehensive approach to entrepreneurship. The Institute differs from regular academic units in many important ways, stemming from its major role as an agent of the new "innovation function" of the university. In this respect, its direct outputs are measured in terms of social and economic indicators (new firms, new products and services, new workplaces, etc.). Its inputs are highly heterogeneous. Its "student body" is made up of senior undergraduates, former students, university professors and their emerging firms. These "students" are motivated by "faculty" to share and cooperate. This "faculty" is, in turn, made up of regular faculty members from various departments, business and legal consultants and former students with strong entrepreneurial expertise (operating as mentors and business angels). The Institute promotes not only education and research but also business-making. Representatives of different segments of business, government and academia

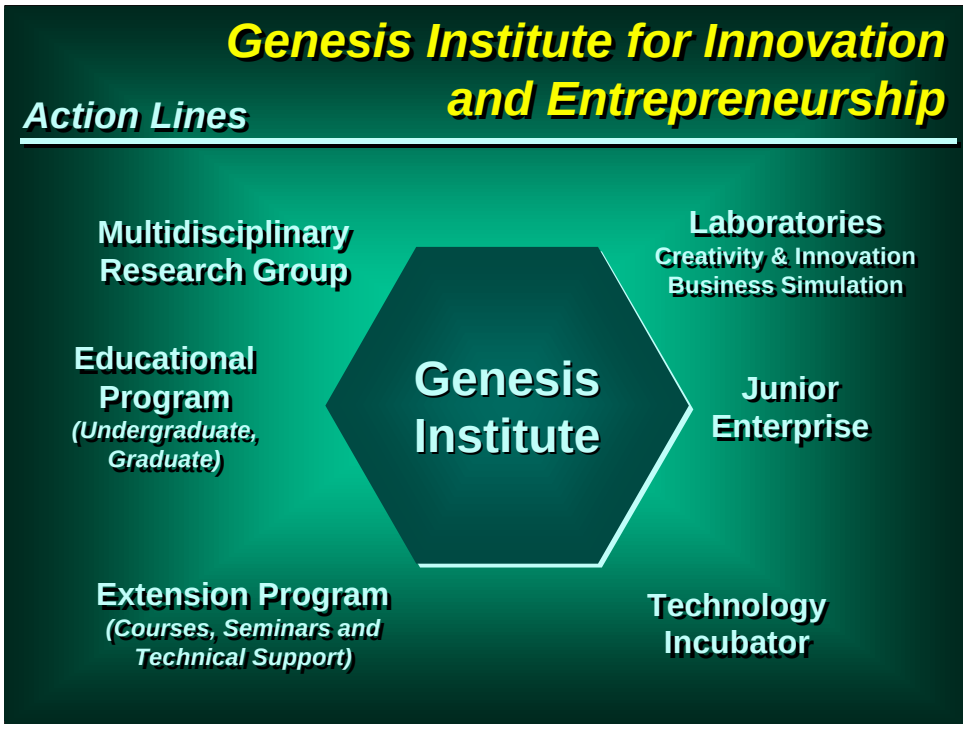


Figure 3 - The Genesis Institute

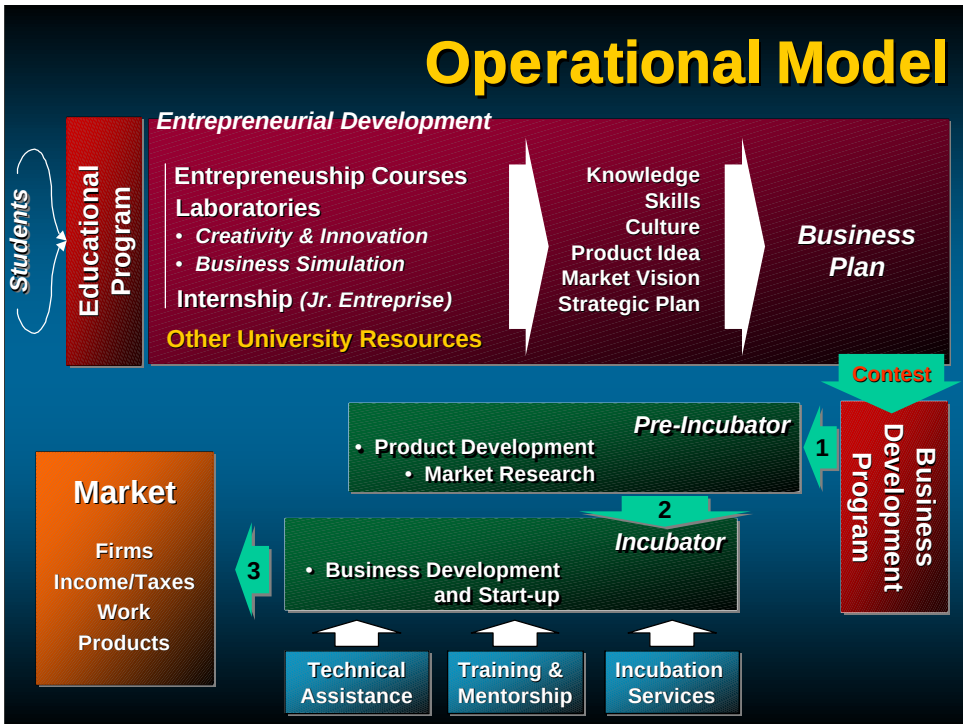


Figure 4 - The Genesis operational model.

provide its strategic direction. Marketing aims to attract not only new "students" but also investors.

