Engineering Research: Innovation & Competitiveness

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National University of Singapore

Outline

What are the major trends ?

What caused these trends?

What is the future like?

What a nation can do?

What universities can do?

What academic can do?

What students can do?

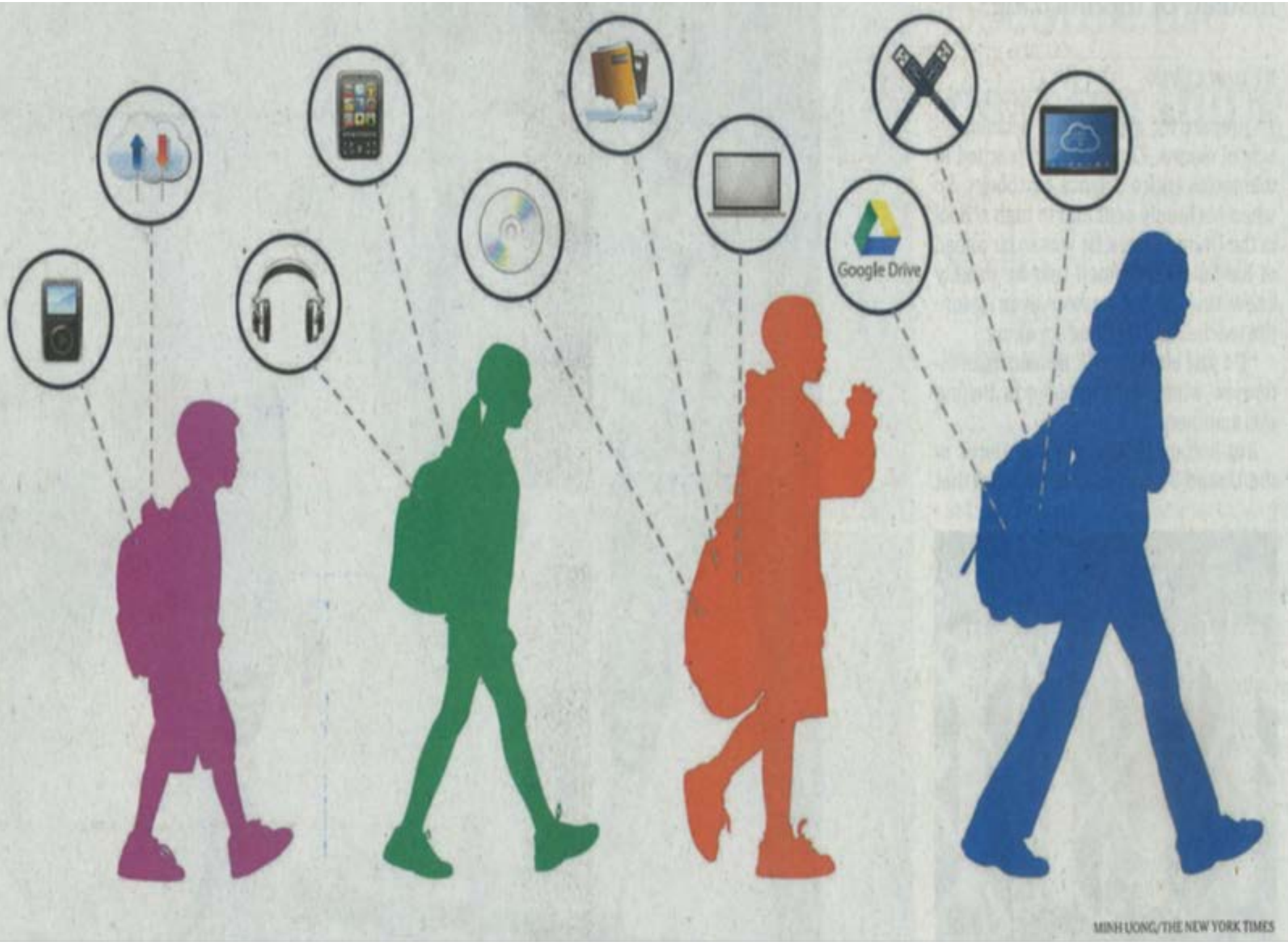
What businesses can do?

Way forward

Smart Watch

1980: ~ 1400 kgs of disconnected technologies

@ Xavier Fouger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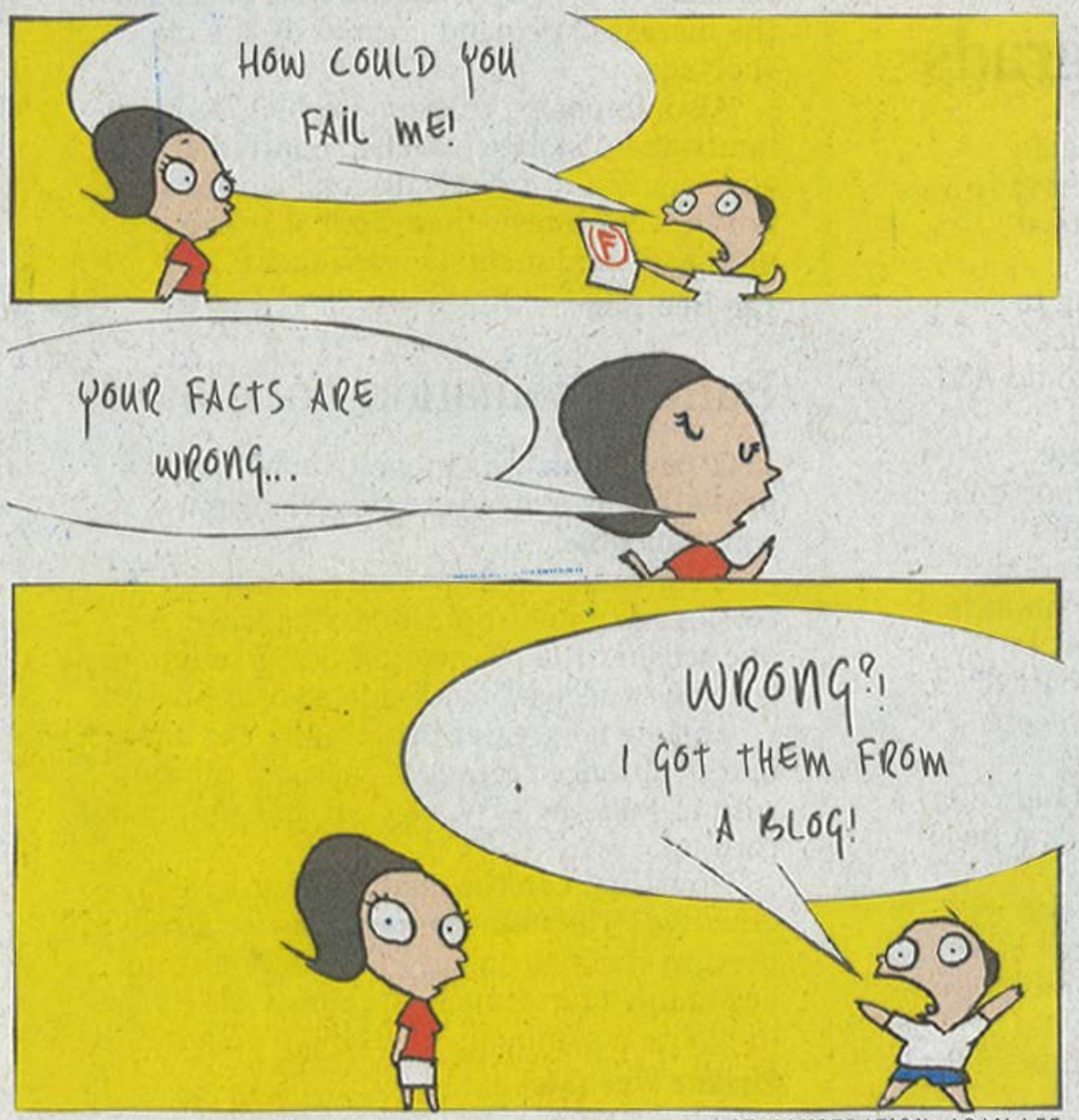
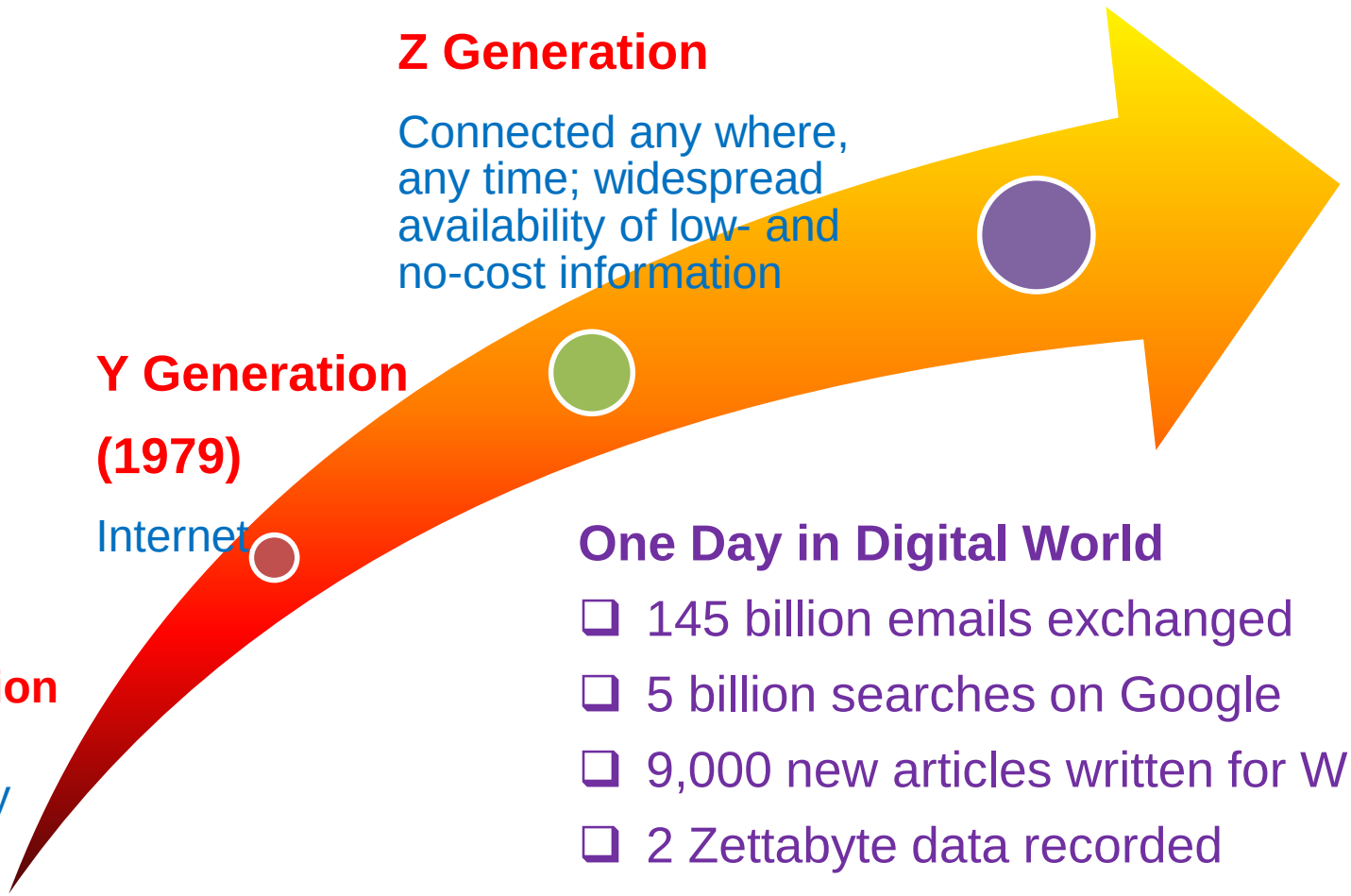
MINH UONG/THE NEW YORK TIMES

