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Orienting engineering education towards innovation, entrepreneurship, and industry partnerships

The case of the MIT-Portugal Program

Abstract

Engineering education has always served as a close nexus between academia and industry, and as a strong determinant of a country’s innovative and economic performance. As many developed countries are struggling with the loss of low-cost manufacturing to global competitors, governments regularly turn to their institutions of engineering education to facilitate the transition into an innovation based economy and move up the value chain.

This paper discusses how engineering education in Portugal is being locally transformed with the help of a strong international collaboration. As part of a larger process of educational reform, the MIT-Portugal Program (MPP) has gathered the country’s leading institutions in an innovative education and research consortium centered on the engineering systems paradigm. MPP has employed a wide range of policy tools to re-orient engineering education in some key areas more towards innovation, entrepreneurship, and industry cooperation. These tools include:

- The creation of 7 new educational programs targeting 4 strategic focus areas in the field of engineering systems. Each program includes mandatory components of innovation, entrepreneurship, management, and leadership skills, and features innovative curriculum design based on modularized term structure, lab and industry rotations, and the recruitment of a highly specific student body with strong industry propensity.

- A focus on internationalization of education and science, raising the percentage of international students to almost 40% (four times higher than comparable Portuguese graduate programs), and fostering international mobility and outreach.

- Extensive networking between groups and institutions, paired with a high degree of student and researcher mobility, allowing students to benefit from the country’s best educators and research labs, intensifying communication and collaboration, enlarging individual scientific networks, and creating critical mass in research power.

- Access to an associated network of 50+ industry affiliates, involving industry broadly in student theses and lecturing.

The paper presents the results of multiple surveys to demonstrate how the program, now in its final year of the first 5-year funding phase, has yielded important and visible successes in overhauling engineering education in key areas for Portugal’s future. MPP is well on its way to becoming the first truly international Portuguese engineering program in terms of networking, competitiveness, and student attraction, and could serve as a model strategy for Portugal for addressing broader challenges at the intersection of engineering education, research, and innovation. Moreover, the Program trajectory holds important lessons for other countries trying to prepare their traditional engineering education with a greater degree of industry orientation, an innovation-prone ecosystem, and a culture of entrepreneurship.
Introduction: The birth of the MIT Portugal Program

In the pursuit of global competitiveness, governments around the world have repeatedly turned to their institutions of higher education for answers and novel strategies. This focus on education follows the insight that for post-industrial societies the primary source of economic growth has shifted from classical factors of production like capital and natural resources towards knowledge, skills, and their translation into technological innovation. Those countries which have lost their low-cost manufacturing and competitive advantage to rising Eastern European or Asian competitors are trying to close innovation gaps and catch up with the world’s leading economies 1,2,3,4,5,6.

Engineering education in particular has often served as a proxy for national innovation capacity and economic performance, and hence one of the major levers for reform. Primarily, engineering education provides the human resources base on which the national innovation system is typically founded, i.e. the education and training of future generations of engineers. Secondly, engineering departments are often a major source of technological knowledge accumulation and a center of research and development (R&D), particularly when research-intensive industries are scarce. Thirdly, higher average skill levels allow firms to rely on more sophisticated technologies, increasing productivity through “directed technological change”7. As the 2003 World Bank report Closing the Gap in Education and Technology summarizes: Advancements in the national education systems and in innovation system go hand in hand – if this is not the case, a country will “remain in a trap of technological stagnation and low growth” and find “a high proportion of their educated emigrate”1.

Furthermore, around the globe schools of engineering have become significant economic players. Engineering departments at MIT, Stanford, or Caltech are a main source of innovation and technology emergence of their region, and significant contributors to local and national welfare 8,9. Accordingly, current theories of innovation assign an active, quasi-entrepreneurial role for universities in the national innovation system (see e.g. 10). This global shift towards an entrepreneurial university paradigm has led to a re-thinking of engineering education along the lines of innovation, entrepreneurship, socio-economic systems and university-industry linkages.

