Tata Center for Technology and Design at MIT

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The Tata Center for Technology and Design at MIT

Abstract

This paper describes the Tata Center for Technology and Design at MIT, a new program aimed at creating high-impact, sustainable, and scalable technical solutions in developing and emerging markets through the rigorous application of applied engineering science and systems thinking. The program is funded by the Sir Dorabji Tata Trust and is based at MIT. The Center matches students and faculty to projects in India and offers training to enable them to create viable and appropriate solutions. Tata Center projects serve as the basis for graduate thesis work to address compelling social/technical/economic challenges. Each funded graduate student attends a weekly proseminar on development topics and spends significant time in India, pursuing a novel research project that addresses a development need and fulfills his or her degree requirements.

A core tenet of the Center is collaboration with stakeholders who represent each link in the chain from inception of an idea to implementation in the real world. This collaboration includes partnerships with small entrepreneurs as well as larger organizations that understand target markets and have a track record of scalable, sustainable success. Tata Fellows are taught how to engage the entire stakeholder hierarchy behind a technical challenge, from executives to engineers to manufacturers to distributors to end users, in order to understand the unique constraints and requirements each imposes on a solution. This paper includes descriptions of three representative Center projects: redesigning the Jaipur Foot prosthetic foot for mass manufacture, quality control, and to conform with international standards; creating low-pressure, low-power, off-grid drip irrigation systems for small-scale farmers; and developing a technology and systems strategy for materials recycling and pollution mitigation in an industrial district with many small and medium sized manufacturing firms.

Introduction

The Tata Center for Technology and Design[1] was launched at MIT in 2012 and is funded by the Sir Dorabji Tata Trust. The mission of the Center is to develop students, faculty, and curricula to create high-impact technologies and services for underserved markets that face severe resource and cost constraints. Participating graduate students, called Tata Fellows, can be drawn from any of MIT's five schools and focus their research on real-world problems rooted in the context of emerging India, with outcomes aimed at fostering enterprise and improving lives. Each Fellow's regular degree curriculum is complemented by periodic visits to India for on-site collaboration with project partners, participation in a weekly proseminar at MIT that includes student project presentations, lectures from subject matter experts, and discussions across a broad range of challenges in developing economies. Each thesis must contribute meaningfully to a rigorous concept-to-market design and implementation project that explicitly responds to an identified need.

Each thesis project is conducted under the supervision of one or more MIT faculty members. The Center acts as a matchmaker between MIT researchers and compelling social/technical problems by offering research grants and graduate fellowships, as well as facilitating connections to entrepreneurial companies and NGOs tied to developing communities and emerging markets. Sponsored researchers must work closely with stakeholders; these partnerships utilize the knowledge and experience of local organizations (including production and distribution capabilities of established companies) and add value to the development space by leveraging the scientific and engineering talent found at MIT. Successful projects will provide a basis for compelling, highly affordable commercial products and services in fields related to healthcare, energy, water, agriculture, mobility, buildings, and infrastructure.

The intent of this paper is to describe the activities within the Tata Center and how its structure is designed to train global engineers and facilitate the creation of high-impact technologies by leveraging relationships between MIT researchers and local organizations. Although the Tata Center is in its infancy and we do not yet have assessment data to support the efficacy of its programs, the strategies outlined in this paper may be useful to other institutions creating research and education programs in emerging/developing markets. This paper describes our methods for combining conventional technical curricula with experiential learning, collaborating with the entire hierarchy within stakeholder organizations, working with partners positioned to bring technologies to market, exploring developing and developed market opportunities for technology transfer, and using technology to create social and economic impact.

Training the Global Engineer

Along with creating high-impact technologies and solutions, the intent of the Tata Center is to train engineers who have a global perspective and who understand how to engage and generate solutions for developing and emerging markets. Each Tata Fellow is required to spend four to six weeks of the summer, as well as a portion of January during MIT's Independent Activities Period mini semester, working with project partners in India. Face-to-face interaction with stakeholders helps students develop tractable solutions appropriate to the Indian context. Such experiences also force students to better comprehend the myriad challenges behind problems that cannot be solved through engineering analysis alone. Technical innovation must be informed by user preferences, cultural norms, supply chain considerations, and government policies.

Time spent in India also gives the Tata Fellows a first-hand view of the economic opportunities in emerging markets. After graduation, these students will integrate into a global marketplace that is markedly different from the developed world-focused industry that has dominated since World War II. China and India are projected to have the first and third largest economies, respectively, by 2050[2], and combined with Brazil and Russia are forecasted to grow from 18% of global market capital now to 41% in 2030[3]. This new industrial revolution in emerging markets must support one billion+ new middle class consumers who demand products to meet their specific needs, and another billion+ people who make less than two dollars per day but require innovative technologies and solutions to rise out of poverty[4]. Market growth in India and other emerging economies presents tremendous opportunities for domestic firms like Reliance, Tata, and Mahindra, as well as US-based multinationals that want to expand their business while rekindling the US economy. Firms like General Electric have demonstrated that high-performance and low-cost technologies, such as ultrasound and electrocardiogram machines, can make a positive impact on emerging markets while also becoming disruptive innovations[5] in rich markets[6].