Figure 4 illustrates how the Institute's resources operate in an integrated fashion, from the development of entrepreneurs to the opening of new firms in the market.

Entrance in the incubator is made through a competitive process, based on business plan analysis and a personal interview. Students prepare for this entrance procedure by taking a three-semester course sequence (Entrepreneurship I, II and III), which counts as regular academic credits towards their degrees. This course sequence is amply supported by laboratory work and focuses on the issues illustrated in Figure 5, below.

As part of the academic preparation for producing a viable business plan, students are advised to identify and explore other resources of the University that can assist them in their future business endeavor. For instance, through close consultation with research faculty engaged in industrial interactions, they can identify research results that can be incorporated into new products or services. They can identify among graduate students potential partners for finalizing their research results into new market products, identify laboratory facilities that may be useful for their developmental work, etc.

By interacting with the university in such a fashion, these future entrepreneurs are not only enhancing their technical and business prospects but are also pursuing endeavors in ways that are attractive to the University. They thus become part of an important new internal community that is dedicated to bringing forth tangible benefits to society, as a direct and deliberate consequence of the University's research activity.

This key point closes this necessarily short presentation of the Genesis Institute. The underlying issue is how to deal with the typical treatment given to research results by traditional (single-culture) research universities. In such organizations, research results are usually not screened for commercial use, and consequently are not protected. Furthermore, they are concluded prematurely at a stage that is found sufficient for the communication of the research results: a paper, a report, a dissertation, etc. At this point, a new research agenda is defined, frequently on an unrelated subject, and the process begins once again. Thus the developmental issues that arise from the perspective of an innovation opportunity based on research results are not addressed, and potential contributions to society are lost.

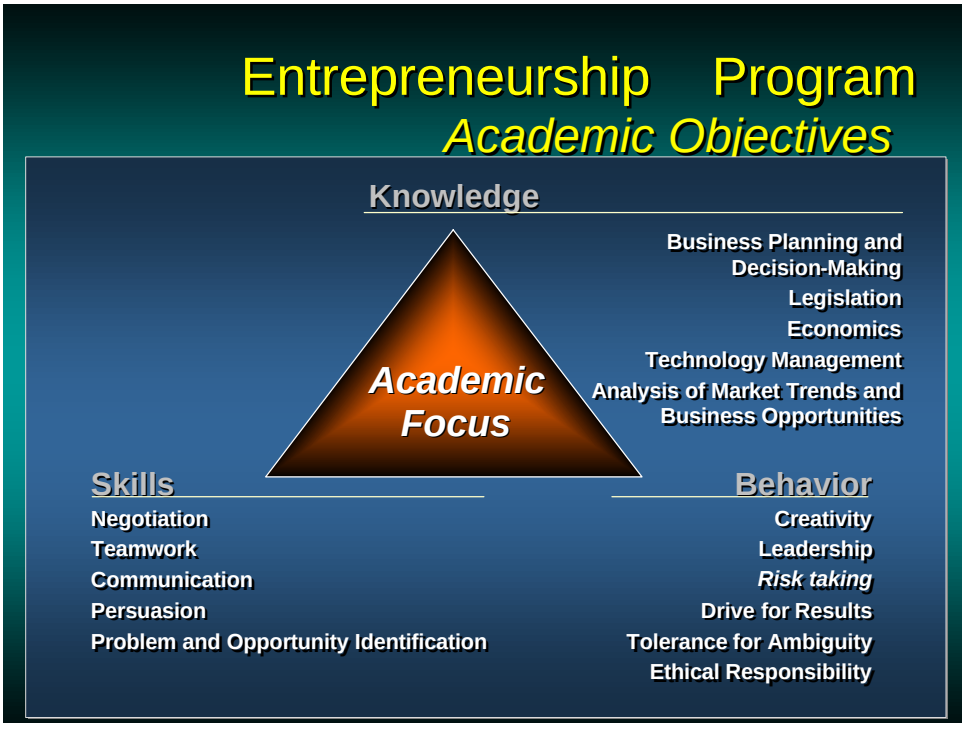


Figure 5 - Entrepreneurship program academic objectives

The general point is that the continuous outflow of innovations based on university research results and capabilities will depend on the university's ability to nurture, in-house, two complementary communities, namely the R&D and the entrepreneurial communities. The complementarity stems from the temporal profile of their motivational drive, as a problem or opportunity evolves from an abstract formulation into a marketable product. (See Figure 6.) These two communities should be allowed to interact in close proximity, so that one may count on the presence of the other right from the inception of an opportunity. Through this mechanism a new and integrated mode of knowledge production is established, endowed with a more evenly distributed motivational drive across the concept-to-market spectrum.

