

Engineering Design and Product Development: a focus of the MIT-Portugal Programme*

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This paper describes the focus area of the MIT-Portugal Programme that deals with Engineering Design and Advanced Manufacturing (EDAM). The EDAM initiative consists of two new post tertiary degree programmes plus affiliated research and industrial liaisons. The paper also discusses the Portuguese innovation and education trajectory and the challenges felt by Portugal as the world becomes more networked (or flat). Some quantitative statistical studies of Portuguese innovation and education metrics are examined to explore the needs for new initiatives such as the MIT-Portugal Programme.

Keywords: global connectivity; technology policy; Portugal; MIT; R&D development

TRENDS IN PORTUGAL AND IMPLICATIONS OF GLOBAL NETWORKS (FLATTENING)

BY STANDARD ECONOMIC MEASURES Portugal developed relatively rapidly after its 1974 revolution and its accession to the EU in 1986. However, more recently the Portuguese model of low-cost manufacturing of components for integrated systems designed and developed elsewhere has demonstrated less economic vitality in the face of new EU entries and lower-cost global sources. Figure 1 indicates that growth has slowed over the past few years while unemployment has persisted [1]. Portugal also made significant strides relative to educational attainments over the period of 10–25 years ago but this has also slowed more recently [2]. The Portuguese government has initiated a number of programmes addressing these issues. Among these are programmes attempting to strengthen their tertiary education system—one of which is the MIT-Portugal Programme.

This paper and the Journal it is part of have as their major theme the implications to education (particularly engineering education) of flattening (we prefer the conceptualization of the ‘Networked Society’ as detailed by Castells [3, 4] and will use globally networked herewith in place of flattening). As indicated above, the MIT-Portugal Programme was instituted following the Portuguese recognition of the need to respond to the challenges

introduced by the rapid increase in global networking in the third millennium.

The overriding challenge brought about by the rapid rise of the globally networked society is the need for each element of a local society to establish effective connectivity to the network [4]. Establishing effective connectivity in turn requires being able to add value to the network at a globally competitive level. For some countries and some elements of society in those countries, the connection to the network may be through a very competitive ‘champion’. However, for such champions to remain viable they must also use the global network to find high value contributors to their value stream so overall global networking is reducing the viability of national champion strategies designed to carry entire national systems. Thus, each element of a society is being exposed to global competition. For a relatively small country such as Portugal, ‘Champions’ have never been a strong possibility so this aspect of global networking is not threatening. However, one point to note is that the networking value challenge applies to all regions and most economic sectors in Portugal. For the purposes of this paper, the major institutions of concern in facing the challenge are Portuguese companies and universities.

In the period of rapid development, the major industrial growth in Portugal was as a European low-cost manufacturing source. Even today, the largest employment is in the automotive sector where the low-cost manufacturing niche is, in the majority of cases, still the basic competitive advantage. Not surprisingly, this employment base is not

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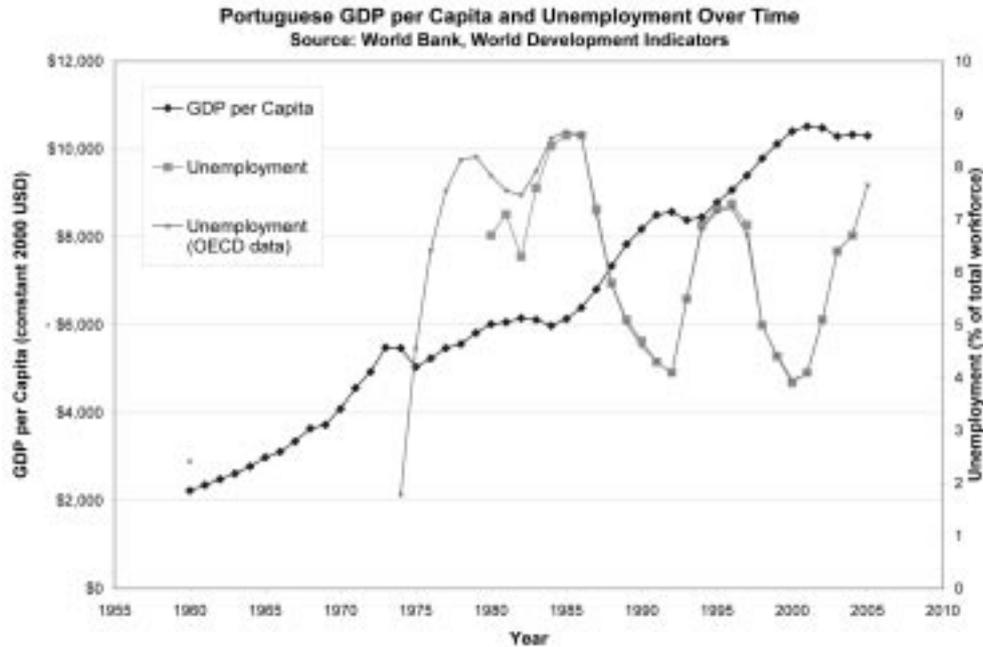


