Teaching Learning Centre for Design and Manufacturing Education at IIITDM Kancheepuram - Toward Extremely Affordable DIY Laboratory Education

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Introduction

India's population growth trends project a large youthful segment which could lead to a "demographic dividend", since most developed countries and large developing countries like China face an ageing population trend. However, there are warnings that in the absence of effective initiatives to equip the youth with workplace skills and provide them dignifying jobs, the dividend could well turn out to be a *population bomb* [1]. An additional challenge in this context is posed by automation and robotics, which threaten to eliminate jobs in large scale across many fields.

The Indian government has in recent years rightly come up with major initiatives such as *Skills India*, *Digital India*, *Startup India*, and *Make in India*. The goal is that numerous well-paying jobs could be generated by promoting indigenous economic development and entrepreneurship, through skill development among the youth and enabling growth through promotion of innovative technologies. The results so far, however, are not encouraging due to many factors [2].

Importance of Manufacturing

The performance of the overall Indian economy is even more disappointing, if one compares it to China's: the two countries had nearly the same GDP in 1990 but in just over a quarter century, China's economy has grown to about five times the size of India's ($14.092 trillion vs $2.848 trillion). There is another interesting dichotomy in the evolution of the economies of India and China, that point to differences in educational innovation in the long run. Over the last two decades – starting with the Y2K scare and related surge in demand for IT jobs – Indian higher education has emphasized training toward jobs in the IT sector, and this has largely been to the benefit of an urban, college-educated and English-speaking segment of the youth population. By contrast, China has placed emphasis on the manufacturing industry and eventually became the *Factory of the World*, as evidenced by the comparison of Indian and Chinese manufacturing sectors in Table 1. This has meant that the Chinese could generate mass employment opportunities on the factory floor, for even rural, non-English-speaking, and high school graduates and dropouts.

Table 1. Comparison of Manufacturing Sectors in India and China (2015)

	India	**China**
Population (% of global)	17.5%	20%
Manufacturing GDP & rank	$240 billion & 10th	$2.9 trillion & 1st
Global Manufacturing Competitiveness Index	2nd	1st
Manufacturing as % of GDP	12.9%	31.8%
Manufacturing Employment & as % of Total	11 million &5.8%	100 million & 34%
% of Global Manufacturing Exports	1.6%	17.5%
% of Global Engineering Exports	1.2%	12.3%
Hourly Wages	$1	$3
Foreign investment profitability index (2015 & 2014)	1 (6)	65 (60)
Global Innovation Index (out of 143 countries, 2014)	76	29

From the above comparison, the tremendous potential of manufacturing for Indian economy is obvious: even a mere doubling or tripling of our manufacturing industry output can lead to tremendous growth in economic output and millions of new, high-paying jobs. Accordingly, India's 2011 *National Manufacturing Policy* has set an ambitious target of 25% share for manufacturing in GDP and manufacturing employment of 100 million by the year 2022. This is an achievable target, as the share of manufacturing in comparable economies in Asia is much higher at 25-34%. According to the 2012 *National Policy on Electronics*, **semiconductor electronic manufacturing alone is expected to create 28 million new jobs by 2020**. This achievement will be remarkable, if we compare the fact that the entire IT industry in India has created 3.1 million jobs.

However, the *National Manufacturing Policy* identifies constraints to the growth of Indian manufacturing sector as "***inadequate physical infrastructure***, complex regulatory environment, and ***inadequate availability of skilled manpower***" (emphasis added). Therefore, the success of the *Make in India* campaign depends very much on the availability of innovative, affordable, high quality manufacturing technology education infrastructure and effective manpower training on a national scale.