Tata Fellows can hail from any of the schools and departments at MIT. Diversity in backgrounds is encouraged, to facilitate cross-disciplinary learning and problem solving for both students and faculty. The Tata Center does not offer a degree per se. Rather, each Fellow must be admitted to a home department and complete its degree requirements for graduation while developing a Tata Center project. The Center and its faculty take great care to identify projects that represent opportunities to develop novel, publishable academic research, as well as make a significant and measurable impact in India and beyond. Tata Fellows will graduate with the honed technical skills that come with an MIT degree and a broadened perspective of how those skills can be used to affect positive change in developing and emerging markets.

The weekly Tata Center proseminar provides a base of common knowledge for all students and faculty in the program and serves as a forum for discussing research and building a social network for people involved in the program. The first hour often includes a lecture from a faculty member or guest with expertise relevant to the Fellows' projects, such as international development, economics, entrepreneurship, design of experiments, or innovation. Speakers are sought from MIT's faculty as well as from outside the Institute. Talks in the past year have included: Prof. Alex Slocum speaking about machine design research[7]; Prof. Esther Duflo speaking about development economics[8]; and Raj Melville speaking about supporting social entrepreneurship at the bottom of the economic pyramid through the Deshpande Center[9]. The second hour of the proseminar is often devoted to presentations by Fellows to update the group on their progress, and/or breakout sessions where teams discuss topics of common interest between projects.

The Tata Center supports curriculum and course development for classes that relate directly to its activities, including the development of new modules to existing classes that cover topics pertinent to development. For example, a new class will be called "Global Engineering," which will explore the marriage between rigorous engineering theory and user-centered, socioeconomic-driven product design that is necessary when creating technologies for developing and emerging markets. Each student team in the class will produce a proof-of-concept technology in collaboration with a partnering organization located in the developing world. Another new class will be called "Operations for Entrepreneurs," and will focus on development of operations capabilities in new organizations. Examples of established classes that will enrich their coverage of technology and design for development include Precision Machine Design[10], which focuses on the creation of medical devices; and Desalination and Water Purification[11].

Stakeholder Engagement

Tata Center projects are developed in collaboration with local Indian organizations to ensure that stakeholders have the opportunity to communicate the constraints and requirements that are critical to developing tractable, appropriate, scalable, and sustainable solutions. We seek companies, NGO's, and governmental organizations that have an established presence in India and a track record of successfully engaging projects' target markets and communities. The Center particularly seeks out relationships with established Indian industrial firms, as these companies know their home market and customers. Their production capabilities and distribution channels position them to quickly and broadly disseminate technologies that result from Tata Center projects. And since commercial firms operate on a for-profit model, they inherently have an incentive to leverage economies of scale, distribute their products as widely as possible, and be economically sustainable.

Typically, multiple stakeholders determine the success or failure of a project. Tata Center projects are structured to engage all of the stakeholders who represent each link in the chain of advancing an idea from inception to implementation in the real world. We stress the mentality of designing *with*, not *for* – that stakeholders are partners on the project and should be encouraged to articulate solutions as well as needs. The innovation process must start and end with end users, as they best understand problems in their own life that can be solved with a product or service, and they are the most qualified to judge the efficacy of a solution. In academically oriented engineering schools, projects are often focused on the ideation, invention, and experimentation stages of the design process. As such, technology-focused research tends to produce proof of concept prototypes that demonstrate viability of a technology but are probably not ready for production. In management schools, by contrast, projects often focus on solving marketing or supply chain problems for existing products, as opposed to optimizing both the product and the supply chain. To bridge these gaps, Tata Center projects are pursued in collaboration with researchers and partners with expertise along the entire value chain, from design to delivery.

One project that demonstrates stakeholder collaboration for design, development, manufacturing, and distribution focuses on redesigning the Jaipur Foot, a prosthetic foot distributed by Bhagwan Mahaveer Viklang Sahayata Samiti (BMVSS), the largest disability organization in the world in terms of providing assistive devices[12]. The Jaipur Foot is handmade by wrapping wooden and foam blocks with rubber and then vulcanizing. The process is time-intensive and leads to a large variation in product quality. BMVSS proposed a project to MIT to design an injection-molded version of the foot for greater uniformity in quality, reduced production costs, and reduced weight of the foot to meet international standards. The project team is composed of BMVSS, graduate and faculty researchers at MIT, undergraduate senior mechanical engineering capstone design classes at Arizona State University and Penn State University, Dow Chemical (which provides polyurethane for injection molding), and Pinnacle Industries (a manufacturing firm that makes other products for BMVSS).

