How to promote interdisciplinary R&D in the academia: the case of the "House of the Future"

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While empirical research does indeed suggest that collaborative R&D has many desirable outcomes, it is also clear that collaborative work is difficult and expensive. The challenge becomes increasingly sharp as complex and expensive research questions require a large pool of resources and a combination of specialized disciplines. As a result, different organizations get involved in interdisciplinary projects to expand the frontiers of knowledge. This paper analyzes the strategy and methodological approaches used to mobilize interdisciplinary R&D within a university-industry network named 'House of the Future'. We discuss the implications of our research for R&D networks design.

1. Introduction

Markets and research are increasingly complex, uncertain and competitive. Technology changes quickly and, increasingly innovation draws on a pool of resources and different areas of expertise: "*One of the features of the modern knowledge economy is that the breadth of the knowledge base on which virtually any industry sits has increased*" (European Commission, 2000). In this environment, one organization's ability to develop stand-alone solutions tends to be limited. Successful innovation requires the ability to access and to use external information, knowledge and expertise (European Commission, 2000).

Innovative organizations are starting to pursue more sophisticated organizational structures in order to pool resources and to overcome the isolation and fragmentation of individuals and of their knowledge. They are looking outside their "traditional" knowledge bases to find new ways to improve products and processes (Qin, Lancaster, Allen, 1997). Inter-

organizational interdisciplinary cooperative arrangements appear as effective solutions. Nevertheless, they seldom occur spontaneously (Roper, Brookes, 1999, OCDE, 1999, Caruso, Rhoten, 2001), and numerous institutional and cultural barriers interfere with their success (Oosterlinck, 2001, Schmoch et al, 1998, Naiman, 1999, Golde, Gallagher, 1999, Pickett, Burch, Groove, 1999, Pellmar, Eisenberg, 2000, Wear, 1999). It thus becomes desirable, from both a policy and theoretical standpoint, to understand the dynamics of interdisciplinary R&D, a topic that has received little attention.

This paper analyzes the case of an institutional strategy developed by the University of Aveiro to stimulate applied thematic research through interdisciplinary and interdepartmental cooperation in collaboration with regional industry. We focus on a research project called "House of the Future" (CdF), an interdisciplinary and inter-institutional network composed of 12 firms and the University of Aveiro. The project seeks to promote firms' technological innovation capacity through the establishment of

partnerships involving academic researchers and practitioners acting in different industrial sectors related with the habitat meta-sector. The paper describes the strategy and the methodological approaches used to mobilize the academic community and to facilitate interdisciplinary applied R&D projects.

2. Importance of interdisciplinary R&D

Despite the growing popularity of inter-organizational collaboration in general, and academy-industry in particular, the study of inter-organizational interdisciplinary cooperation is in its infancy, and much is still unknown about interdisciplinary impact on networks formation, dynamics and performance.

Trying to solve multidisciplinary problems with mono-disciplinary solutions is an artificial way to approach the R&D process (Roper, Brookes, 1999, Naiman, 1999). Interdisciplinary R&D responds to growing complexity and increasing overlapping of technologies and scientific disciplines. Interdisciplinary R&D teams, involving individuals from different disciplines may be more effective than many isolated mono-disciplinary teams, as they minimize redundancy, balance diversity and complementarity, and capitalize on synergies in information, knowledge, cultures and techniques. The intersection of different mental models and perspectives over the same questions, results in qualitatively higher joint comprehension of specific issues (European Commission, 2000, Hargadon, 2003, Romm, 1997, Rinia et.al, 2001, Ivanitskaya, 2002, Nissani, M., 1997).

Interdisciplinary R&D improves creative performance, as breakthrough innovations often result from bringing together previously unrelated ideas, and recombining them in new ways to create original products or processes. In these circumstances, the quality, variety and availability of knowledge to be recombined it is crucial for its success (Caruso, Rhoten, 2001, Romm, 1997, Pellmar, Eisenberg, 2000, Schmoch et al, 1998, Nissani, M., 1997, European Commission, 2000).

In addition, breakthroughs in one field proved to be of great importance for progress in other fields. Methods and instruments from diverse disciplines provide idiosyncratic solutions to complex problems (Ivanitskaya, 2002, Rinia et.al, 2001, Caruso, Rhoten, 2001, Pickett, Burch, Grove, 1999).