Fig. 1. GDP and unemployment in Portugal over the past 25 years

growing but instead shrinking as Portuguese wages surpass a number of new (low cost) EU entrants and Portugal also faces competition from China and elsewhere. In this situation, it is clear to Portuguese companies as well as the whole of society that high value manufacturing innovation will be necessary to even maintain what exists now as an industrial base supportable at higher wages. A larger Portuguese industrial challenge will be to expand the capability to utilize the knowledge base that has been developed in creating globally innovative high value products (or subsystems) and thus add value (and establish effective connectivity) to the global network. It may be possible to fulfil this objective by moving 'upstream' in sectors where Portugal is already involved (for example, the automotive and aerospace sectors) but it may be more feasible to develop new innovations in sectors with smaller competitors and more potential growth opportunities (for example, medical devices).

Similarly, the first challenge to the Universities is to examine and improve their offerings relative to the needs of Portuguese industry. Such examination indicates only limited focus on product design, product development, innovation, leadership and entrepreneurship which the Portuguese companies see as essential skills for what they need to execute in response to their global networking challenges. These skills are an important guide in the curriculum development for EDAM's degree programmes. Closely coupled to the first challenge facing the Portuguese Universities is the challenge to develop effective global network connectivity. On an educational level, this entails being clearly able to deliver to students an outstanding educational experience that prepares them for the

modern networked society as well as or better than educational experiences that are possible to obtain anywhere else in the world. Of course it is very difficult to assess the capability of any educational system to achieve this outcome. One possibly important measure of this capability is the attraction of outstanding international students to educational programmes within a country. In this regard, the Portuguese educational system appears to be somewhat weak at least with respect to attracting students from throughout Europe.

QUANTITATIVE EXAMINATION OF PORTUGAL IN INNOVATION AND EDUCATION

Innovative behaviour has been recognized as a key factor in economic growth. The classical model of economic growth accounts for labour and capital. Robert Solow's neo-classical growth model expanded this model to include technological progress, which accounts for the economic growth that is not measured by using labour and capital alone. Innovation plays a large part in technological progress, but defining a good measure of 'Innovation' has been troublesome. Multiple factors are clearly involved and unravelling causation (vs. correlation) and particularly establishing the relative importance of various causes in various specific contexts is unsurprisingly difficult. We do not propose to untie this Gordian knot in this paper but instead to briefly examine some approaches to better understand the position of Portugal.