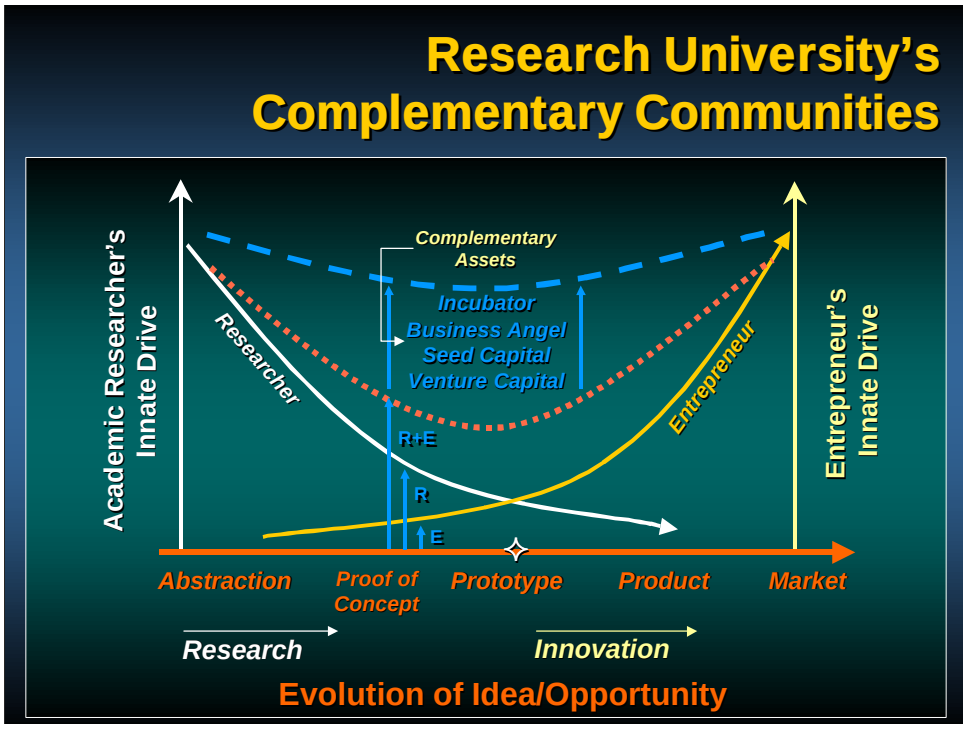


Figure 5 - The researcher - entrepreneurship duet.

In accordance with this vision, the Genesis Institute is not only the host environment for breeding the internal entrepreneurial community, with strong links to the research community, but also the source of other key complementary assets that come into play in the innovation process. The atmosphere, resources, networks and services characteristic of university-based incubators constitute powerful complementary assets of the innovation process, by elevating the motivational drive of the researcher-entrepreneur duet.

Through the efforts of the Genesis Institute, research professors at PUC-Rio are now becoming increasingly familiar with the advantages of breeding and of teaming up with a new class of colleagues – the young entrepreneurs emerging from the Institute's educational program and entering the incubator. The general perception of the Institute's mission is changing in a very positive direction, away from that of an "exotic experiment" conducted by a few "dreamers". The current vision is now changing. First, it recognizes the Institute a new and permanent institutional asset, to be nurtured and shared by all. Second, there is an increasing reliance on its mission to enhance the university's ability to respond to societal demands and, at the same time, to offer its students vital elements for enduring professional and personal development.

Students are also responding favorably to the new opportunities offered by the Institute, since the start of the educational program in 1997. Enrollment in the three-semester courses (Entrepreneurship I, II and III) averages 20 students per class and is growing. Reflecting the increasing interest of the University administration and of

industry in this new educational program, a new laboratory-style classroom, specifically designed and equipped for these courses, has been created with their financial assistance.

The incubator started its activities in the second semester of 1997 with 9 firms, generating 57 workplaces, 35 of them occupied by students, alumni or faculty members of the University. The growth of this activity is being carefully managed by a Selection Committee, which includes representatives from several industrial sectors and government. The exercise of prudence in this respect is essential, as all stakeholders involved gain experience in this vital new university function.

Finally, it must be emphasized that the Genesis Institute is just one of the underpinnings of the Engineering Education Reform being advanced by the University's Center for Science and Technology. The Institute and the Liaison Development Office make up the core of the organized effort to instill an entrepreneurial outlook in the institutional culture and University activities. There are a host of other parallel efforts in this same direction, as described in [6], [7] and at http://www.ctc.puc-rio.br.

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