Obviously, interdisciplinary strategies are vital to solve problems that are, themselves, of a multidisciplinary nature, and that can only be understood by bringing together insights and methodologies from the various relevant disciplines. This is usually the case with the valorisation of R&D results, as they are transformed into new products and services economically viable (Schmoch et al, 1998, European Commission, 2000, Ivanitskaya, 2002, Romm, 1997, Roper, Brookes, 1999).

As a consequence, an increased number of organizations practice interdisciplinary research, fostering holistic visions whilst enhancing their ability to contribute to social developments (Nissani, M., 1997). Interdisciplinary R&D activities are put into practice by interdisciplinary teams, which may be facilitated internally in the organizations, crossing various functions, or can be developed in the framework of inter-organizational cooperative arrangements. One of these types of arrangements takes the shape of interdisciplinary R&D projects between firms and academia (European Commission, 2000). The interdisciplinary R&D projects developed in cooperation between academia and industry have been found to contribute to better exploitation of limited research capacities, to the speeding up of technology transfer between science and industry and to the generation of synergies (Roper, Brookes, 1999, OCDE, 1999).

3. Barriers to interdisciplinary R&D

In spite of the benefits for economically viable innovation, multisectoral / multidisciplinary activities and interdisciplinary R&D projects involving academia and industry rarely surge spontaneously (Alves et.al, 2004, Caruso, Rhoten, 2001).

The academic political discourse recognizes the importance of interdisciplinary R&D. Yet, this is hardly put into practice due to important organizational and other barriers that do not allow its development (Caruso, Rhoten, 2001, Oosterlinck, 2001, Schmoch et al, 1998). The barriers can be summarised into universities' organizational design, lack of motivation, lack of incentives and complexity of managing interdisciplinary teams.

Regarding organizational design, the fragmentation of disciplines within the academic institutions, especially those with a departmental organizational structure, inevitably obscures important features of modern R&D activities (Bourke; Butler, 1997). Traditional R&D culture has not prepared academic researchers to face these challenges (Caruso, Rhoten, 2001, Naiman, 1999, Roper, Brookes, 1999).

Secondly, there is a lack of motivation, because academic researchers do not acknowledge the importance and the benefits of interdisciplinary R&D (Caruso, Rhoten, 2001, Naiman, 1999).

Thirdly, there is a lack of incentives because the rigid academic reward system does not contemplate interdisciplinary R&D as a dignifying pursuit. The interdisciplinarians are still considered "Jack of all trades, masters of none" (Caruso, Rhoten, 2001, Naiman, 1999, Golde, Gallagher, 1999, Pickett, Burch, Groove, 1999, OCDE, 1999).

Finally, interdisciplinary R&D projects are more complex to manage. Interdisciplinary R&D lacks an articulated conceptual framework. Communication,

knowledge transfer, interpretation processes and consensus are complicated due to the diversity of concepts, approaches and work styles emerging from different disciplinary backgrounds (Caruso, Rhoten, 2001, Schmoch et al, 1998, Golde, Gallagher, 1999, Pickett, Burch, Groove, 1999, Pellmar, Eisenberg, 2000, Wear, 1999, Naiman, 1999, Roper, Brookes, 1999).

All these circumstances limit spontaneous interdisciplinary R&D initiatives within the university and between universities and industry, as well as the success of interdisciplinary teams. Successful strategies used by universities to promote it are rarely described in the literature, maintaining this area of study rather obscure and is a factor in the replication of unsuccessful efforts (Caruso, Rhoten, 2001). Next we draw on the scarce existing literature to derive conditions to promote successful academia-industry interdisciplinary R&D.

4. Drivers of successful interdisciplinary R&D

Drawing on existing literature it is possible to identify conditions to promote academia-industry interdisciplinary R&D. Changes in organizational design, in motivation and team capabilities are necessary.

First, an appropriate organizational design and a strategic vision are crucial. It is necessary to create structures dedicated to the support and promotion of interdisciplinary R&D initiatives in the academia or between academia and industry, with a horizontal view that allows generalist discussion, facilitates contacts and helps organizing and inspiring interdisciplinary R&D teams (Naiman, 1999, Golde, Gallagher, 1999). It is also essential to define a global realistic interdisciplinary R&D strategy and promote a small number of specific interdisciplinary R&D projects with sufficient charisma and mobilizing potential to succeed and to lead to the appearance of more similar projects (Pickett, Burch, Groove, 1999, Pellmar, Eisenberg, 2000, Bradley, Hoeppner, 1991).