The decade of the 2010s has been designated as the decade of ***Innovative India***. Yet, Indian engineering and technology professionals, teachers, and students lack in the area of creativity and innovative thinking. While Indian education, starting at the school level, is often blamed for this lack of innovation, in a focused domain-specific higher educational initiative like ours, fruitful efforts to inculcate innovative teaching and learning can nevertheless be undertaken with careful planning and implementation. A 2013 study by the McKinsey Global Institute lists 3D printing, advanced robotics, cloud technology, mobile Internet, Internet of Things, semi-autonomous and autonomous vehicles, and renewable energy as among 12 major *disruptive technologies* of our times [3]. Many of these technologies are based on the use of actuators, sensors, controllers, and software which are also the basic tools and components of modern manufacturing for value addition, innovation, and competitiveness. These disruptive technologies provide a $20 trillion economic opportunity for India [4]. Therefore, innovative design and manufacturing education can also help India catch up with the developed world in the pursuit of these disruptive and value-adding technologies.

As economic competition becomes global, India has a major advantage in terms of *skilled manpower*, that can produce innovative and advanced yet *frugal* (*jugaadh*) technologies, products, and solutions for domestic consumption, import substitution, and the export market. The need of the hour is ***to foster innovative teaching learning methods in higher education on a large scale, in a short period of time, for maximum impact*** on the national endeavors to leap frog India into a global manufacturing hub. Therefore, **hands-on education in design and manufacturing can provide Indian students and graduates with creative, innovative, problem solving, and R&D skills**. The entry of these well-educated graduates into the workforce of the future Indian manufacturing industry will provide a boost to the competitiveness and growth of high-tech engineering industries in India.

Teaching Learning Centre for Design and Manufacturing

The Teaching Learning Center (TLC) for Design and Manufacturing Education at Indian Institute of Information Technology, Design, and Manufacturing (IIITDM)-Kancheepuram, was established in October 2015 with funding from the Ministry of Human Resource Development (MHRD) under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching (PMMMNMTT). Its objective is to provide at the national level to innovative, hands-on, state-of-art education, affordable and creative teaching and learning materials, and training to faculty and students of universities and colleges, *as well as polytechnics, it is and even high schools*, in the areas of innovative product design, subtractive (computer numerical control-based) and additive manufacturing (3D printing), prototyping, and product development and commercialization.

This article provides an overview of the TLC, its activities on manufacturing education technologies design, development and dissemination, and schools and community outreach. Further information on the centre can be found at tlc.iiitdm.ac.in [5], [6].

Extremely Affordable DIY Technologies using Open Source Hardware and Software

The word *engineering* has its roots in the Latin term for 'to create'. Engineering education is fundamentally practice-oriented, but in resource-poor academic institutions in India the access to hands-on laboratory instruction is constrained by the high cost of equipment and instruments. Many teachers also have limited training with state-of-art equipment, and so resort to purchase and use of commercial black-box type kits which provide students only limited learning outcomes.

The TLC works to design and develop e-learning materials and common Do-It-Yourself (DIY) and Build-Your-Own (BYO) low-cost laboratory instruction modules for adoption and use in engineering universities, colleges and polytechnics. The modules are mainly built using inexpensive commercial off-the-shelf (COTS) materials and components, open source hardware, and free open source software, making them *extremely affordable*.

The activities of the TLC include:

- Development and dissemination of e-learning materials online (video recordings of course lectures, special topics and talks, workshop proceedings, demos of lab modules, etc.)
- Design and development of low-cost and innovative practical instruction modules
- Hands-on short-term workshops for teachers from universities, colleges, polytechnics and high schools
- Development of how-to manuals, induction training programs, and Web-based Virtual Labs
- Collaboration with academic and research institutes in India and abroad
- Internships by college faculty and students

- Serve as model Maker Space facilitating innovations by students, faculty and startups, and
- Community service and outreach programs and workshops for school teachers and children

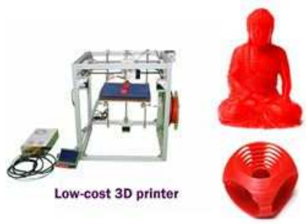
DIY/BYO technologies for fabrication of the following basic manufacturing engineering education equipment have been developed, using open source hardware and software.

- Desktop 3-axis CNC mill (with PVC/aluminum frame)
- Desktop 2-axis CNC lathe
- Desktop 3D printer
- Double-sided PCB machine
- 3-axis robot arm and mobile robot
- CNC router
- CNC vinyl cutter
- CNC laser cutter/engraver, and
- CNC plasma cutter.