Since 2002, the Community Research and Development Information Service (CORDIS),

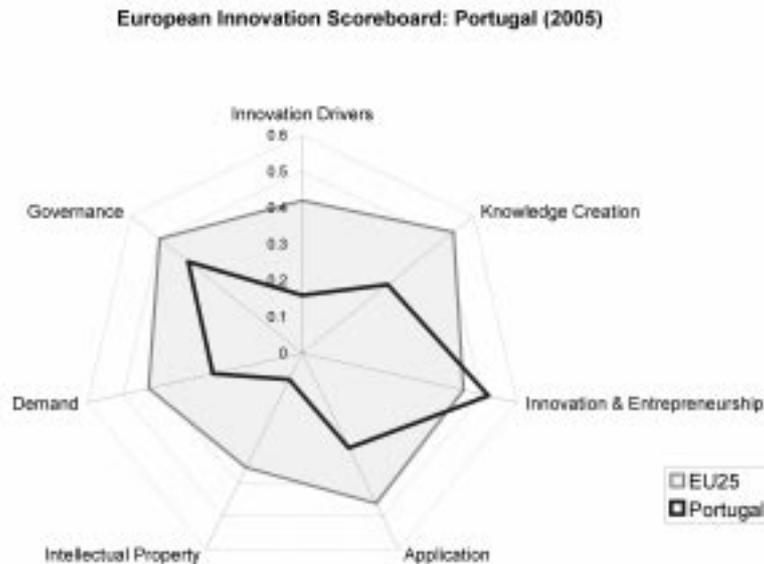


Fig. 2. European innovation scoreboard: Portugal (2005).

has published an annual European Innovation Scoreboard [5], which compiles many statistics relevant to innovation capacity for European Union member countries. CORDIS groups these statistics into categories and creates composite indicators to measure individual countries' performance in the areas of knowledge creation, application, etc. Figure 2 represents these index values for Portugal compared to the average values for the 25 countries in the European Union.

The different axes of the radar plot represent composite indices which CORDIS has created to capture elements of innovation. Thus, each axis is comprised of a simple average of the 5–10 metrics used in its construction without attempting to isolate important causes (or correlated effects). Therefore, any interpretation must be done with caution. According to CORDIS, Portugal's higher-than-average performance in Innovation & Entrepreneurship is due to firms acquiring innovations developed outside Portugal and introducing them onto the Portuguese market. The other indicators are low because of low rates of education, R&D spending, IP generation, and innovation demand. According to CORDIS, no other European countries share a similar pattern of strengths and weaknesses with Portugal. This last point is particularly relevant as it emphasizes the fact that each context is different and thus 'mass-produced' solutions are not recommended.

The World Bank published a list of factors relevant to innovation capacity in its report on *Closing the Gap in Education and Technology* [6]. The World Bank's list of 'Potential Benchmarks for . . . National Innovation Systems' is of particular interest in that it includes statistics it designates as 'antennas'. Among these measures are the number of students studying abroad and the interaction with foreign universities. While the 'Closing the Gap' report looks specifically at Latin Amer-

ican and Caribbean countries, the indicators it puts forth are applicable to national innovation systems in general.

Similarly, the Eurostat statistics agency lists indicators that it deems relevant to innovation and research [7]. These include measurements of educational attainment and population internet usage. The Organization for Economic Cooperation and Development (OECD) also has a list of indicators driving science, technology and industry [8]. However, these publications lack the analytical depth of the CORDIS and World Bank reports.

Educational attainment and expenditure on R&D are two common themes addressed in innovation statistics from CORDIS, Eurostat, OECD, and the World Bank. Figure 3 is a plot of Education Attainment vs. GDP per capita for OECD countries. The OECD's 'Years Education Attained' data are for those 25–64 years old, so it reflects each country's current workforce educational state which results from their education history of the past 40 years. This plot shows Portugal's GDP is relatively high considering their workforce's current level of education but also demonstrates the clear fact of the lagging status of Portugal for this important overall educational index.

The United Nations Education, Scientific and Cultural Organization (UNESCO) publishes a different educational statistic which they label 'School Life Expectancy'. This measure observes the current enrolment at each level of education and calculates the years of education that the average school-age child can expect to receive. This measure is a snapshot of the current state of education that does not reflect a country's educational history. Figure 4 plots School Life Expectancy versus GDP per capita for 2004. This plot shows that the life expectancy of schooling does not correlate at all with GDP as one would expect