PUNCHLINES



ST ILLUSTRATION: ADAM LEE

Changes shaping the generations



One Day in Digital World

- ❑ 145 billion emails exchanged
- ❑ 5 billion searches on Google
- ❑ 9,000 new articles written for Wikipedia
- ❑ 2 Zettabyte data recorded

Teaching and Learning Tools

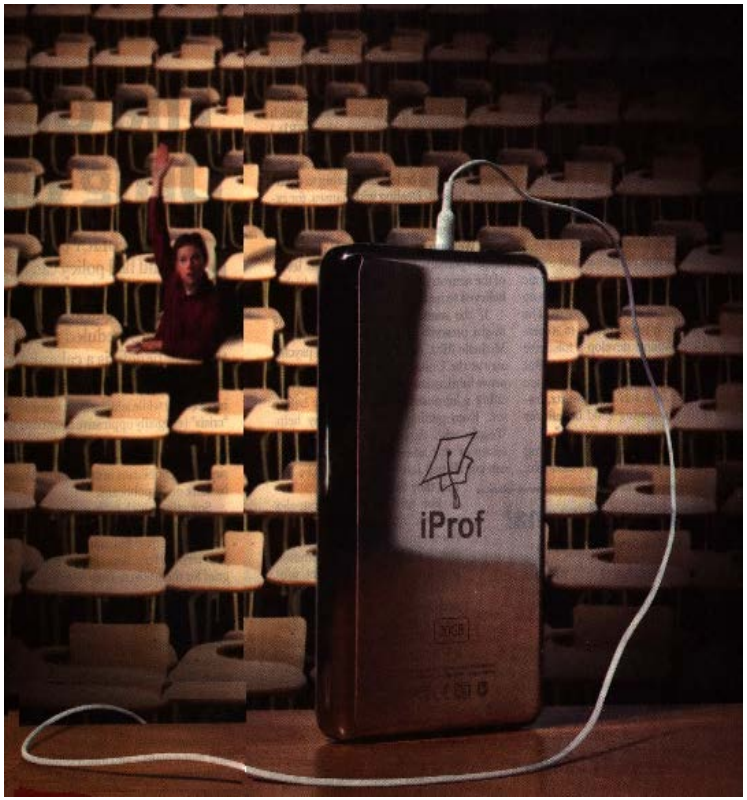
X-Gen

Minimal technology aids in learning inside or outside class room !

Y-Gen

Z-Gen

Tomorrow's Learning



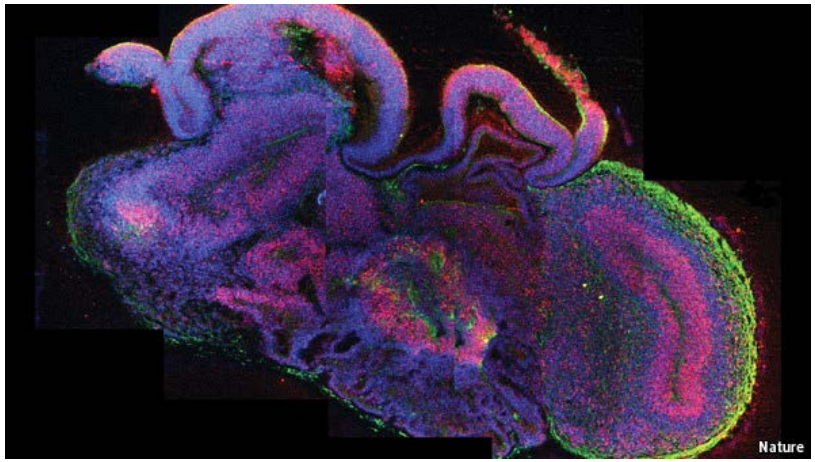
Professor, no need to go to class room!

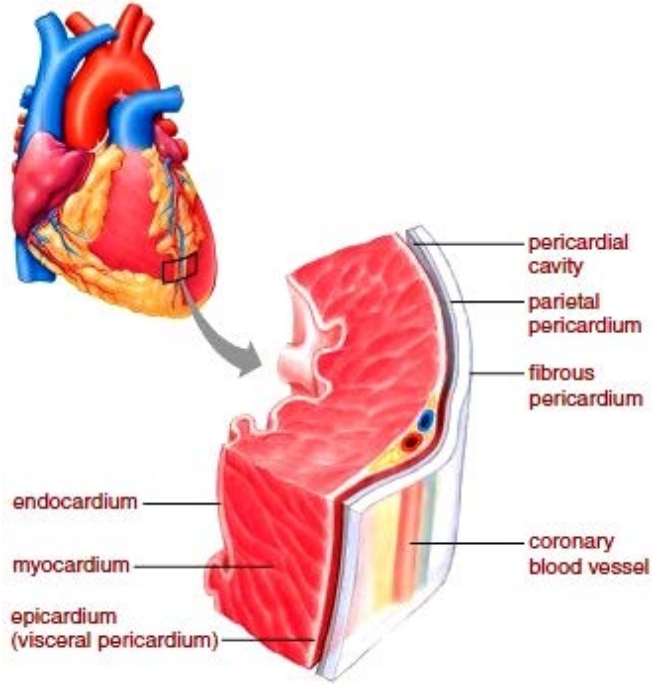
Sit anywhere classroom

Library in your iPad

@Lucille Craft

Regenerative Medicine





(Reuters) - Scientists have grown the first mini human brains in lab, 29 August 2013, Lancaster, *et al Nature*

Lab grown (In Vitro) meat!