In 2005, the Portuguese Ministry of Science, Technology and Higher Education (MCTES) invited the OECD Directorate for Education to evaluate the performance of tertiary education in Portugal 11. The review found that there was no “formal strategic higher education planning in effect at either the national level or the institutional level,” and that Portugal should take steps to “build excellence” and better integrate the “the tertiary sector in the economic, social and regional life of the country.” Finally, the report emphasized that the main point of reference for Portugal continues international, and mainly to be “whether Portugal is performing well in comparison to its European partners.”

In 2006, the Portuguese government launched the MIT Portugal Program (MPP) as the forerunner of a series of international collaborations to foster internationally competitive engineering education and research in Portugal, and serve as an incubator for change in the Portuguese system. MPP sits visibly as part of a larger reform agenda built around the ‘National Action Plan for Growth and Jobs – PNACE 2005-2008’ 12 and the ‘Technological Plan’ 13, and fits well into the strong commitment of the Portuguese government to a gradual build-up and
outward-orientation of the national science, education and innovation systems. The goal of the MPP is to demonstrate that a “strategic investment in people, knowledge and ideas” can have a positive, lasting impact on the economy by addressing key societal issues through quality education and research in the emerging field of engineering systems.”

MPP operates a consortium that links a single high-profile U.S. research university – MIT – with a whole segment of the Portuguese HE and research system, including 8 schools of engineering, science and technology and 20 research centers, as well as government and industry from Portugal (cf. Fig. 2-6). The program gathers 236 Portuguese faculty and over 50 faculty from MIT (plus administrative staff), and led to the creation of 23 new faculty positions and 8 new post-doc positions in Portugal. With a budget of 59 M€ (80 M$), the program enrolls or has graduated at total 425 graduate students at Portuguese institutions, plus about 140 graduate students who receive research funding at MIT.

This paper discusses major educational outcomes of MPP Phase 1. The presented results draw from three sources: (1) an annual comparative student survey that covers educational practices, student research, networking, industry linkages, and program administration, and was carried out with approximately 100 MPP students and a reference cohort of 200 non-MPP students enrolled in Portuguese graduate programs in engineering; (2) a series of 20 semi-structured faculty interviews, including faculty both inside and outside MPP; and (3) a variety of statistics obtained from the program coordination office. The paper will discuss the program outcomes in the context of Portugal’s challenges in engineering education, and establish how these outcomes are benefitting the system as a whole.

Challenges to engineering education in Portugal

Portugal looks back at a proud university heritage, with the University of Coimbra dating back to as far as 1290. The modern history of Portugal’s education system, however, carries the marks of a half-century of dictatorship until 1974, after which the country has found itself struggling with insufficient access to higher education, inherited structural deficiencies, a comparably low trust in governmental leadership, and modernization delays up to the present day.14 Partly as a result of these historical circumstances, Portugal has been lagging behind in key indicators of education and technology in comparison to its European neighbors and OECD peers for most of the years since 1974.15,16,17.

The elitist system of the dictatorship era was followed by an era of rapid massification. Portugal’s tertiary cohort has increased from 30,000 in the 60s, to approximately 400,000 students in 2000. Tertiary education attainment of 20 year-olds has increased by 10% from 2005 to 2008 alone, including now a third of this age group comparable to EU average (though still less than some leading industrial nations).18 On the downside, the vivid expansion has led to a stark divide between a highly educated and flexible young generation that compares favorably in terms of OECD standards, and a majority of the working population with very low education attainment and few advanced science degrees, leading to a “dual society” (ibid.). Furthermore, there is a need for the Portuguese system to better include non-traditional groups of students such as older (mid-career professional) students or internationals, who are generally viewed as a key ingredient for excellence in tertiary education. The decade-long necessary focus on domestic
access and equity has also delayed the emergence of strong national research universities of international rank and with innovation impact. It has been suggested that Portugal should realign its science funding to reward excellence at universities, to free productive research time of faculty and graduate students in inefficient curricula, to involve industry in teaching and curriculum, internationalize the student and faculty body, and to address “faculty inbreeding, career structures and related incentives as hampering factors preventing a faster development of the university research base”. The literature on competitiveness indicates that for a small country like Portugal, this excellence and competitiveness may realistically be attainable in a few key areas of specialization only.