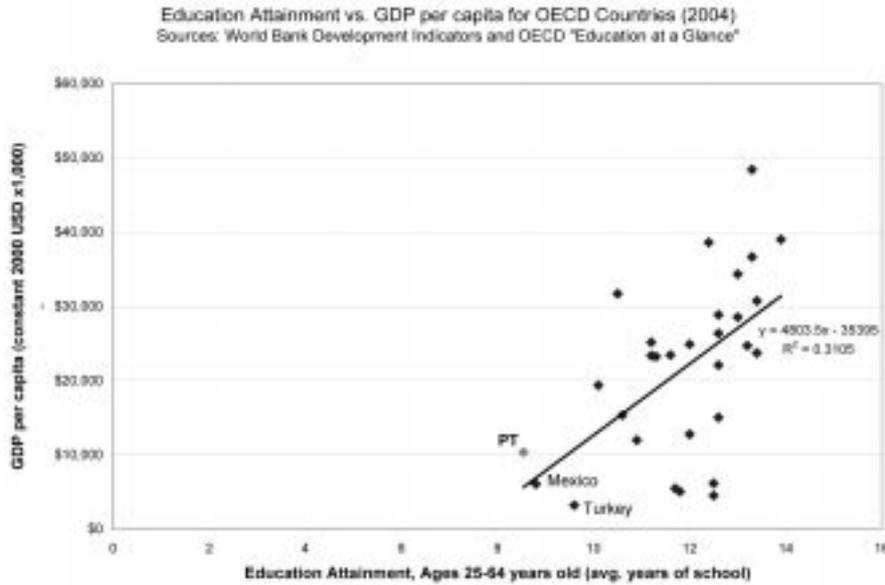


Fig. 3. Education attainment 25–64 vs. GDP per capita (2004).

because if anything it predicts future educational attainment and not that which affects current GDP. However, to the extent it does adequately predict future educational attainment, Portugal's school life expectancy is much more competitive (than its current attainment-see Fig. 3) with its OECD peers. This may bode well for the future of PT economic performance but one can note that PT may remain on the low side of a much more 'bunched' set of comparators.

The proportion of a country's population with science and engineering degrees is of particular interest in a paper concerning engineering education. Figure 5 plots the S&E graduates per 1,000 inhabitants versus GDP per capita. There are three points worth noting relative to this figure. First,

while there is again a clear correlation between this metric and GDP per capita it is not as strong as that found between GDP and the overall educational attainment of a country's population. Second, we note that Portugal is again lagging in this indicator relative to the OECD comparator countries so increasing engineering and science graduates seems a viable strategy for Portugal. Third, we note here that Portugal sits 'below' the line in this figure and thus one might very tentatively conclude that Portugal has not yet learned to effectively utilize the technically educated portion of its workforce.

A few other elements known to affect economic development were also examined. However, in one case (Net Foreign Direct Investment), a negligible

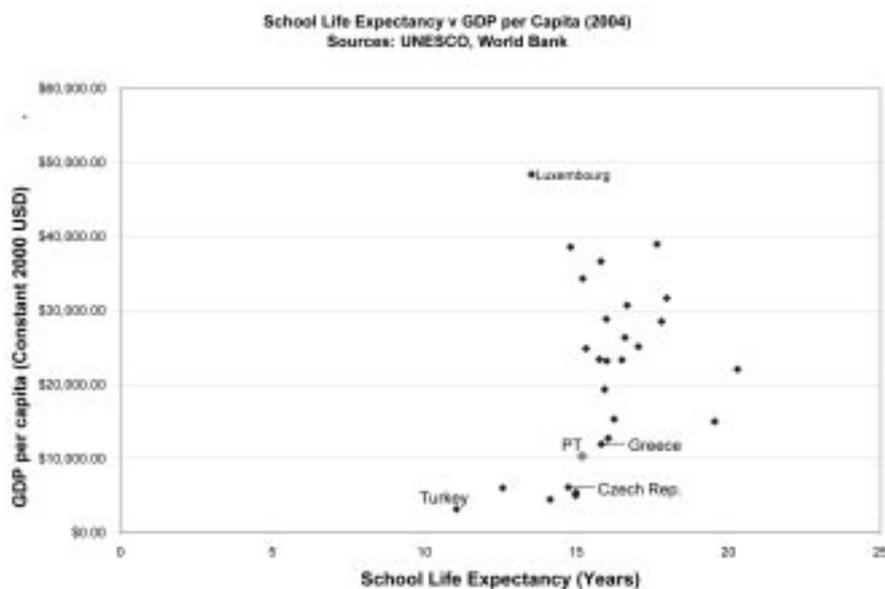


Fig. 4. School life expectancy vs. GDP per capita (2004)