Engineering Innovations inspired the societies

Steam engine

Industrial revolution I

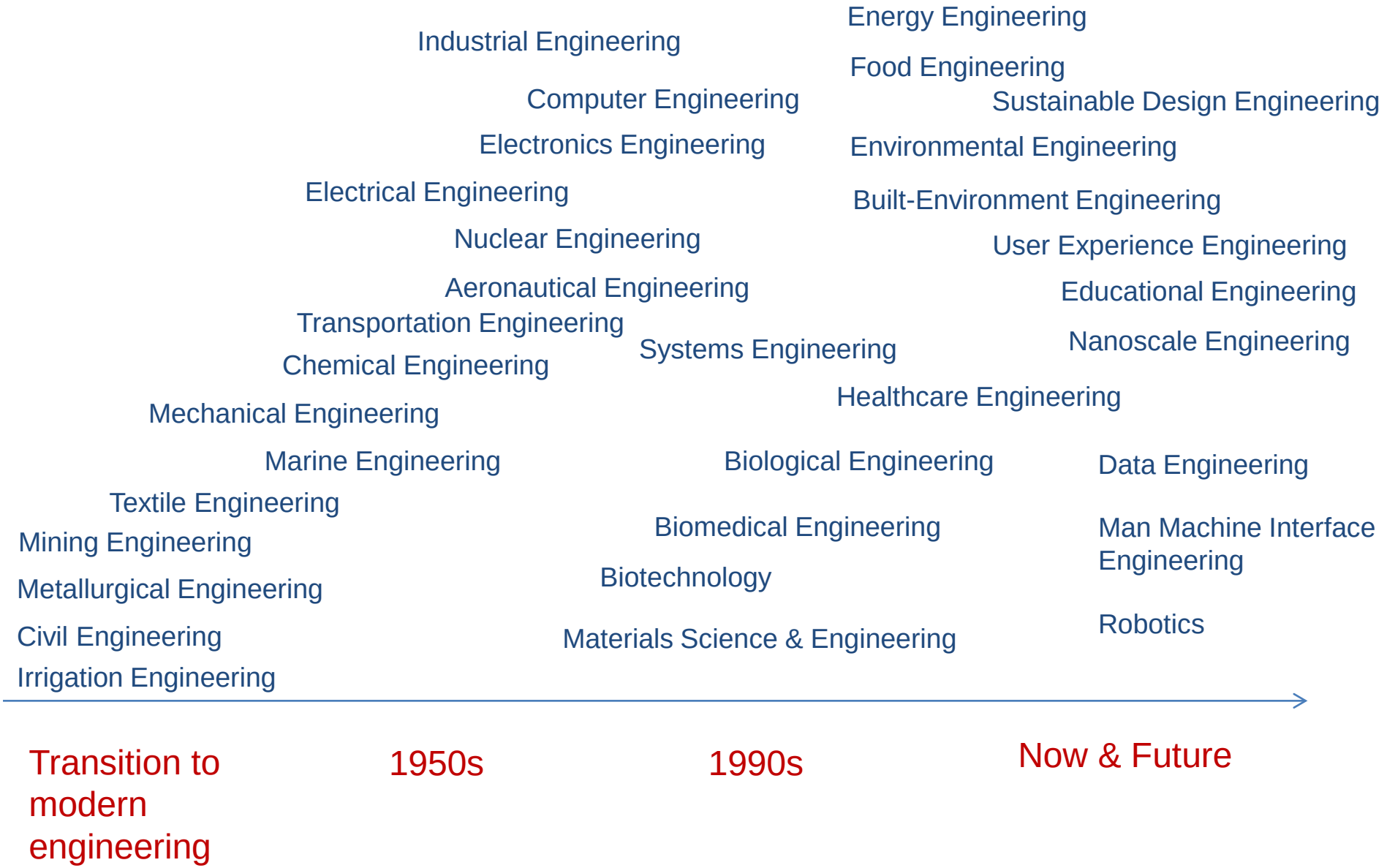
Electricity
Internal combustion engines
Modern communication
Entertainment
Petroleum
Chemicals

Computing

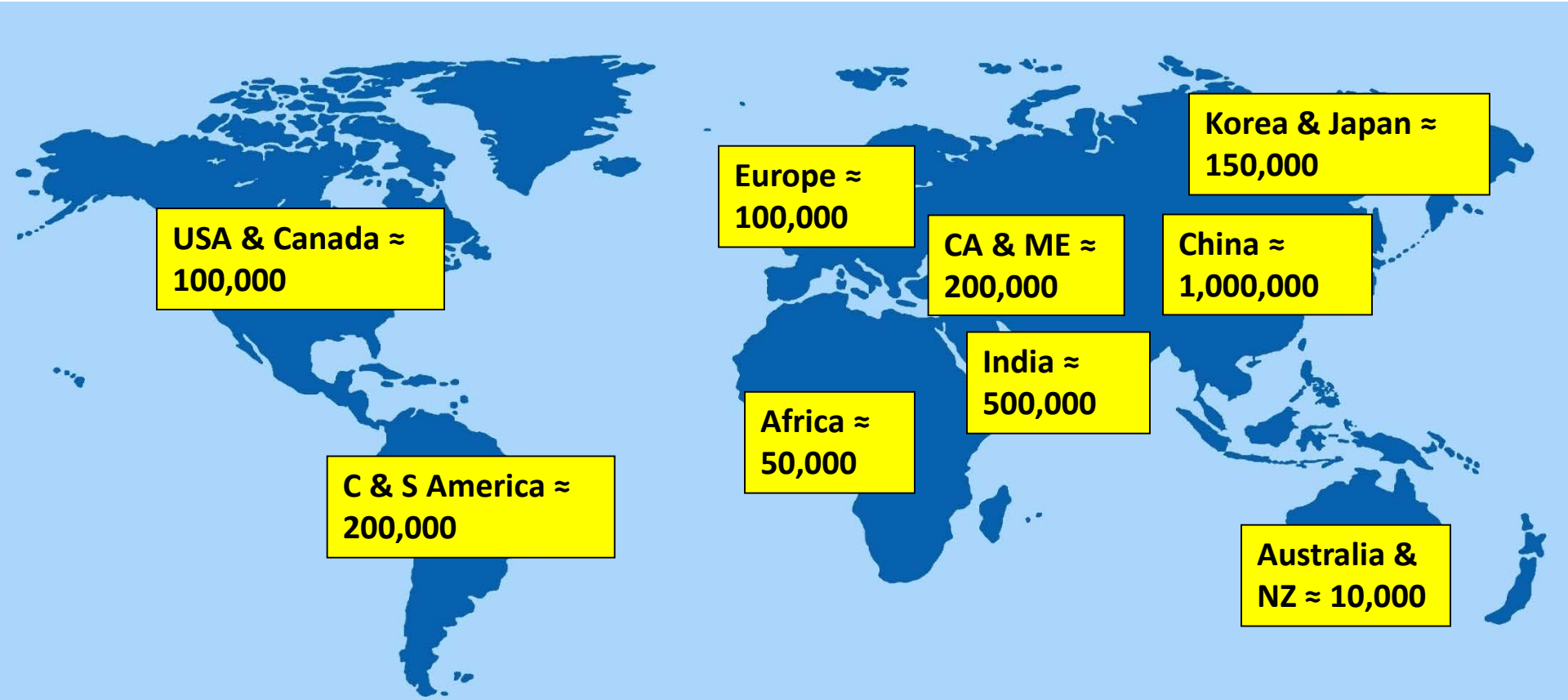
Air transportation

Modern Medicine

New domains of engineering



Engineering graduates by numbers



~ two million engineering graduates per annum

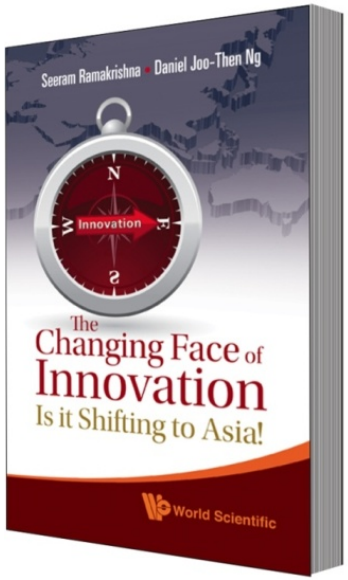
~ 6,000 Engineering colleges

GEDC
GLOBAL ENGINEERING DEANS COUNCIL

World Today

- The share of emerging economies in the world GDP is over 50%
- One-quarter of world's total manufacturing output is high-technology manufacturing (~ 4 trillion dollars)
- Manufacturing & engineering are considered key to sustainable economic growth

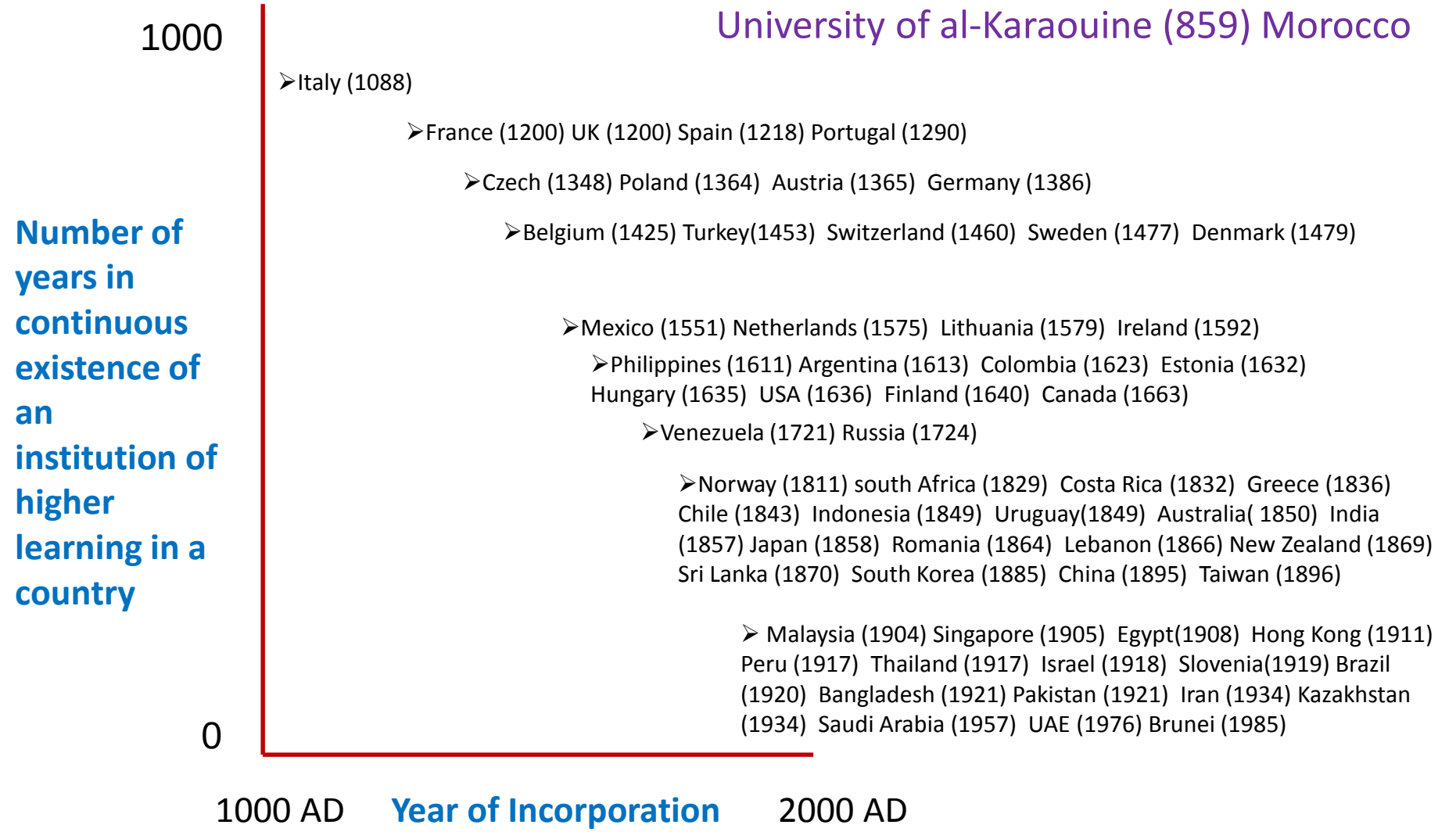
Transformational Forces ?