On the whole, human capital is still “inadequate to allow rapid adjustment to the changing international environment” and move Portugal up the value chain. Although Portugal attracts a relatively large share of its students into the sciences and engineering, the overall number of advanced research degrees produced per annum remains critically low, and so does the number of workers with advanced research degrees in industry. After its integration into the European Union in 1986, Portugal has increasingly diversified its economy, creating a rapidly expanding service sector. Many formerly state-controlled companies have been privatized, including the financial and telecommunications sector. However, Portugal’s exports are still dominated by agricultural and food products, textiles, cork, chemicals, oil products, paper, as well as some machinery, witnessing a lack of high-technology and high-value added goods. At the same time, the country is losing its low-cost manufacturing base to Eastern European and Asian competitors, and has been facing increasing pressure to foster R&D-intensive industries at the basis of its economy. In particular, there is a need to address a persistently large gap between universities and industry, as well as other “economic, social and regional” stakeholders in the country. Portugal should facilitate interaction and permeability between universities and industry, and train scientists and engineers in innovation management, entrepreneurism and industry-related skills (ibid.).

Portugal’s higher education system is also subject to pan-European reform pressures. For example, the Bologna Process requires re-structuring of existing educational programs in Europe to promote international mobility, visibility and compatibility. Bologna has led to the creation of a whole new sector of graduate programs (the so-called Bologna 3rd cycle programs), in which universities can set new, competitive benchmarks in the European higher education area. The Lisbon Agenda, on the other hand, defined a series of innovation and technology goals on EU member states to foster economic growth, competitiveness, and employment in knowledge-societies. With an explicit focus on innovation-centered and employment-relevant education, it has been an important trigger for national university reforms. MPP must be understood as a response to both the Bologna Reforms and the Lisbon Strategy.

In summary, MPP must be understood as a reform strategy addressing the following challenges:

- The promotion of excellence and competitiveness through the creation of strong graduate programs in engineering and science to address the lack of human capital with advanced scientific degrees
- The internationalization of Portuguese education through the recruitment of international students, the establishment of cross-country collaborations, and the utilization international standards to benchmark research performance.
• The orientation of engineering education towards entrepreneurship and innovation through the involvement of external stakeholders, and the establishment of industry-university linkages.
• The creation of critical mass in research and education through the clustering of competencies around the Engineering Systems paradigm, and the promotion of dense networks of national researchers and institutions.
• Support of ongoing reform processes in Portugal and Europe.

The MIT Portugal as a response to challenges in engineering education

Creating focus areas in engineering systems and re-designing engineering curricula

MPP’s educational programs were designed to purposefully break with the Portuguese tradition in engineering education in many ways. MPP education is centered on the engineering systems (ES) paradigm that addresses economically and societally highly relevant engineering issues from a trans-disciplinary systems perspective, involving engineering, management, social sciences. ES naturally emphasizes connections between university research and industry, particularly with respect to the place of large-scale engineering systems at the heart of economic and private sector interests. In contrast, Portuguese faculty report the traditional engineering education in their country to be rather “narrow” and “very technical,” with limited socio-economic contextualization and industry-geared problem-solving.

MPP has targeted four focus areas for education and research: Sustainable Energy Systems (SES), Transportation Systems (TransS), Bioengineering (BioE), and Engineering Design and Advanced Manufacturing (EDAM). Each of the four focus areas involves at least three Portuguese universities plus MIT, and involves multiple industry partners. The four areas were identified during a 1-year assessment period by the Portuguese Ministry of Science, Technology and Higher Education (MCTES) in coordination with MIT as strategically important for Portugal’s future with a high chance of international competitiveness. The confinement to four focus areas stands in contrast to a Portuguese equity tradition university funding, which has often lead to a sub-critical dispersion of funding across many fields and places.