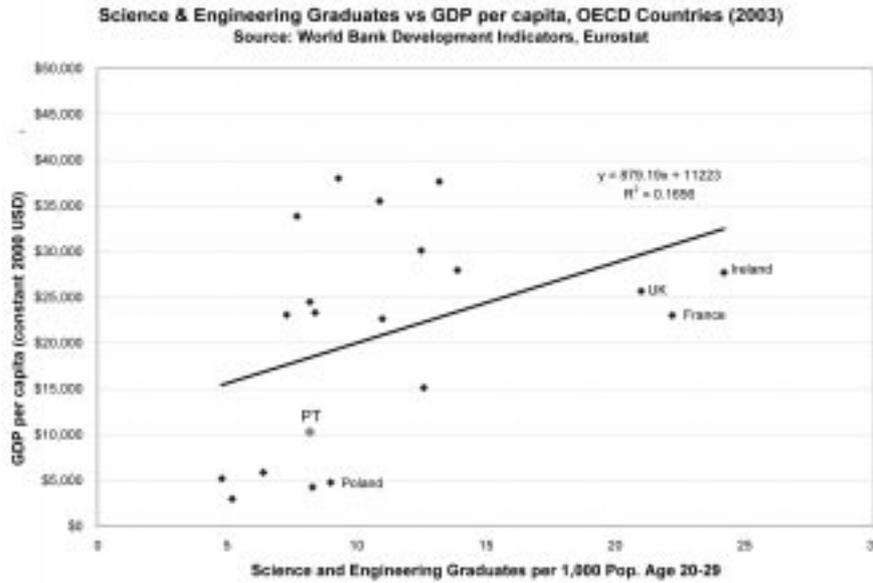


Fig. 5. Science & engineering grads vs. GDP per capita (2003).

effect (even counter to the normally assumed direction) is found in the data we examined. For gross expenditure on research and development (GERD), including public and private spending, a strong correlation with GNP is found as shown in Fig. 6.

The data in Fig. 6 are very clearly correlated (but the direction of causation may be debatable) and show Portugal lagging the OECD comparator countries. We note that the ‘low-cost’ manufacturing strategy initially followed by Portugal would be expected to result in low privately funded R&D spending. Strategies that increase the national level of product development (the dominant activity in privately funded R & D in countries such as the US) would be one way to improve Portuguese standing in this metric.

THE MIT-PORTUGAL PROGRAMME

The MIT-Portugal Programme is an ambitious initiative addressing educational and research activities developed by collaboration between MIT and a selected group of Portuguese (PT) Universities. The programme consists of four focus-areas: Biotechnology, Sustainable energy systems, Transportation system and Engineering Design and Advanced Manufacturing (EDAM).

EDAM is specific partnership between MIT and three PT universities: Universidade do Minho; Faculdade de Engenharia da Universidade do Porto and Instituto Superior Técnico, involving also several research and engineering centers. The EDAM agenda was developed in clear recognition of the above discussed status of the PT industrial