Second, it is indispensable to motivate and mobilize researchers for interdisciplinary R&D. It is important to create opportunities for regular informal gatherings between researchers from various disciplines, where people can meet, talk, change opinions (i.e. organizing thematic meetings on issues of interest of various disciplines). These encounters create trust, open communication and stimulate partnerships (Naiman, 1999, Pellmar, Eisenberg, 2000). It is also important to distribute relevant information about: a) the necessities of the industry, the competencies of the academia and their work practices and b) success cases of interdisciplinary R&D, which helps acknowledging that this type of R&D is possible and brings benefits (Pellmar, Eisenberg, 2000). The existence of an effective academic reward system that recognizes the importance of interdisciplinary R&D and has instruments to evaluate the results of research activities (new products, new solutions and new scientific production) can help overcome the lack of motivation (Pellmar, Eisenberg, 2000, Wear, 1999, Pickett, Burch, Groove, 1999).

Finally, the complexity associated with the functioning of interdisciplinary teams can be tackled through different means. Training in specific areas (i.e. interdisciplinary team management, principles and ways of functioning of interdisciplinary R&D, etc) allows shaping the behaviour of the individuals and also helps to better manage and organize interdisciplinary team work (Pellmar, Eisenberg, 2000, Bradley, Hoeppner, 1991, OCDE, 1999). A clear definition of the organization, functioning and monitoring of interdisciplinary R&D team activities (task definition, responsibilities, procedures, control mechanisms etc.) allows for the optimization of the communication processes (and of the inherent knowledge share) and for the evaluation of team performance (Holmes, 1994, Naiman, 1999). As interdisciplinary R&D is a group process, careful selection of researchers is essential. This goes on two levels. It is important to choose individuals with particular characteristics (i.e. he/she shows interest in other fields and is ready to ask for explanation and test ideas and concepts, has strong communications skills and is willing to work cooperatively and learn), which helps overcoming the communication barriers inherent to these projects. It is equally important to ensure the complementary of participants' knowledge, thus increasing the efficacy of the process and ensuring optimum knowledge integration (Caruso, Rhoten, 2001, Holmes, 1994, Bradley, Hoeppner, 1991).

Overall, if interdisciplinary R&D is to be promoted, as advocated by the academic political discourse, universities must change their management practices and adopt and implement strategies to pro-actively promote interdisciplinary R&D, defying established cultural and behavioural patterns.

The awareness of the importance of these drivers does not provide a clear cut formula for successful interdisciplinary R&D. It is important to keep on analyzing case studies that shed more light on the dynamics of these collaborations. In the next section we contribute to this analysis by presenting the case of the "House of the Future" project and the approaches used to promote interdisciplinary R&D projects within the University of Aveiro and jointly with industrial partners.

5. Case study

5. 1. The "House of the Future" project: an interdisciplinary and multisectoral experience

The "House of the Future" project is the result of a four-year collaboration between the University of

Aveiro and a dozen companies of the habitat meta-sector. This collaboration has been supported by a multisectoral network (Aveirodomus Association), aiming to develop innovative products in the habitat field and to prepare the construction of a House of the Future.

Table 1 – "House of the Future" co-operation network: main characteristics

Network start date:	1999
N.º of partners (May 2004):	13
Funding:	Self-funding (100% private)
Strategic goals:	Innovation in the Habitat field; Create conditions to build a House of the Future.
Network type:	Open diagonal network

The network members are mostly medium-sized firms acting in the habitat meta-sector and the university. Each member pays an annual fee (around 6.000 euros) to participate in the network and the funds are used to organize and manage all network activities.

Each network firm acts in a different sector of the habitat area. The concept of a House of the Future calls for wider competencies that those present today in the network. The network is open to new members in order to fill in the competency gaps.

The network members have been working to accomplish a first tangible challenge, formalized in a project called "House of the Future". The project, partly financed by public funds, will engender the Construction Plans of the House of the Future, and will develop futuristic products in the area of the habitat.