3-axis CNC mill

2-axis CNC lathe

PCB machine



Low-cost 3D printer

CNC router

3-axis robot arm

CNC laser engraver **Low-cost mobile robot**

CNC laser cutter **CNC plasma cutter**

The following are the infrastructure facilities of the TLC:

- Design and Prototyping Studio – for CAD/CAM/CIM, 3D printing, 3D scanning, robotics, AR/VR
- Manufacturing Lab – for design and development of CNC manufacturing equipment
- Advanced Manufacturing Lab – for digital fabrication, and design and development of advanced
- Manufacturing equipment: laser cutting, plasma metal cutting, electric discharge machining, etc.
- Electronics Lab – Electronic prototyping and printed circuit board (PCB) machining
- Mechanical Workshop – for basic wood and metal working, mechanical fabrication, machining, and welding
- Conference Hall – for conducting workshops, meetings, and presentations

Schools Outreach for STE(A)M Education

TLC is providing the technical and pedagogical mentoring to SRF Foundation's InnoSTE(A)M Labs initiative in nearly 30 government high schools in Chennai, Bengaluru, Trichy, Salem, Mumbai, Pune, Kolkata, Noida, and Hyderabad. The labs are funded by Capgemini Corporation as part its Corporate Social Responsibility (CSR) School Adoption Program. Under this scheme, Maker Spaces have been established in the schools, for selected children in Grades 5-9 and their teacher-mentors, with provision of hand and power tools, supplies and materials, electromechanical components, test & measuring equipment, open source hardware and software, and desktop computer numerical control (CNC) milling machines. TLC project staff are working to develop, test, and disseminate curricular materials in the fields of computer aided design and manufacturing (CAD/CAM), CNC, electronics, robotics, programming, development of web technologies and mobile phone apps for students of high schools. Full-time SRFF technical staff mentored by TLC engineers then take care of regular training and support for the school teachers and students. Based on the tools learned, students will be encouraged to pursue innovations through periodic design competitions for the participating schools at local and national levels, involving unstructured or open-ended themes, as well as on theme-specific topics related to community problem solving. ***Extreme affordability*** of teaching learning materials is a key objective of the program, so as to maximize the impact and reach of the project.

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About the author

Dr. S. R. Pandian is presently Dean (Planning) and teaches in the Department of Electronics and Communication Engineering at Indian Institute of Information Technology, Design and Manufacturing-Kancheepuram. He did his BE in ECE from Thiagarajar College of Engineering, Madurai, and then completed MTech from IIT Kanpur and PhD from IIT Delhi, both in Electrical Engineering. His areas of specialization include robotics, control, mechatronics and autonomous systems, with applications in energy, environment and education. He has more than 130 publications in international and national journals and conferences. From 1992 till 2000, he was involved in teaching and research in robotics at Ritsumeikan University, in Japan. During 2001-12, he did teaching and research in USA at University of Michigan, Flint, Tulane University, New Orleans, and Southeastern Louisiana University. He invented a pneumatics-based system for power generation based on children’s play, which was selected by the New York Times as one of the best ideas of the year 2003. His inventions have been featured in Discovery Channel, Canada, many national and international media, and a school text book in Texas State. He was also a finalist in 2005 for the Louisiana Innovator of the Year award. In 2007, Dr. Pandian was one of nine inventors from around the world featured in a special program on human power conversion on SBS TV, Korea. Dr. Pandian returned to India in 2012, and worked in Velammal College of Engineering and Technology, Madurai first as a Professor and Head of the Department of Information Technology, and then as Director-Research, before moving to IIITDM. He is active in education, research and outreach in robotics and intelligent systems. At IIITDM, he is now Coordinator of MHRD-funded Teaching Learning Center for Design and Manufacturing Education, which aims to design, develop and disseminate innovative and low-cost, build-your-own laboratory modules for design and manufacturing education in universities, colleges, polytechnics, ITIs, as well as schools.