The four focus areas have created a total of 7 new graduate degrees, 4 Doctoral programs and 3 Advances Studies/Masters programs, whereby awarded degrees in conjunction by all participating Portuguese universities. In addition to their Portuguese degrees, MPP graduates receive a certificate from MIT. All MPP education programs feature follow an innovative curricular design without precedence in Portugal, drawing largely from MIT practice in terms of curricular structure, course contents, and teaching/learning methods. For example, all education tracks include mandatory components in the economic and business aspects of engineering, as well as training in meta-disciplinary skill sets such as innovation, entrepreneurship, management, and leadership. MPP courses are taught in English (even by Portuguese faculty in front of an entirely Portuguese class) and are often co-taught by Portuguese and MIT faculty, whereas MIT participation occurs through teaching blocks by visiting faculty or through video lecturing.

For two focus areas, MPP semesters are structured in a modular way and largely independent of the regular Portuguese academic calendar to facilitate the specific learning goals and multiple
institutional involvement of the program. For example, the BioE focus area curriculum is based on an intense, fast-rotating scheme of 2-week modules (c.f. Table 1). Throughout their term, BioE students rotate between the various universities in Lisbon, followed by the universities of Minho and Coimbra, and conclude with two 9-week lab rotations all over Portugal. This mobility gives students access to the best teachers in the country, helps them build critical research networks among otherwise rather isolated groups and department, and contributes to the formation of knowledge integration communities.

One highlight of the curriculum is the ‘Bio-Innovation Teams’ course, which is an adaptation of the popular ‘i-teams’ at MIT. In this class, students assess the market potential and develop business plans for emerging technologies in cooperation with companies. A recent study by Dori and Silva evaluated the learning outcomes of the MPP modular course structure, concluding that it has raised student learning compared to regular term structure, and has been instrumental for incorporating hands-on activities and students-faculty interactions.

Many MPP students spend extended periods of time at MIT. MIT hosts up to 33 graduate students per year, whereas the duration of the students’ stay at MIT varies between a few weeks and up to 2 years. During that time, students perform research at MIT labs and audit courses. These students continuously work with research supervisor on both sides of the Atlantic, which consolidating in effect the new transatlantic linkages between scientists at MIT and in Portugal. International mobility in MPP occurs mostly under a project-based, need-oriented and often short-term framework, which underscores the professional and research-centered character of the program. Students focus on specific research objectives and thus obtain an impression of a life as a researcher rather than a mere attendee of classes. Time spent at MIT is found to be one of the key sources of influence with large benefits for student ambition, connectivity, research experience as well as an increased awareness that “Portuguese universities can indeed play ‘premier league.’”

**Recruiting top international and national students**

MPP features, for the first time in Portugal at this scale, a proactive student recruitment policy (both nationally and internationally) in conjunction with a program-internal selection process. The number of applications to MPP has been increasing consistently over the years, with this year’s PhD admission rates of the focus areas of 17.8% for EDAM, 27.8% for BioE, 15% for TrSys, and 21.1% for SES. Averaged over the first four years of MPP’s existence, the total admission rate is below 25%, comparing favorably with renowned international programs.

Internationalization of the student body has been a central concern for the program. Portugal has traditionally been a sending country, and is currently re-setting its strategy to become a receiving country and benefit from the immense cohorts of mobile, bright, flexible students, much like Australia, Canada, Ireland, Spain or Israel have done before.

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1 The actual number varies from year to year and has consistently been higher, including Portuguese students who have been funded by separate, i.e. non-MPP scholarships by FCT. Furthermore, a number of Portuguese students who are not part of MPP have benefited from the newly established links and come to MIT as a result of the program.
Figure 1 gives the percentage of internationals in the MPP entering cohorts since 2007. It can be seen that the value has been rapidly rising, attaining a value of 38% for the past two years, as opposed to an average of 9% for comparable Portuguese graduate programs in engineering.