The Construction Plans for the actual construction of the first version of the House of the Future is divided in nineteen sub-projects, to be developed by separate teams subject to strong co-ordination.

5.2. University of Aveiro: a promoter of interdisciplinary R&D

The University of Aveiro saw the "House of the Future" project as a unique opportunity to stimulate inter-departmental co-operation and R&D whilst encouraging co-operative initiatives with the regional industrial fabric.

This fitted well within a strategy of promotion of interdisciplinary R&D recently adopted by the current Rector's Office of the University of Aveiro. Interdisciplinary R&D thus became part of the university agenda and has been set as a priority.

The implementation of this strategy is facilitated by the fact that the university has no faculties. Departments tend to be small and homogeneous, and report directly to the Rector. The research oriented departments are concentrated on a single campus.

The Rector's Office support for the House of the

Future Project was decided in May 2003, and included financial resources to create a structure to study and implement the conditions for interdisciplinary R&D in the University in the habitat meta-sector.

The operational component of this structure is a Management and Co-ordination team (M&C team), itself multidisciplinary in nature, made of three professors and two research assistants with different educational backgrounds and experiences. The professors have experience in strategic management, innovation and network management, and in co-operation with industry.

The general objective of the M&C team is to create a propitious atmosphere for interdisciplinary R&D in the academia, based on the sharing of relevant information and knowledge, joint collaboration of university researchers and professionals in interdisciplinary teams and the design of a creative and sociable environment able to build up trust and common understanding.

The M&C team has as specific goals: a) to identify all research opportunities related to the "House of the Future" Project, taking into account the know-how and interest of the university research units and the needs of the companies; b) to stimulate the creation of interdisciplinary and applied research projects, focused on specific research areas related to habitat; c) to test and observe phenomena related to innovation and development of products and processes and d) to learn more about how to support and manage university-industry cooperation and integration of academic and industrial knowledge.

The M&C team has been directly involved in: a) the stimulation and co-ordination of the participation of the university in the preparation of the Construction Plans of the House of the Future; b) the development and application of a methodology to identify and develop new products and systems for the House of the Future; c) the development, in the University, of products that will be part of the first version of the House of the Future; d) the creation of a Conduct and Intellectual Property Rights Code to be followed by all participants in the project; e) the creation of an interdisciplinary Strategic Committee to promote the project in each department; f) the establishment of the interface between academic researchers and industry partners; g) the dissemination of the benefits and potential drawbacks of interdisciplinary R&D.

The M&C team began its work with a round of 10 out of the 17 departments of the University, explaining the House of the Future Project, and presenting its opportunities and challenges. A total of 101 researchers attended those sessions and 44 of them expressed their interest in participating in the project.

Besides the M&C Team, the structure to promote the project includes a Strategic Committee. It takes the shape of an interdisciplinary body made up of senior professors from all the departments involved (in some

cases, the Heads of Department).

The Strategic Committee has twofold objectives. Firstly, it lays down the strategy of the University in what concerns its participation in the House of the Future Project and evaluates and monitors its global evolution; secondly, it provides an interface between the M&C Team and each one of the Departments involved.

The Committee meets, on average, every two months, to debate issues related to interdisciplinary R&D to be performed internally or in co-operation with the firms belonging to the "House of the Future" network. The debates address potential R&D projects, sources of funding, people that might be involved, etc.

The Strategic Committee helps overcome the barriers posed by the departmental structure of the University of Aveiro. Its members have generalist perspectives and proactive approaches. They communicate well with their colleagues in the departments, and so the information related to the project's evolution and requirements spreads out easily and intelligibly. The mobilization of the colleagues to particular initiatives is better co-ordinated. Tangible proposals to the project were more easily identified.

The M&C team created an electronic Newsletter and a Website[1] dedicated to the House of the Future Project, in order to give it added visibility. The Newsletter adopted a very informal language, and is open to radical and futuristic solutions and challenges. The Newsletter is now going on its fifth issue and is reaching 400 subscribers. It is e-mailed bimonthly.

Thirdly, the M&C Team targeted "opinion makers" in the university for informal contacts. The purpose was to make them look favourably at the project, and then promote it through their influence in the academic community.