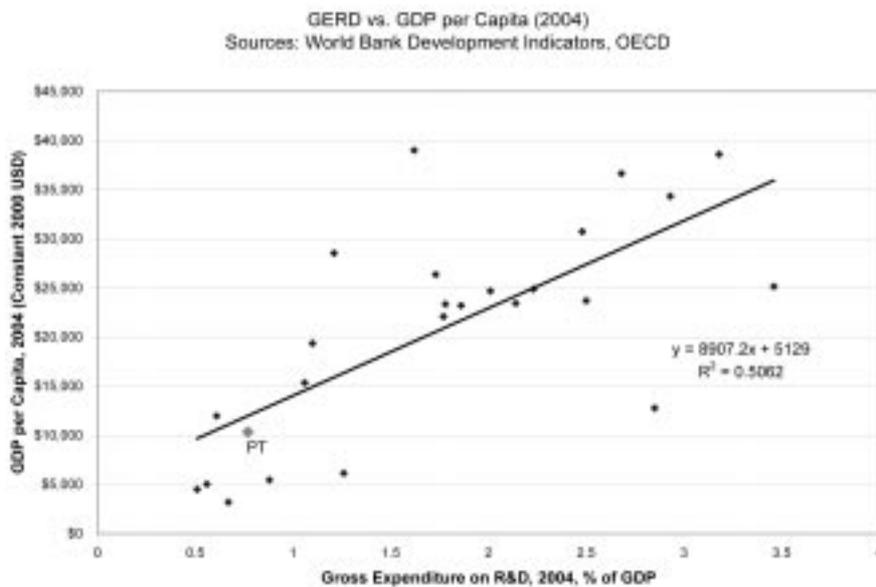


Fig. 6. GDP per capita as a function of R&D spending.

and PT innovation systems. In particular, an objective resulting from the status we just reviewed is strengthening of the educational system for developing superior human resources which will enable PT industry to move ahead on their respective value-chains. A second objective is to foster the participation of the educational system in the national innovative system. To allow some initial focus on specific industrial interaction, three industrial sectors were selected as preferential targets: automotive, aeronautics and medical devices.

This framework and the initial assessment performed by the EDAM team resulted in the following mission statement:

To develop a new educational engineering paradigm in Europe, with high quality research closely linked to novel curricular programs, to promote a new entrepreneurial attitude towards knowledge-based manufacturing and competitive product development.

Following the mission intent, a specific need and the opportunity for a new type of post-graduate education programs based on an integrated learning education approach, was identified. This approach involves bringing together science and advanced technology for product development within a social and economical context. The lack of such context appears at least as prevalent in Portugal (and for most other European nations as

well) as it has been found to be in modern engineering education in the United States [9, 10, 11]. Interactions and interviews with Portuguese companies that are working with the EDAM faculty have uncovered very similar findings to those published in US based surveys from the 1990s [10, 12]. The US has had a decade of experience with the ABET criteria that is moving the engineering educational system to correct such deficiencies [10, 13] but EDAM is among the first attempts to address the problem in Portugal. Thus, the programs being developed as part of the EDAM initiative are focusing upon leadership and other behavioural aspects of engineering education. Moreover, the new programme's attempt to assure the promotion of intellectual and risk taking challenges, by the development of a provocative attitude in the students, inducing continuously looking for new and better products and technologies enabling a knowledge-based, learning society. The foundations of the new programmes are based upon teaching design creativity [14] within the context of product development [15] that can be implemented.

These objectives are expected to be fulfilled through two main types of actions: education initiatives for human resource development (HCD) and educationally and industrially coupled research (ECR).