<table>
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<tr>
<th>Course Module</th>
<th>Description</th>
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<tr>
<td><strong>Core Courses</strong></td>
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| M1. Introduction to Technological Innovation | ● Product identification and design  
● Market scanning and data collection  
● IP and licensing strategy  
● Business model; Strategic management of technology and innovation |
| M2. Bioprocess Engineering Course | ● Fundamentals of growth and metabolism, transport phenomena  
● Bioreactor design  
● Measurement, modeling, monitoring and control |
| M3. Cell & Tissue Engineering Course | ● Cell development biology, stem cells for tissue engineering  
● Biomaterials and delivery of growth factors and other molecules  
● Patents |
| M4. Computational Biosystems Science & Engineering Course | ● Analysis of high-throughput data  
● Differential equation modeling  
● Sequence and structural bioinformatics |
| M5. Laboratory Rotation I | ● Experimental and research lab techniques in bio-engineering  
● Communication, cooperation and research skills in research environments |
| M6. Laboratory Rotation II | ● Experimental and research lab techniques in bio-engineering  
● Communication, cooperation and research skills in research environments |
| M7. Bio-innovation Teams (with seminar) | ● Market research and technology-based entrepreneurship  
● Interaction with venture capital firms, entrepreneurs and researchers from different companies/research labs/technology developers, and establish communication with the same groups  
● Promotion of market-oriented projects in bioengineering |
| **Elective Courses** | |
| E1. Biomedical Devices and Technologies | ● Emerging bio-nano topics (synthetic biology and others)  
● Microfluidics and lab-on-a-chip systems, cell-chips, carbon nanostructures, self-assembly  
● Materials for biomedical applications  
● Biomineralization, bioactivity and biomimetics, biocompatibility |
| E2. Nanobiotechnology and Biomaterials | ● Hybrid human: human augmentation and smart suits  
● Active prosthetics, neural prostheses and neuromorphic control  
● Rehabilitation technologies, human-robotic systems |
| E3. Neuroscience: Molecular to Systems Neurobiology and Brain Diseases | ● Engineering genes and genetic therapies  
● Stem cells |
| E4. Principles and Practice of Drug Development | ● The pharmaceutical industry and the drug development process  
● Basic science: discovery innovation, emerging technology, toxicology |

Table 1 Educational Curriculum for the MIT-Portugal EDAM focus area
The surveys indicate that MPP attracts an excellent student cohort. Some Portuguese faculty describe the difference between MPP students and their non-MPP counterparts as “huge,” and confirm that the program gathers “the best students in their field” and beyond (i.e. from adjacent fields). Faculty also observe a significantly higher level of ambition and motivation of MPP students than their non-MPP peers, which they describe as “contagious across the whole group.” MPP students are reported to show a greater degree of independence in their work, more precise achievement goals, and often a stronger commitment to work. This observation is in accordance with the self-reported workload of students measured in the surveys, where MPP Doctoral students are found to work on average 4 hours more per week than their non-MPP peers (44h as opposed to 40h), with a significantly smaller number of MPP students working less than 30 hours (Figure 2).
Interestingly, MPP student enter their graduate studies with much higher expectations towards their program than their non-MPP peers. Figure 3 shows self-reported student expectations when making their enrolment decision. Here, “0” means “not important at all” and “4” corresponds to “very important” to the enrolment decision. It can be seen that MPP students put greater emphasis on all the quality of education, the link between research and industry, internationalization of the program, the English language, and the employment prospects.

MPP students show higher industry and innovation propensity than comparable non-MPP students, particularly for the PhD cohort. The data indicates that a significantly higher fraction of PhD students in MPP have a background in industry work (both R&D & other), amounting to about 46% subtotal, as well as other private sector work of 32%. For the same categories, non-MPP PhD’s display values of 28% and 25% only. Together, industry and private sector backgrounds account for 78% of the MPP PhD cohort, as opposed to 53% for non-MPP, indicating a relative increase of almost 50% in the areas that are fundamental to MPP and the innovation agenda. Moreover, Figure 5 summarizes the self-reported student plans after graduation, indicating that MPP Doctoral candidates are more interested in working in industry than their non-MPP peers, and particularly for the industry partner of their MPP research. MPP students also show a higher likelihood to work as an entrepreneur.