Fourthly, the M&C Team identified and stimulated "academic entrepreneurs" amongst the researchers involved in the project. Informal discussions are taking place to get them more involved in the project, expecting to obtain "low hanging fruits"[2] that prove the benefits of the interdisciplinary co-operation and R&D.

The M&C team organized seven creativity sessions involving 30 University researchers, and five sessions involving 32 professionals from the Aveirodomus network firms.

The techniques used in those sessions were brainstorming and brainwriting. The techniques were very well received by the participants, and were extremely successful. In the University, these creativity sessions were used as opportunities to promote inter-departmental and multidisciplinary perspectives and interchanges. Some professors met for the first time in those sessions.

In the University, the sessions had two concrete goals: a) obtaining as many ideas as possible about the House of the Future, in order to help define its conceptual model and to identify opportunities to develop new products and systems; b) captivating and motivating the participants, creating opportunities for collective work in an informal and amusing way, helping overcome existing barriers.

These initiatives also helped the M&C Team to get to know better the academics involved, their way of interaction, their expectations and interests, their real desire to co-operate.

The M&C team, in its contacts with the academic community, underlines the advantages of getting together academics and industrialists in a formal network around a common goal. The firms in the network provide funding opportunities, possibilities to test prototypes and to develop products jointly.

The M&C Team co-operates closely with the "House of the Future" network and is aware of the product development requirements of the participating firms. With its horizontal perspective of the academia and industry requirements and capacities, it tries to identify joint R&D opportunities.

The M&C Team has developed perceptions that qualify the idea that university and industry are two different worlds, with very different ways of thinking and acting. No doubt that language, attitudes and values are diverse. However, in the domain of speculative thought, as was the case in the creative sessions mentioned above, the similarities between participants from university and industry were remarkable.

The analysis of interests from academics and professionals undertaken by the M&C Team led to the creation of multidisciplinary and multisectorial working groups to develop the sub-projects that will define the Construction Plan of the House of the Future (see Table 2).

Table 2 - Sub-Projects' Multidisciplinary teams

Sub-projects	Departments involved	Firms involved: main areas of activity
Architecture	Civil Engineering, Communication, Art and Design, Physics	Architecture, Ceramic tiles, Civil Engineering and building, Furniture & fixtures, Pre-fabricated concrete elements
Access & mobility	Civil Engineering, Communication, Art and Design, Electronics, Health, Physics	Aluminium Profile, Architecture, Hardware
Acoustics	Ceramics and Glass, Civil Engineering, Environment and Planning, Physics	Architecture, Flushing cisterns and sanitary equipment, Pre-fabricated concrete elements
Air quality	Ceramics and Glass, Chemistry Mechanics	Aluminium profiles, Architecture, Ceramic tiles, Flushing cisterns and sanitary equipment
Civil Engineering	Ceramics and Glass, Civil Engineering	Aluminium profiles, Architecture, Ceramic tiles, Civil Engineering and building, Pre-fabricated concrete elements
Communications	Communication, Art and Design, Electronics, Mechanics, Physics	Architecture, Kitchen appliances
Domotics	Civil Engineering, Electronics, Mechanics	Aluminium profiles, Architecture, Hardware, Kitchen appliances
Electricity	Electronics, Mechanics, Physics	Architecture, Kitchen appliances
Energy	Electronics, Environment and Planning, Mechanics, Physics	Aluminium profiles, Architecture, Civil Engineering and building, Flushing cisterns and sanitary equipment, Kitchen appliances
Entertainment	Communication, Art and Design, Electronics, Engineering and Industrial Management, Physics	Architecture, Kitchen appliances
Furniture & Fixtures	Communication, Art and Design, Physics	Architecture, Furniture & Fixtures, Hardware, Kitchen appliances
Gardening & Sprinkling	Biology, Civil Engineering, Electronics, Environment and Planning, Mechanics	Architecture, Civil Engineering and building, Flushing cisterns and sanitary equipment
Heat isolation	Ceramics and Glass, Chemistry, Civil Engineering, Environment and Planning	Aluminium profiles, Architecture, Pre-fabricated concrete elements
Illumination	Communication, Art and Design, Electronics, Mechanics, Physics	Architecture
Maintenance & cleaning	Chemistry, Communication, Art and Design, Physics	Architecture, Civil Engineering and building
Recycling	Biology, Ceramics and Glass, Civil Engineering, Communication, Art and Design, Electronics, Environment and Planning	Aluminium profiles, Architecture, Civil Engineering and building
Security	Electronics, Environment and Planning, Mechanics	Aluminium profiles, Architecture, Hardware
Specific rooms	Ceramics and Glass, Chemistry, Communication, Art and Design	Architecture, Flushing cisterns and sanitary equipment, Hardware, Kitchen appliances, Pre-fabricated concrete elements
Water	Civil Engineering, Environment and Planning, Mechanics	Architecture, Civil engineering and building, Flushing Cisterns and sanitary equipment