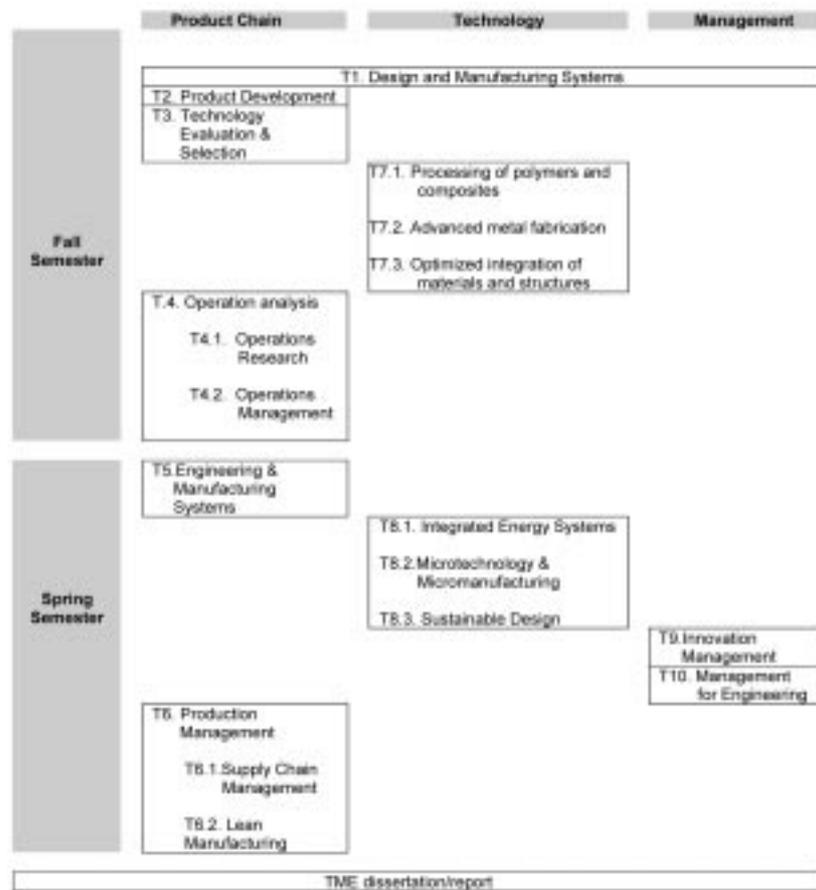


Fig. 7. The TME curriculum.

HCD involves an extensive list of actions for training and exchanging PT faculty and researchers and for joint curricular development. However, the core initiatives are the two post-graduate programmes being designed and developed under the MIT-Portugal Programme:

- Advanced Course: Technology Management Enterprise (TME);
- Ph.D. programme: Leaders Technical Industries—Europe (LTI).

These programmes will be launched in September 2007 and the respective curricula are presented in Figs 7 and 8. Both programmes will be a joint degree (or diploma) from the three Portuguese universities involved and will have joint faculty with MIT and Portuguese professors from all three universities. All programme activities including all courses will be in English.

TME is an advanced study course leading to a 3rd Cycle of High Education Diploma (this is a relatively new Bologna designation for a post-master level course), requiring a learning effort of 90 ECTS (European credit system). The objectives of the programme are to train intensively technical managers for product development and production systems; and to develop human resource competences for bridging complex technical and management issues under a demanding production environment. It is to be noted that the backbone of this curriculum is the Product Development and innovation activities.

TME will target as students technical staff of Portuguese and European companies (with an engineering education) aiming at developing a career in technical or production management, with 2–3 years of practical experience. The typical educational background (5 years) will be mechan-

ical, materials, polymer, electronic, chemical and industrial engineering. Industrial experience of candidates will be a preferential selection criterion.

It is intended that TME graduates will be capable of leading multidisciplinary teams in product development and manufacturing operations to address a multitude of challenges in engineering design and manufacturing, namely: innovative product development, advanced processing / fabrication solutions, optimization of production processes under an integrated perspective of the product cycle.

LTI is a doctoral programme including a curricular part (Table 2, Fig. 8), two industrial internships and a research thesis. It is viewed as a novel doctoral programme promoting both deep and wide capabilities in product development, research and innovation. The objectives of the programme are to train knowledge-based leaders for technologically strong companies, enabling a new European paradigm in managing product development and production systems, supported by a doctoral level education. Furthermore, LTI aims to develop human resource competences fostering the innovative application of new knowledge in successful products and/or processes.

LTI will target recent graduates in engineering aiming at developing a career in technical or production management, with 2–3 years of practical experience. The typical educational background (5 years) will be mechanical, materials, polymer, electronic, chemical and industrial engineering. As with TME, industrial experience of candidates will be a preferential selection criterion. LTI graduates are intended to be capable of: leading multidisciplinary teams addressing new and complex challenges in product development and manufacturing operations; planning and