It is interesting to look at the role of academia in both student experience and future plans. For work experience, the gain in industry and private sector experience for MPP students seems to replace mostly students who would otherwise directly come from academia (13% MPP as opposed to 25% in non-MPP). Equally, MPP PhD students are less prone to work in academia.
after graduation, indicating that MPP caters to less traditional careers in Portugal, where the standard expectation for Doctoral students is still an academic career.

Surveyed MPP faculty remark positively on the different and more diverse backgrounds of MPP students. The different backgrounds contribute to a noticeably broader perspective of students on their research, in accordance with the Engineering Systems teaching paradigm. On the contrary, faculty describe the ‘traditional’ (non-MPP) Portuguese engineering student as “extremely focused on technical matters.”
**Strengthening education linkages to industry**

MPP has built a network of 50+ industry affiliates with national and international companies. The program has taken a multi-level approach to involve industry in education and research. All curricula implemented by MPP have been strongly geared towards industry needs, innovation and entrepreneurship, and were often designed with industry input. Figure 6 shows that MPP students ascribe to their program a much higher industry and entrepreneurial orientation, a stronger education in economics and business, more contact on a working level with industry engineers and scientist, and course teaching by faculty from industry. Moreover, MPP students indicate that they think about their research more from an application perspective.

![Self-reported industry linkages (Doctoral students)](image)

**Figure 6** Student-reported industry linkages. The number “0” to “4” correspond to a scale from “strongly disagree” to “strongly agree.”

Faculty perceive the new courses introduced around the issues of innovation, entrepreneurism, management, and leadership as welcome, effective and unprecedented in addressing a general lack of training in these issues in Portugal:

“MPP definitely contributes to acquiring these skills. […] To my best knowledge, there is no existing PhD program in Portugal that has innovation in the curriculum, because they are focused on pure science. […] All the students give terrific feedback. It is really interesting to them to explore that different area.”

“We have the bio-teams course where we collect some technologies offered by the industrial affiliates, and then will have our students from the BioE […] divided into teams that will be dedicated to these technologies, and there will be a competition. At the beginning, it was hard to convince the industry affiliates to become in fact an affiliate to the program. But it is really interesting to see that after 2-3
years now we have industries and companies offering laboratory rotations to the students. In the first year, I couldn’t have imagined that, and now it’s reality.”

There seems to be general consensus that that the skill sets and goals put forth by this education component are tremendously important:

“Very important! I think this is something that is lacking in our courses in Engineering in Portugal. [...] They are not used to this.”

“Yes, this is definitely important. It has not existed in Portugal before, [and] it has been a major concern of the MIT-Portugal Program. We were aware that this was a lack of teaching. It was already on our ‘back mind,’ so to speak, but it was never implemented.”

“I think would be very important [...] for all the engineering schools to have some entrepreneurship at the PhD level. I think this is crucial.”

Students are expected to perform their thesis research in collaboration with an industry partner, ideally on a topic that was generated by the industry affiliate. For example, the EDAM program requires each PhD student to have an industry advisor in their doctoral committee. Several very positive examples of thesis collaboration have emerged in the past, including involvement with big national and international companies, which in some cases led to subsequent hiring of the student by the industry partner.

However, the challenge of establishing university-industry linkages in Portugal is not to be underestimated, and the industry component is generally taking off slowly. Faculty see the main reasons for the slow evolution in Portugal’s traditional lack of these linkages, whereby MPP is considered a “major paradigm shift,” with “substantial barriers” to be overcome in terms of communication, institutional boundaries, and the matching R&D interests and needs. Faculty remarked that MPP education and research has raised entrepreneurial spirit among graduate students, and was successful in reducing traditional barriers between universities and the private sector including industry lecturers in teaching. The surveys reveal that MPP fosters a more application-oriented engineering education approach, and promotes the non-academic job market to students. Interestingly, Portuguese faculty who are not affiliated with MPP broadly confirm the impression that innovation and industry relevant education has been lacking in Portugal, that the non-academic job-market has been much neglected in traditional PhD tracks in engineering, and that MPP can be instrumental in addressing both.