- ❑ Trade
- ❑ Finance
- ❑ Culture
- ❑ Global supply chain
- ❑ Competent talent flow
- ❑ Liberalization of tertiary education

Modern Tertiary Education is Relatively New in Emerging Nations

Plato Academy (387BC)
Takshashila; Nalanda University (5CE), India
University of al-Karaouine (859) Morocco



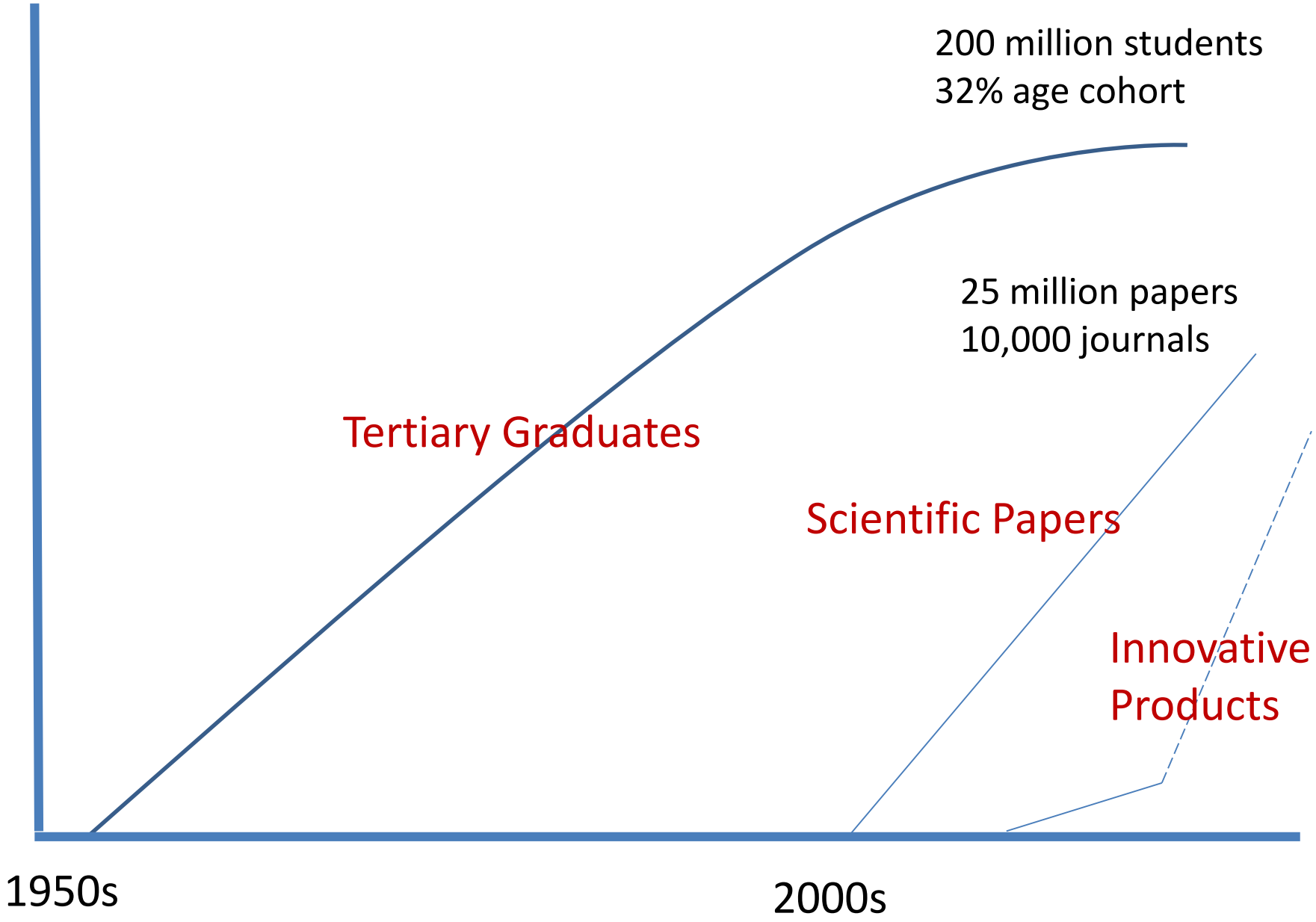
Planning parameters?

- ~ One university per million population
- ~ 5,000 to 10,000 graduates per year per million population
- ~ 50 to 100 PhDs per year per million population

Diversity among universities

Age	Size	Nature	Focus	Research
Historic ~ 100 years & above	Very Large ~ 30,000 students	Public	Comprehensive with medical school	Intensive & pervasive
Mature ~ 50 years & above	Large ~ 12,000 students	Private but publicly funded	Comprehensive	Intensive
Established ~ 25 years & above	Medium over 5,000 students	For profit	Specialist	Moderate
Young ~ 25 years & below	Small below 5000 students	On line & Life long learning		Limited or none

Democratization of Education, Research & Innovation



~ 50% of degree holders are holding jobs that do not require a degree

McKinsey & Co report dated 2013

A18 Cambodian opposition leader ends exile
A28 Detroit insolvent

"There is a mismatch in what our education system is producing and what industry is looking for."
– Mr R.V. Kanoria, former head of the Federation of Indian Chambers of Commerce and Industry

So many graduates, so few skilled

Almost half of India's 5m fresh degree holders each year are unemployable

Students at Khalsa College in Amritsar. Some 12 million Indians are expected to join the workforce every year over the next decade. PHOTO: AGENCE FRANCE-PRESSE

By KRITTIVAS MUKHERJEE
IN NEW DELHI

GIVEN his first-class degree in accountancy, young Kunal Gurab appears over-qualified for his current job as a data-entry executive at a leading Indian outsourcing firm.

"I took up this job because I failed to find a job of my choice in finance," said the 24-year-old employee at a call centre run by Tech Mahindra just outside New Delhi.

"In all job interviews, I was told my course did not teach me the skills needed for accounting or banking."

Mr Gurab's disconcerting discovery reflects the experience of almost half of the five million Indians who receive college degrees every year but are unemployable in an economy left thirsting for skilled hands.

Poor-quality education is largely responsible for the problem, alongside a lack of vocational training to develop job-relevant skills. A mismatch between students' aspirations and the job market is also to blame for the growing army of unemployable graduates in India.

Last month, in a first-of-its-kind employability audit among Indian graduates, hiring solutions company Aspiring Minds found that 47 per cent of the respondents were not worth recruiting because they lacked English fluency and skills such as problem solving or use of computer software.

"There is a mismatch in what our education system is producing and what industry is looking for," said Mr R.V. Kanoria, former head of the Federation of Indian Chambers of Commerce and Industry (FICCI), one of India's top industry lobbies.

India has a workforce of about 480 million but, according to an FICCI estimate, only 5 per cent of that pool have "marketable skills", compared to 50-60 per cent in countries such as Japan and Germany.

Agriculture still employs over half of India's workforce in low-wage, low-productivity jobs even as labour needs shift from farming to industry.

This has massive implications for the country's young. More than half of India's 1.2 billion people are under the age of 30, and some 12 million Indians are expected to join the workforce every year over the next decade.

"We don't want a glut of educated unemployed in a skills-driven job market," said Mr Dilip Chenoy, CEO of the government-backed National Skill Development Corporation.

India has a workforce of about 480 million but, according to an FICCI estimate, only 5 per cent of that pool have "marketable skills", compared to 50-60 per cent in countries such as Japan and Germany.

When India liberalised its economy in the 1990s, it helped improve living standards for millions, but its socialist-era education system remained heavily regulated, churning out a greater number of literates grown on a culture of rote learning and white-collar dreams.

Millions of educated Indians still lack fluency in English, the language of business in the former British colony.

In the growth years, that mattered less. Hundreds of technical schools opened overnight, producing graduates who were snapped up and then trained on the job. But as the economy slows, employers are getting pickier.