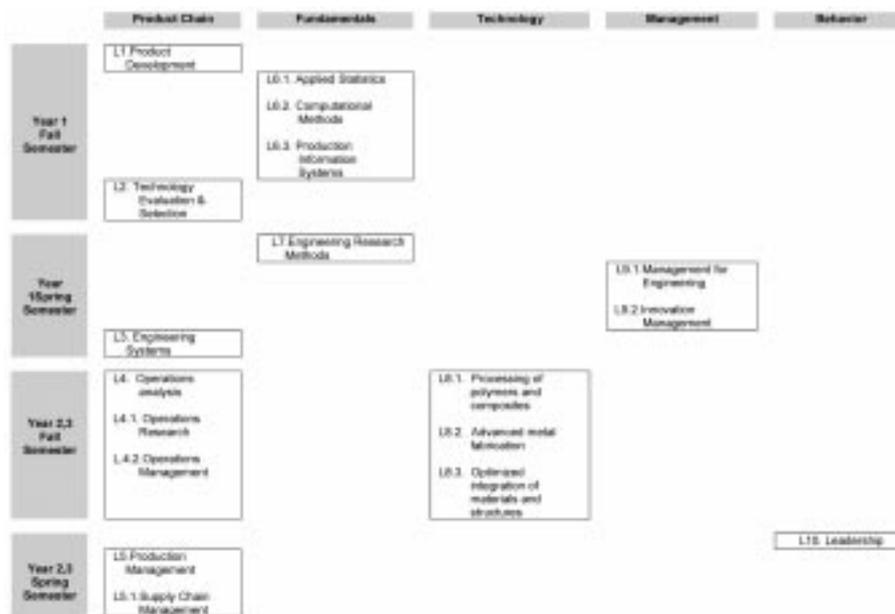


Fig. 8. LTI curriculum.

managing innovation strategies of technological-based companies; and to develop and implement research programs under industrial environments.

The curricular parts of both programmes are assembled upon a clear backbone of courses addressing the product development chain from the conceptual stages to the management of manufacturing operations and of the supply chain. A variety of complementary elective courses covering related technical areas are also part of the curricula design. These will be selected according to the previous education and experience of the student.

Students of TME and LTI will be a major element in developing the research (ECR) initiative as will the EDAM industrial partners. This mode of prioritization of the research is being followed in order to attain the focus area goals in terms of innovative, globally-appealing curricula and innovative opportunities for the larger research initiatives with possible short-term impact. Numerous potential opportunities for research projects have been identified and grouped in strategic research topics, namely: design for function and performance; design for manufacturing; eco-design; supply chain management; design for pleasure; mobility concepts; aeronautics solutions. The initial small set of research projects are being launched in 2007 concurrently with the educational programmes.

In the longer term, the TME and LTI programmes will be taught by Portuguese faculty without MIT participation but more importantly, the capabilities developed through these programmes are expected to be diffused within the Portuguese educational system. While this definitely includes other universities, it is also expected to involve moving courses on product development and engineering design into earlier parts of the engineering educational process as described in [16, 17, 18].

CONCLUDING REMARKS

The overall issue of effective connectivity in the globally networked world challenges an entire society. The contribution of one programme such as the EDAM initiative or the total MIT-Portugal Programme is therefore quite limited in its ability to be seen as the solution. The focus of EDAM is the development of a new educational paradigm that ambitiously attempts to promote a new entre-

preneurial attitude towards knowledge-based manufacturing and competitive product development. Although this goal is obviously aimed at critical issues in moving Portugal forward, the challenges of moving such initiatives throughout the Portuguese industrial and educational systems are formidable and involve reform activities that go beyond the purview of the MIT-Portugal Programme. The EDAM efforts are also attempting to develop the new educational programmes in such a way as to eventually attract globally competitive students to Portuguese universities. Although the requirements for achieving this goal are as yet unclear, if it is reached, one possibly important effective network connection will be achieved (at least for that part of Portuguese educational system that reaches this status).

Clear evidence was shown above for the value of improving the Portuguese standing in regard to total education attainment. Some potential value in improving both the number of technical graduates as well as utilization of these engineering/scientific graduates was also shown. It is possible that indirect effects of the MIT-Portugal Programme (resulting from use by Portuguese faculty of the skills developed in TME and LTI and from activities involving MIT personnel in secondary and lower schools) may aid Portugal in making progress relative to these issues. We have also demonstrated that Portugal is lagging in private R & D spending. Although this will not be directly impacted by the EDAM initiative, if more effective PT product development results from the education and research efforts, we might expect increases in R & D spending, but again this will only occur with widespread diffusion of capability which remains beyond the MIT-Portugal Programme purview. Despite the lack of direct economic growth, evidence supporting the focus on design, creativity, innovation and product development that is the main intent of our efforts, we remain very confident of the benefit of such focus to a society such as Portugal in the globally networked world we now all live in.

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