**Faculty training**

MPP puts a major emphasis on junior faculty. The program has hired 23 new faculty members on junior faculty positions to support its teaching and research activities. The surveys reveal a key role of these young faculty in establishing a new engineering systems teaching paradigm centered on entrepreneurism and innovation. Surveyed junior faculty confirm that their teaching has become significantly more geared towards innovation and management as a consequence of their involvement in MPP. MPP is perceived as a “drastic shift” compared to what these young faculty themselves experienced during their course of study.
“I am also in a learning process in the MIT-Portugal Program, in this new engineering approach of bringing together economic aspects, management, etc.”

“Probably after they finished their curricular part, and I have no doubts, the students are better prepared for issues of management than most of the teachers that are teaching them.”

The findings underline that the program has an enormous impact on these junior faculty. They report an observed “boost” in career opportunities, a drastic expansion of their scientific network, and important new inputs in their research. Conversely, young faculty seem to be more eager to explore and exploit the range of opportunities offered through the program, and more willing to try new methods and curricula. Mobility has been found a key driver of this change. MIT hosts approximately 15 Portuguese professors as visiting faculty each year, with varying lengths of stay between weeks and full terms. It has become good practice and a central part of the mobility scheme to audit MIT classes in order to gain a comparative perspective on teaching in MIT entrepreneurial ecosystem, and to potentially adopt these courses in Portugal.

**Networking and clustering**

Networking and building have gradually occupied the center of current European science and higher education policy, involving much industry-borrowed terminology such as “clusters of excellence”

A large body of literature suggests that scientists engaging in, and connected through, networks on show a higher average productivity (in econometric terms) than those working in isolation (see e.g.

MPP emphasizes networking and clustering in several ways – through joint degrees between the participating Portuguese universities, through nation-wide shared curricula, and through inter-institutional mobility, all of which did not exist before at a comparable level. In that, MPP breaks radically with traditional patterns of “isolation” and “competition” between Portuguese universities, groups and individual researchers. The surveys and interviews underline that the program is perceived as a decisive move towards clustering of competences.

“Networking is really important. Now we speak with people we were not used to, and we have to work together. Communication plays a big role here.”

“Now we know a lot more people, we know what they are doing, how we can interact in terms of research and in terms of teaching, and that was very positive.”

“The strongest point is collaboration and common production of both education and research. [...] It is a very effective way of improving, and I think this is maybe most positive element.”

“Without MIT and outside the MIT Program, [interaction and networking] is very small. This is a practice that MPP started – it is an achievement of the MIT Portugal Program. Before, the level of relation between the Portuguese universities was very very scarce.

Non-MPP faculty, on the contrary, still describe a Portuguese higher education landscape where few inter-university collaborations exist, and those that do exist are on an individual level and typically not institutionalized.
“There is no network that picks up the best and says ‘we should associate this one with that one.’”

“Portugal never had a program for cooperation inside Portugal. I mean, a real program. It’s senseless to cooperate inside the country at this moment, where there is no funding and bureaucracy is too much.”

The high degree of networking within MPP has been found positively correlated with a rise in communication and connectivity on the student level. MPP communicate more frequently about their research with all key interlocutors, including graduate students within their own research group, outside their own research group, and outside Portugal; as well as post-doctoral and senior scientists within their own research group, outside their group, and outside Portugal. MPP students also show a higher communication with prospective students, which points toward a high degree of program identification and to the possibility of alumni network building. Figure 7 shows representative results of this communication analysis for “Communication with graduate students outside student’s research group.”