Experts said India must improve the quality of courses and teachers. It must also overcome a culture that values conventional education more than job-oriented vocational training.

The government is responding with an ambitious plan that aims to arm 500 million youth with employable skills by 2022. This includes building more skills training centres, developing curricula and training teachers.

Such is the talent crunch that some of India's famed information technology firms now fund skills development programmes in engineering schools.

"Of half a million engineers graduating every year, not more than a quarter are employable," said Mr Vinay Shirsat, founder of hiring firm Vindsor.

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Tertiary education institutions are subjected to···

Rating

(Self) Benchmarking

Ranking

Accreditation

(Self) Evaluation

Quality Assurance

(Self) Assessment

External Validation

Various ranking organizations list up to 500 universities worldwide

Ranking Organization	Research Related	Education	Internationalization	Per Capital Performance	Industry Income	Employer Perception
HEEACT	100%	0%	0%	0%	0%	0%
ARWU	80%	10%	0%	10%	0%	0%
THE	62.5	30%	5%	0%	2.50%	0%
QS	60%	20%	10%	0%	0%	10%

Academic reputation International awards

Employer reputation

Research volume Research income

Citations per faculty

Faculty : student ratio

Qualifications of faculty

International Faculty

The Australian

Implications of Rankings

- Isomorphism of universities as they are captive to the prestige
- Hierarchism of universities

- Brain drain
- Concerns on sustainability; vaguely understood performance based funding

- Priority to the disciplines relevant to ranking
- Less attention to the teaching there by affecting the quality of education

- Stakeholders attention
- Justification for investments

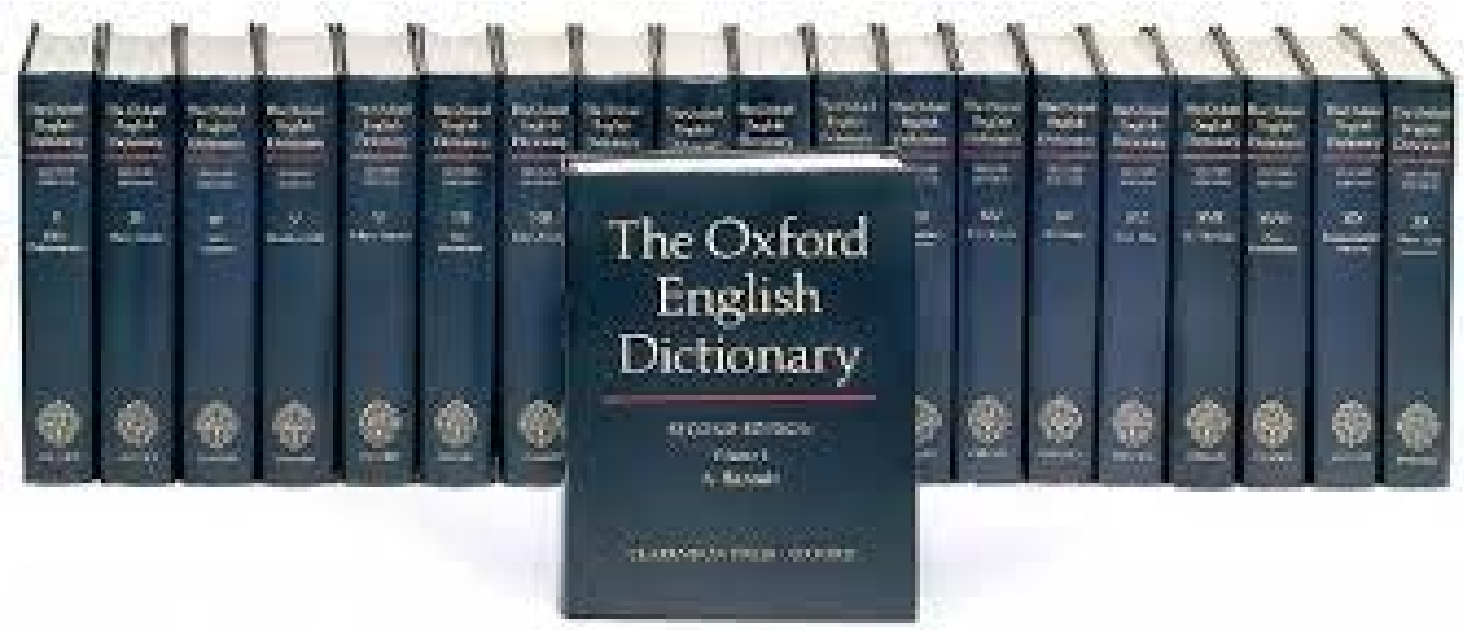
- Attraction of talent
- Mobility of talent

- Opportunities for partnerships
- Streamlining of operations
- Aspiration for new standards

Oxford Language Dictionaries Online
The world's most trusted dictionaries

Oxford Dictionaries Online (ODO)

MOOC, n.: a course of study made available over the Internet without charge to a very large number of people.




On-LineTeaching Vs Face to Face Classroom Teaching
Yes
No
If this module is offered fully on-line would you take it?
Fully on-line teaching will enhance my learning outcomes i.e. deep conceptual understanding and problem solving skills
Level of student engagement is better in face to face teaching
Level of student engagement is better in fully on-line teaching
Face to face classroom helps me to connect with lecturer & students
Fully on-line teaching helps me to connect with lecturer & students
A blend of face to face classroom teaching and on-line teaching will elevate my learning
I prefer blackboard style of teaching
I prefer ppt style of teaching
I prefer a blend of blackboard and ppt style of teaching
I prefer self-education
14: 10
EXIT
MOOCs

Regular classroom lectures augmented with on-line support:

Online video lectures, peer assessment, class rooms, engagement, etc.

Real classroom discussions, interactive sessions, problem-solving activities, etc.

"Human teachers will become far more valuable in the future"

He was raised by a single mother and attended public schools, discovering an aptitude for maths. "By high school, if you wanted to be a really good competitive student – like if you wanted to get straight As and be top of your class and get high scores – then you had to engage a little bit more seriously, and so I [did]," he says.

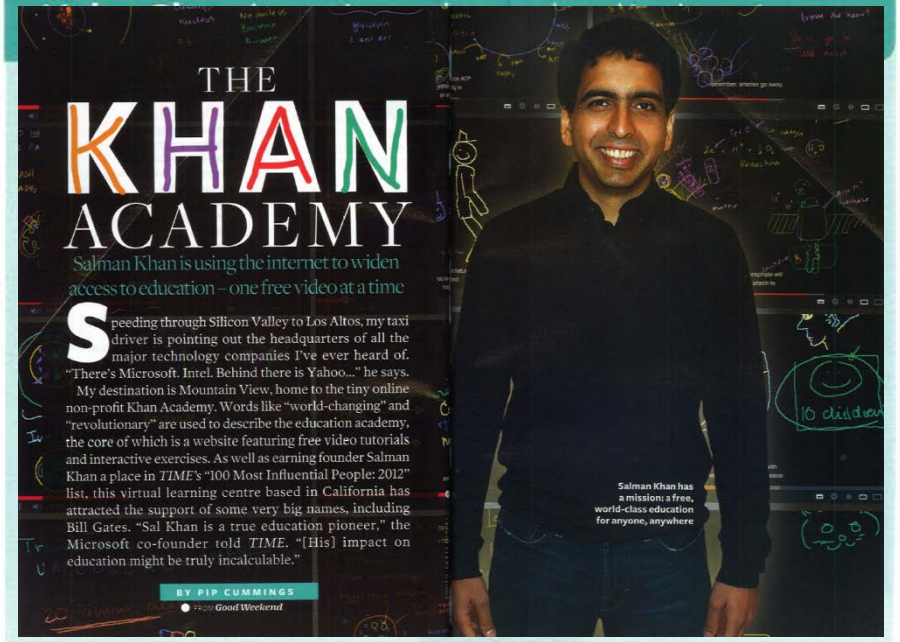
In person, Khan's is not a messianic presence. He is whip-smart, but he is also goofily funny, self-deprecating and attentive. He has the unbounded imagination of a computer scientist mixed with the precision of a mathematician, and the endearing geekiness of both. His generosity and self-assuredness are conveyed in the videos he makes – more than 4100 to date – which he keeps deliberately simple. You only hear his voice as he works through step-by-step diagrams on an electronic blackboard, as if a friend were sitting beside you. The site now boasts a full maths curriculum – reflecting its origins and his speciality – as well as units in science, computer science, finance and economics, and humanities.

Khan has written a book about his vision for education, *The One World Schoolhouse: Education Reimagined*. He lays out his vision for the future of education, including self-paced learning and the idea of the "flipped classroom", in which students take instruction online outside of class and do their "homework" in the classroom. He also questions Western orthodoxies, such as how many years we attend school, at what age we begin, and why we think it reasonable to move past a unit of study with anything less than total mastery of it.

According to Khan, "the biggest misconception is that this whole project is somehow a way to replace human teachers." But, he says, "human teachers will become far more valuable in the future because [the classroom] will be a more interactive place and they are going to be doing the things computers cannot do, which is form bonds, motivate, mentor, diagnose."