BMVSS is providing a direct connection to Jaipur Foot users, who are frequently engaged to express feedback and suggestions for the new foot. Design requirements include the ability to squat, walk barefoot, and withstand long durations submerged in water – critical factors for success that would be hard to capture in modeling and mechanical performance testing. BMVSS also brings perspective on the medical, logistical, and financial factors associated with distributing prosthetics at scale. MIT is leading the research on designing a high performance, injection-moldable version of the foot that can meet or exceed the performance of the current Jaipur foot while reliably lasting 3+ years in the field. The students at ASU and PSU are contributing to the project in substantive ways that align with their experience level and semester-long time constraints, such as designing test fixtures to characterize the flexural and fatigue behavior of current and future versions of the foot. Dow Chemical is contributing vital understanding about polyurethane processing, such as how storage time of the two materials used to make it, polyol and isocyanate, can affect the mechanical properties of the resulting mixture. Pinnacle Industries has set up a prototype injection molding line for the foot and has learned about the challenges associated with bonding the foot body to the keel, which is a rigid member that connects the foot to the leg prosthesis. Each of the stakeholders on the project is adding value to progress the technology towards commercialization, and each is contributing unique requirements, insight, and feedback that the other partners may not have been able to provide, which will streamline dissemination and mitigate mistakes.

Tata Fellows also seek to engage the entire stakeholder hierarchy within a partnering organization, from executives to engineers to manufacturers to distributors to end users, as each tier has a unique perspective and imposes unique requirements on a problem. A Center project that demonstrates the value of hierarchical stakeholder interaction is the collaboration with Jain Irrigation to create low-cost, off-grid drip irrigation equipment. Drip irrigation reduces the water consumption for growing crops by up to 60% compared to flood irrigation[13], which is important for a country like India, where agriculture accounts for 70% of fresh water usage and the usage rate is projected to exceed the replenishment rate by 2025[14]. Drip irrigation is also an effective means of lifting subsistence farmers out of poverty by enabling them to grow more and higher value crops[4].

The executive level of Jain determined that there was a large potential market for low-cost, off-grid drip irrigation systems. Current solar-powered systems for a one-acre field cost $3,000-$5,000, but poor farmers could only afford a price of $300. Jain's agronomists determined the system must be able to deliver 25,000 L/acre/day to support thirsty crops such as wheat and cotton. Their power systems engineers said such a system would require a 1 hp pump, that with solar cells would account for 80% of the system cost. The irrigation engineers identified that 90% of the pressure drop in the system occurs over the drip emitters. And the production engineers noted that low-density polyethylene is the cheapest material they work with, and that other materials, such as silicone, significantly drive up the cost of the drippers. It took this company-wide engagement to realize that the largest opportunity to reduce system cost was by reducing pressure in the system, to reduce pumping power. The technological keystone to achieve this aim – which is the focus of the project – lies in redesigning the drip emitters to run at low pressure, deliver a constant flow rate with variations in pressure, and be fabricated from low-cost material. Furthermore, the executives and farmers mandated that we use thick-walled tubing to convey water to the drippers, even though cheaper thin-walled tubing is available. This is due to the Indian government subsidizing the thick-walled tubing at 60%, making it cheaper to the farmer than the thin-walled tubing, and because bullocks have the tendency to puncture the thin-walled tubing when they step on it.

A third project addresses development of a technology and systems strategy for materials recycling and pollution mitigation in an industrial district with many small and medium sized manufacturing firms. In Muzaffarnagar, an industrial town 100 km north of Delhi, several dozen paper mills, another dozen sugar mills, and a large range of other SME manufacturing entities collectively contribute to significant environmental degradation to the region's air, water, and soil. Building on strong connections between MIT and the local chapter of the India Industry

Association, four MIT students, a team of advising faculty members from a range of academic departments, and engineers from firms in Muzaffarnagar are using this region as a laboratory for testing a range of strategies for pollution control in Indian industrial clusters. Taking a regional approach allows the team to analyze many manufacturing facilities in an integral ecosystem, providing an opportunity to develop scalable results.

Conclusion

The Tata Center for Technology and Design is providing a venue for MIT faculty and students to develop and apply technological, systems, and management skills to make a positive impact on developing and emerging markets. We have structured a program that provides Tata Fellows with an immersive experience in India that will broaden their perspective on the technological, systems, and management challenges and opportunities in development, as well as training for how to implement tractable and successful solutions. Partnering closely with the various stakeholders related to a technology will ensure that Tata Center projects are driven towards suitability, scalability, and sustainability.

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