![Communication about own research with: graduate students outside student's research group](chart.png)

Figure 7 Student communication about own research

Furthermore, MPP students are better connected to other research groups working on related issues. Figure 8 shows that a larger fraction of MPP students is connected to other Portuguese research groups, both in terms of awareness and actual contact. It can be seen that non-MPP students are slightly ahead in their awareness of foreign groups, which does, however, not lead to more contacts. This fact can be understood as a lower quality of student connectivity, i.e. the ratio of contacted groups to known groups, where MPP students are starkly leading (Figure 9). In other words, even though non-MPP students seem to know more international groups, MPP students have more contacts relative to the number of groups they know. One could argue that knowing about other groups per se does not constitute meaningful connectivity, and that only true interaction should count as an indicator of quality, which would underscore the importance of the MPP findings. This paper does not take a strong stance on the issue, but is content with pointing out the successes of MPP in creating high-quality networking.
When looking at the *average connectivity per person* (i.e. number of groups known to each student), the data shows that MPP students possess on average more contacts to Portuguese groups and also more contacts internationally (Figure 10).

![Figure 8 Student connectivity I](image1)

![Figure 9 Student connectivity II](image2)

![Figure 10 Student connectivity III](image3)
Program spillovers

Given the focus of the program on specific fields and institutes, it is a tempting question to ask what MPP will do to Portuguese higher education as a whole. Given the above-discussed differences between MPP and its environment, it can be argued that MPP has indeed benchmarking quality for the Portuguese system with respect to orienting engineering curricula towards innovation, entrepreneurship, and industry needs; a competitive recruitment strategy with focus on internationalization; and strong educational and research networking. In fact, there is evidence that MPP education practices are already spilling over to the outside. For example, MPP faculty continue teaching other (non-MPP) classes at their institute, noting that their program affiliation has “significantly influenced” their teaching style, which is now more geared towards innovation and industrial problem settings. This has in turn create some pressure on other courses and faculty to adopt new approaches. MPP faculty report that they have been approached by their colleagues and asked directly about contents and methods. In some instances, there was also an explicit interest about the course evaluation system that MPP uses, and how it could be transferred to other classes.

Furthermore, there have been examples where MPP has already served as a blueprint for the design of new programs created at Portuguese universities (e.g. at Universidade Nova de Lisboa [New University of Lisbon]), partly due to the active involvement of MPP faculty in the formation process. Finally, MPP seems to stimulate the self-formation of excellence clusters in Portugal. For example, the University of Coimbra, which originally was not part of the Sustainable Energy Systems focus area, successfully engaged in a process of self-assessment and self-formation with the explicit goal to create an over-critical cluster and to participate in the opportunities provided by MPP. In 2008, two years into the program, faculty and leadership at Coimbra had created a cluster with critical mass, leading to the inclusion into MPP-SES.

Conclusions

The MIT Portugal Program was launched as an experimental strategy to re-orient Portuguese engineering education towards innovation, entrepreneurship, and industry needs in some key fields at Portugal’s leading institutions. This paper has shown how the involvement of an international partner has been instrumental in achieving this goal, and how the achievements are spilling over into the Portuguese system. The paper discussed interrelated strands of action:

- Introducing innovative graduate programs
- Fostering internationalization and mobility
- Encouraging networking and clustering
- Building industry linkages

The author would like to stress the radicalness of the changes that MPP inserted locally into the system. MPP’s modular term structure, innovation and entrepreneurship centered engineering education, faculty and student mobility, and forceful internationalization stand out in the present institutional environment. Without the involvement of an external partner, the necessary
momentum for changes of this sort could most likely not have been obtained. It is clear that changes of this magnitude will take time, and hence continuity matters for the program. The first five years of MPP have unlocked a great degree of dynamism within the institutional partners involved, including a substantial and necessary adjustment phase. It is unrealistic to expect that national education culture can be revamped within 5 years. The program must build on the current achievements and sustain its momentum during the second phase, to include the main lessons, strengthen the network, and spread the outcomes throughout the Portuguese system.

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