FROM PIP CUMMINGS/FAIRFAX SYNDICATION, *GOOD WEEKEND* (SEPTEMBER 29, 2012), © 2012, FAIRFAX MEDIA

A NEW DAWN IN EDUCATION



THE KHAN ACADEMY

Salman Khan is using the internet to widen access to education – one free video at a time

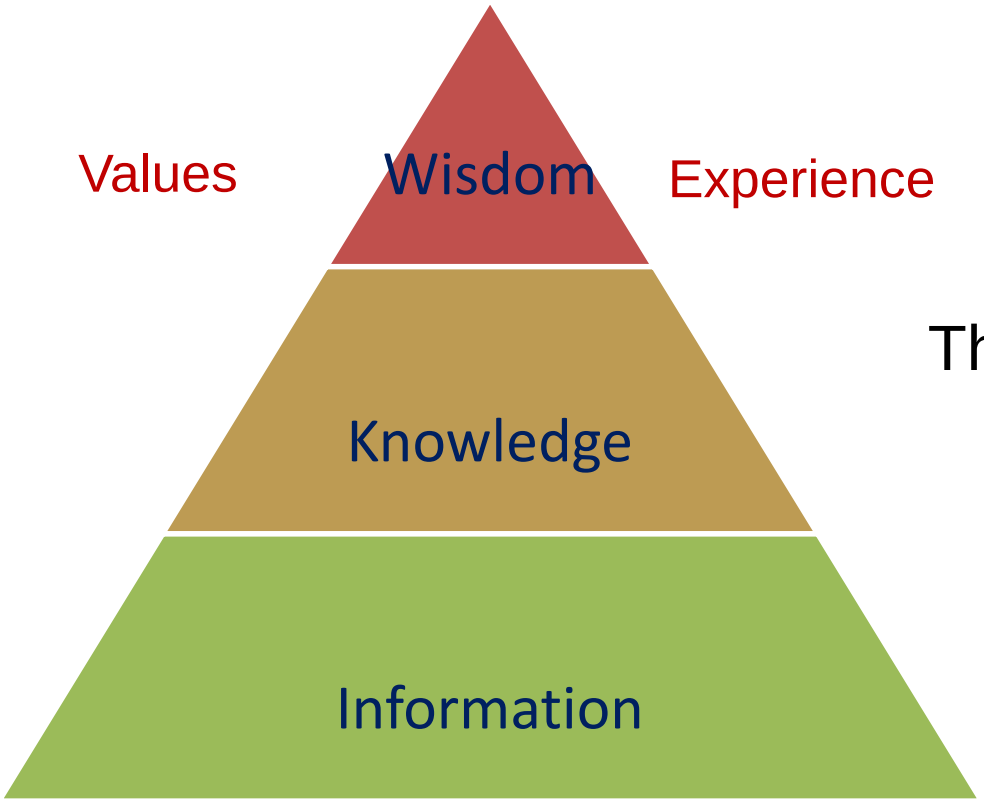
Speeding through Silicon Valley to Los Altos, my taxi driver is pointing out the headquarters of all the major technology companies I've ever heard of. "There's Microsoft. Intel. Behind there is Yahoo..." he says.

My destination is Mountain View, home to the tiny online non-profit Khan Academy. Words like "world-changing" and "revolutionary" are used to describe the education academy, the core of which is a website featuring free video tutorials and interactive exercises. As well as earning founder Salman Khan a place in *TIME's* "100 Most Influential People: 2012" list, this virtual learning centre based in California has attracted the support of some very big names, including Bill Gates. "Sal Khan is a true education pioneer," the Microsoft co-founder told *TIME*. "[His] impact on education might be truly incalculable."

BY PIP CUMMINGS

FROM *Good Weekend*

Salman Khan has a mission: a free, world-class education for anyone, anywhere



Thought

Expression

Speech

Writing

Content Loss

Big Screen Vs Small Screen

Engineering Research

1600-1920s

1 author per paper

20th Century

2 to 3 authors per paper

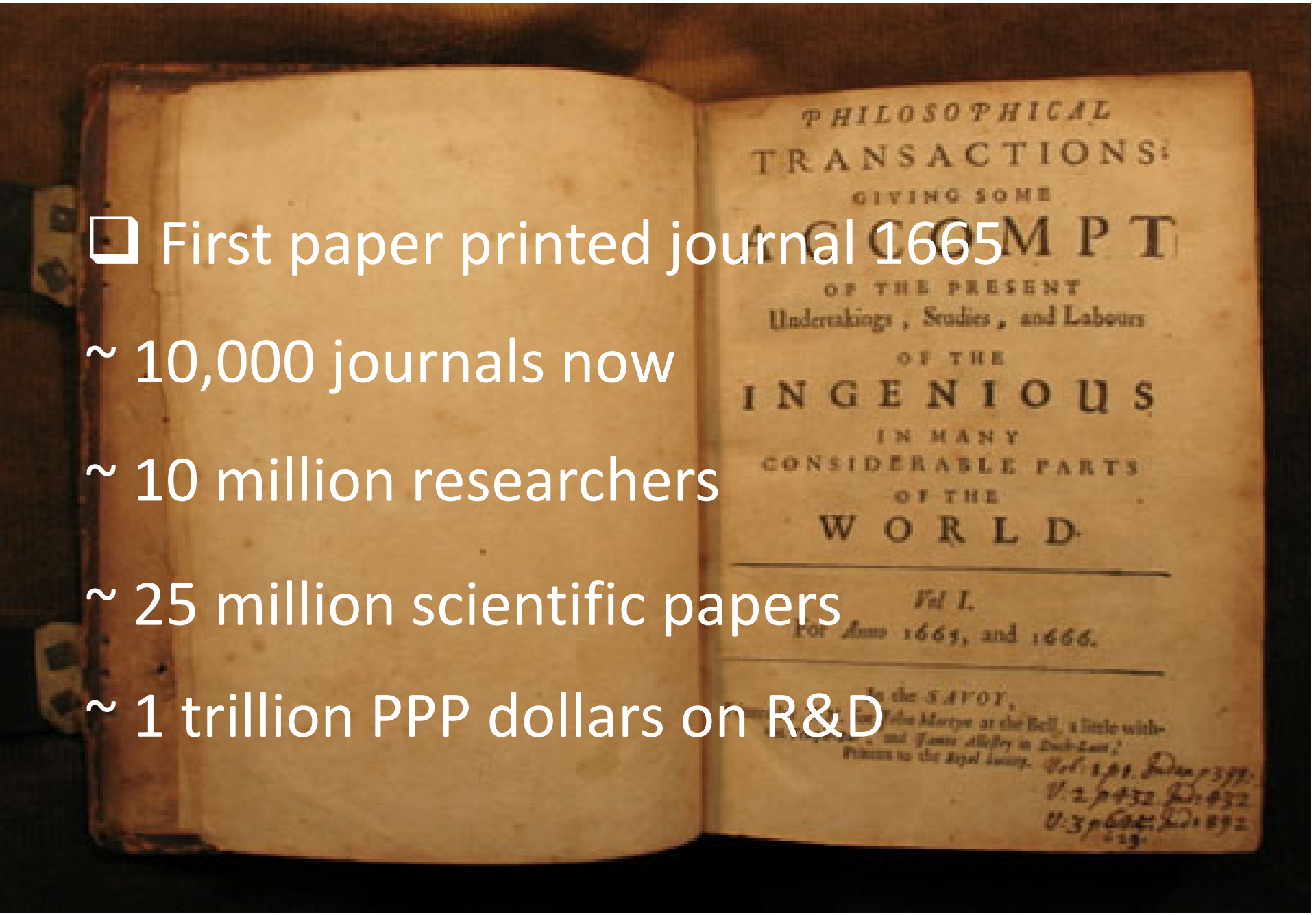
21st Century

~ 5 authors per paper

100 authors per paper !

Why?

- Problems are complex & need diverse disciplines
- Research is expensive
- Bean counting; publish or perish



- First paper printed journal 1665

~ 10,000 journals now

~ 10 million researchers

~ 25 million scientific papers

~ 1 trillion PPP dollars on R&D

Measure of research quality, significance & impact

Is this the way for engineering research?

Bibliometrics

(No. of Papers; Citations; h index, etc.)

Peer Review

Emerging Trend:

- Reporting on research is a profession by itself now! Many new jobs have been created
- Bibliometrics have been projected as the objective and best proxy indicator
- Appealing to stakeholders who are away from the operations
- Enable benchmarking on bigger scale

Traditional Practice:

- peer review has been the tradition for centuries

Innovation is the result of unique interactions among diverse actors such as businesses, financial sector, government, education institutions & socio-cultural ecosystem which lead to structured cycle of research, training, productisation & market activity

Innovation

Up to 1920s

- Significant role of Europe
- Sporadic innovations led by scholars and entrepreneurial individuals
- Apprenticeship model of skills learning
- Limited pool of innovators (~1000)