These teams involve researchers from various departments and professionals from various firms. Consequently, there is a variety of competencies and high multidisciplinarity in most teams. The average team size is 12 people.

The creative sessions mentioned before produced nearly 700 ideas. They were registered and classified in a repository of innovative ideas by the M&C Team, which also ensures fast access and continuous update.

The M&C team has ensured that these ideas were disseminated in the university and in the firms which are part of the network, the idea being that they can, by recombination, give rise to more and more powerful new ideas.

The innovative ideas in the repository can turn out to be excellent opportunities to stimulate R&D projects, involving firms and the university.

In fact, they already instigated 21 concrete new product development projects amongst the firms in the network.

Furthermore, 23 potential applied interdisciplinary

R&D projects have been identified in the university, linked to the "House of the Future". They are circulating between researchers from various departments, looking for interested partners. The Strategic Committee has been instrumental in the intermediation of these processes.

The M&C Team is currently evaluating all these potential projects and trying to identify synergies between academia and industry, aiming to promote future joint R&D projects. This led already to three actual R&D teams, involving researchers from the university and professionals from industry.

Table 3 – Results

Multidisciplinary teams	23
Repository of innovative ideas	700
New product development projects – ongoing	21
Applied interdisciplinary R&D projects – potential	23

The M&C Team is preparing a number of convergence sessions within the university, based on the innovative ideas contained in the repository. The purpose is to identify more product and system based

interdisciplinary R&D projects that could be developed by academic researchers.

It is expected that after the combination of the R&D projects from the two levels (university and firms) and after the convergence sessions, more interdisciplinary R&D teams will be formed.

7. Conclusions

The University of Aveiro is using an innovative approach to promote interdisciplinary R&D amongst its various departments. It takes advantage of a charismatic initiative with a multidisciplinary profile to bring researchers from various departments together in common R&D projects. At the same time, it is trying to reinforce university-industry linkages.

The Rector's Office considers inter-departmental R&D to be of strategic relevance, and decided to fund an internal project that looks into the theoretical and practical aspects of the promotion of innovative multidisciplinary initiatives. This internal project is led by a structure (the M&C team) that is, itself, multidisciplinary.

The M&C team contributes to the overall strategy by putting it into practice. It is instrumental in the motivation and encouragement of university researchers and in the creation and support of effective interdisciplinary research teams. The M&C team has striven to establish trust, understanding and open communication, by disseminating the benefits of interdisciplinary cooperation and by alerting to the possible difficulties that may arise. It also helps to eliminate barriers between the university and industry by facilitating cooperation with the firms of the "House of the Future" network.

An important feature was the creation of an interdisciplinary Strategic Committee, involving Senior Professors from different departments. This Committee is active in the definition of internal strategies and in the consolidation of the interdisciplinary R&D programme. It is an important instrument to overcome communication barriers, to disseminate strategic information, to persuade colleagues to participate in the project, and to improve the decision-making process.

This approach described in this paper is producing encouraging results. There are 19 interdisciplinary teams prepared to work in the subprojects that will integrate the construction plan of the "house of the future"; there are 700 new ideas that may point to many challenging R&D projects; the firms in Aveirodomus have identified 21 product development projects, and there are 23 potential R&D projects within the university, which can lead to university-industry joint projects - 3 of which have already been initiated.

It is too soon to claim that the strategic approach of the University of Aveiro is successful. It was initiated one year ago, and more time and further analysis are required before more consolidated findings can be proposed.

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[1] http://www.egi.ua.pt/casadofuturo/

[2] The "Low-hanging fruits" expression is used to designate the first results obtained from a medium or longer-run project with no immediate results. They usually help motivating the participants, proving the project is successful and going as planned.