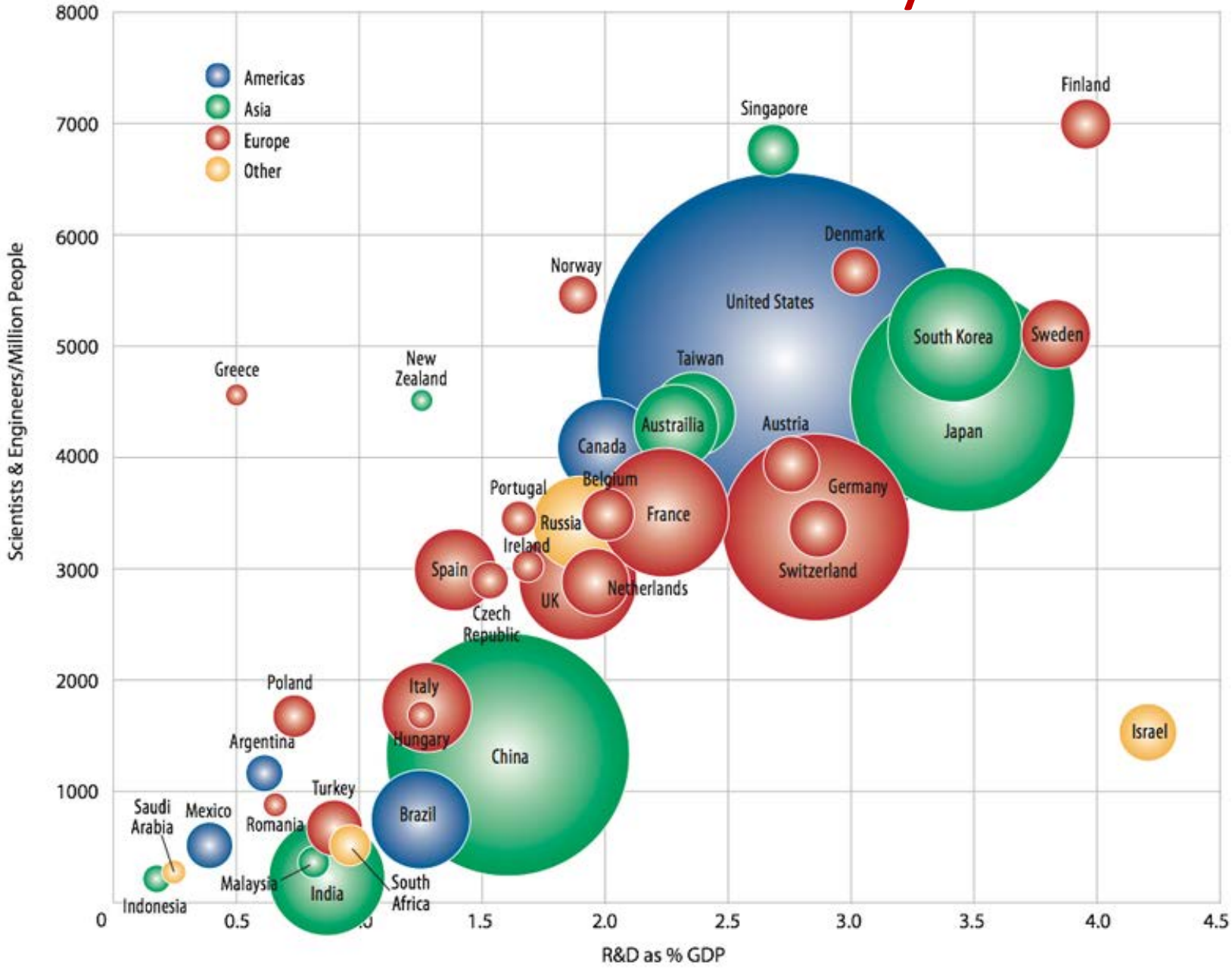
20th Century

- Significant role of USA
- Corporation led Innovation
- Systematic learning
- Scientific research & technology led innovations
- Standard products for markets around the world

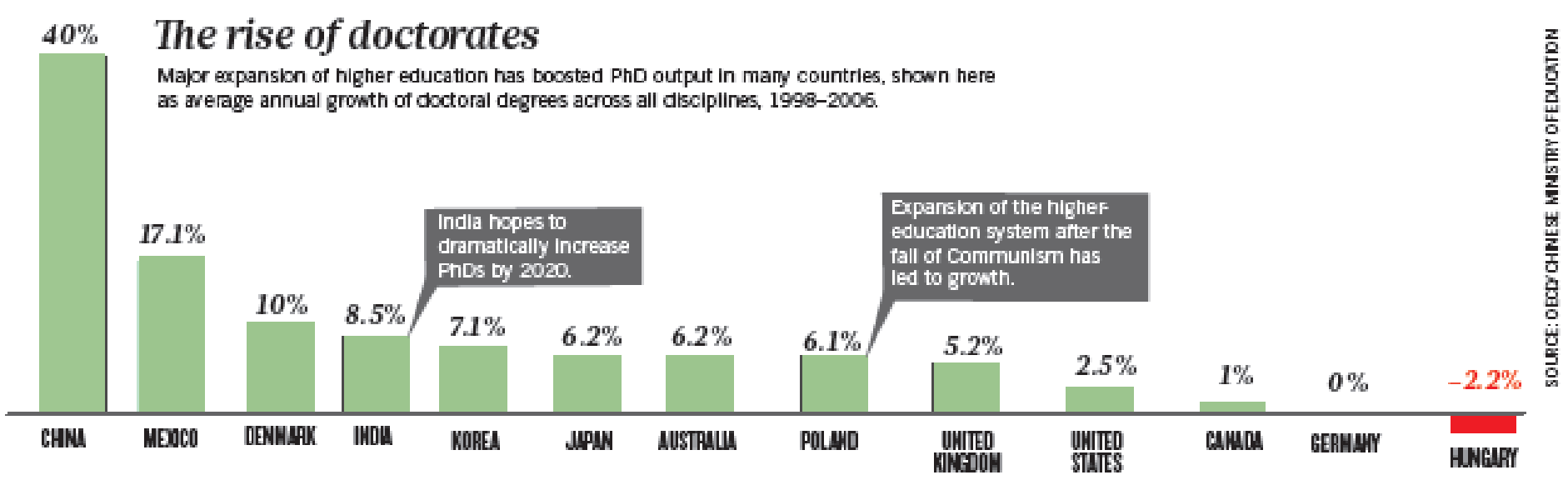
21st Century

- ✓ Investments by governments around the world
- ✓ Globally distributed Innovation nodes
- ✓ Participation of universities
- ✓ Open source innovation

Research & Innovation Intensity of Nations



The Changing Face of Innovation, Seeram Ramakrishna, 2011, World Scientific Publishers



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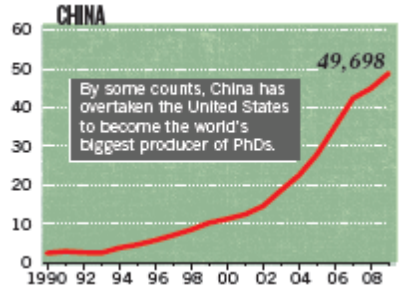
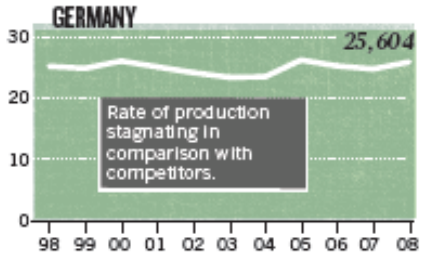
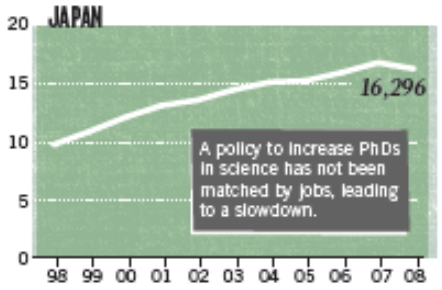
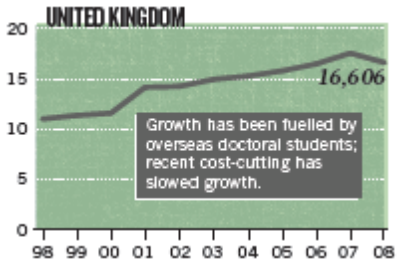
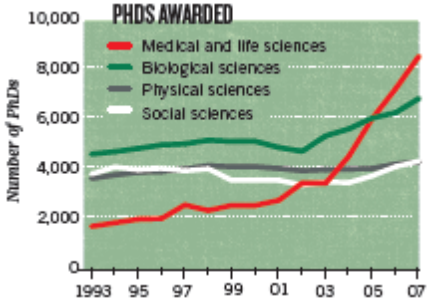








United States:



100 PhDs per million population ?

The annual number of science and engineering doctorates graduating from US universities rose to almost 41,000 in 2007

WORLD ACADEMIC SUMMIT INNOVATION INDEX

Rank		Average value per researcher (US$)
1	South Korea	97,900 (S$123,100)
2	Singapore	84,500
3	The Netherlands	72,800
4	South Africa	64,400
5	Belgium	63,700
6	Taiwan	53,900
7	China	50,500
8	Sweden	46,100
9	Denmark	43,600
10	India	36,900
11	Russia	36,400
12	Turkey	31,000
13	Canada	27,200
14	United States	25,800
15	Australia	25,600

Sources:
TIMES HIGHER EDUCATION,
THOMSON REUTERS

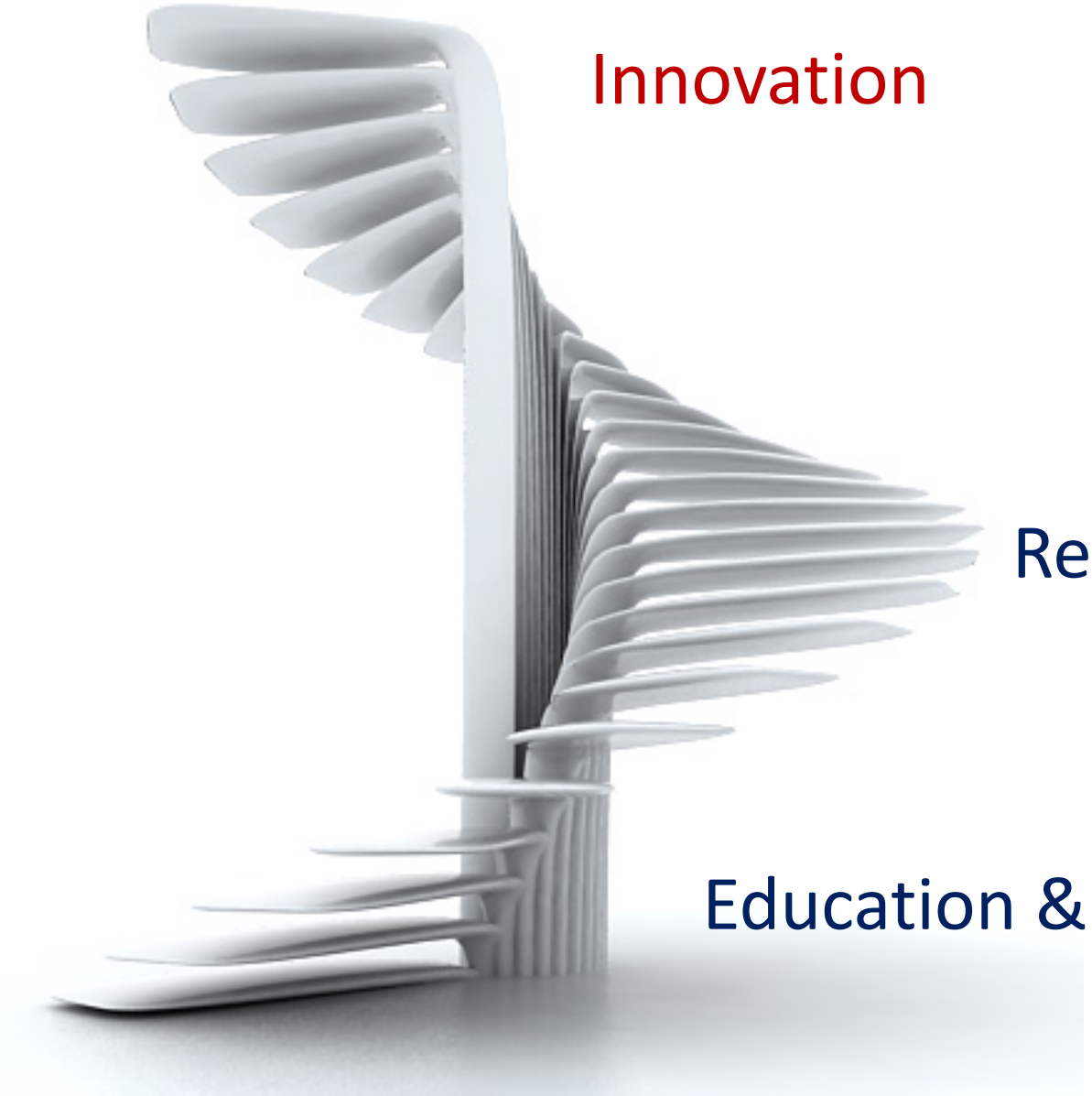
Translation:

Culture of enterprise & excellence

Switzerland created an ecosystem conducive to innovation by focusing on the framework conditions:

- keep bureaucracy small
- provide for social mobility via a) keep school drop-out rates low and provide young people with relevant job skills, and b) allow people at different ages & life stages to acquire new skills & change jobs

Ladder of Competitive Advantage



Innovation

Research

Education & Skills

http://www.torabiarchitect.com/blog/?p=39

What Nations can do ?

- 1/3 nations account for more than 90% of global expenditure on research & innovation
- Emerging nations are to invest more in research & innovation
- Incentivise universities and businesses to collaborate
- Test bedding opportunities for research led innovations
- Eliminate bottle necks associated with cross-border flow of talents
- Transparent and competitive IP policies
- Facilitate diverse learning pathways (academic, skills, & life-long)

- A global hub for a range of industries including financial services, transportation, pharmaceuticals and education
- Most millionaires per capita

Singapore 1965

- No water
- No Energy
- No Natural Resources
- No hinterland
- Migrants from India & China

Singapore is the 2nd most competitive country – World Economic Forum

Singapore is the 2nd most innovative country – by BCG, INSEAD, French Business School, and World Intellectual Property Organisation (WIPO)

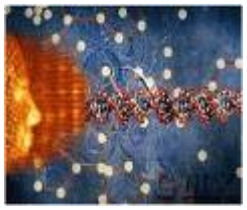
Singapore

- Education is the 2nd largest item in government spending (29%) for Government Budget 2012
- Growing importance of tertiary education & innovation

1960 - 1969
Labour intensive

1970 – 1979
Skill intensive

1980 - 1989
Capital intensive



1990 - 1999
Technology Intensive

2000-
Knowledge/ Innovation Economy

2012 ~ 45,000 RSEs

1990s ~ 5,000RSEs

R&D Investments

1991-1995:	$ 2 billion
1996-2000:	$ 4 billion
2001-2005:	$ 6 billion
2006-2010:	$ 13.55 billion
2011-2015:	$ 16 billion

Internationalization of Research at Home

One third of researchers are foreigners

Global Strategic Partnerships with

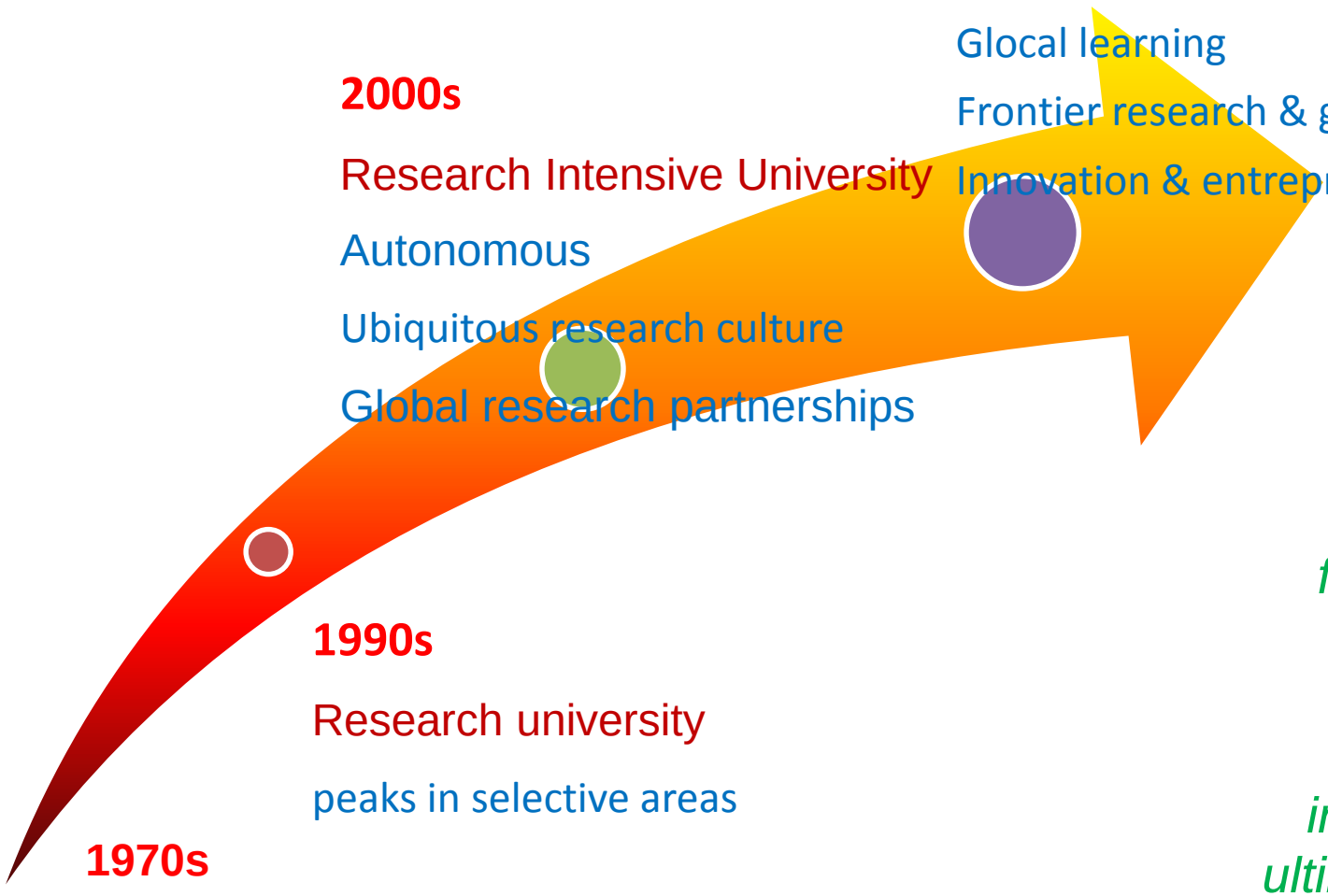
- MIT on infectious diseases, environmental sensing & modeling, Bio-systems & micromechanics, and future urban mobility areas
- ETH on future cities
- UC Berkeley on energy and building efficiency in tropics
- Technion on heart regeneration
- Cambridge University on low carbon chemical industry
- Technical University of Munich on electromobility in mega cities

CREATE is home to 1000 researchers in 650,000 sq ft research space

What a university can do?

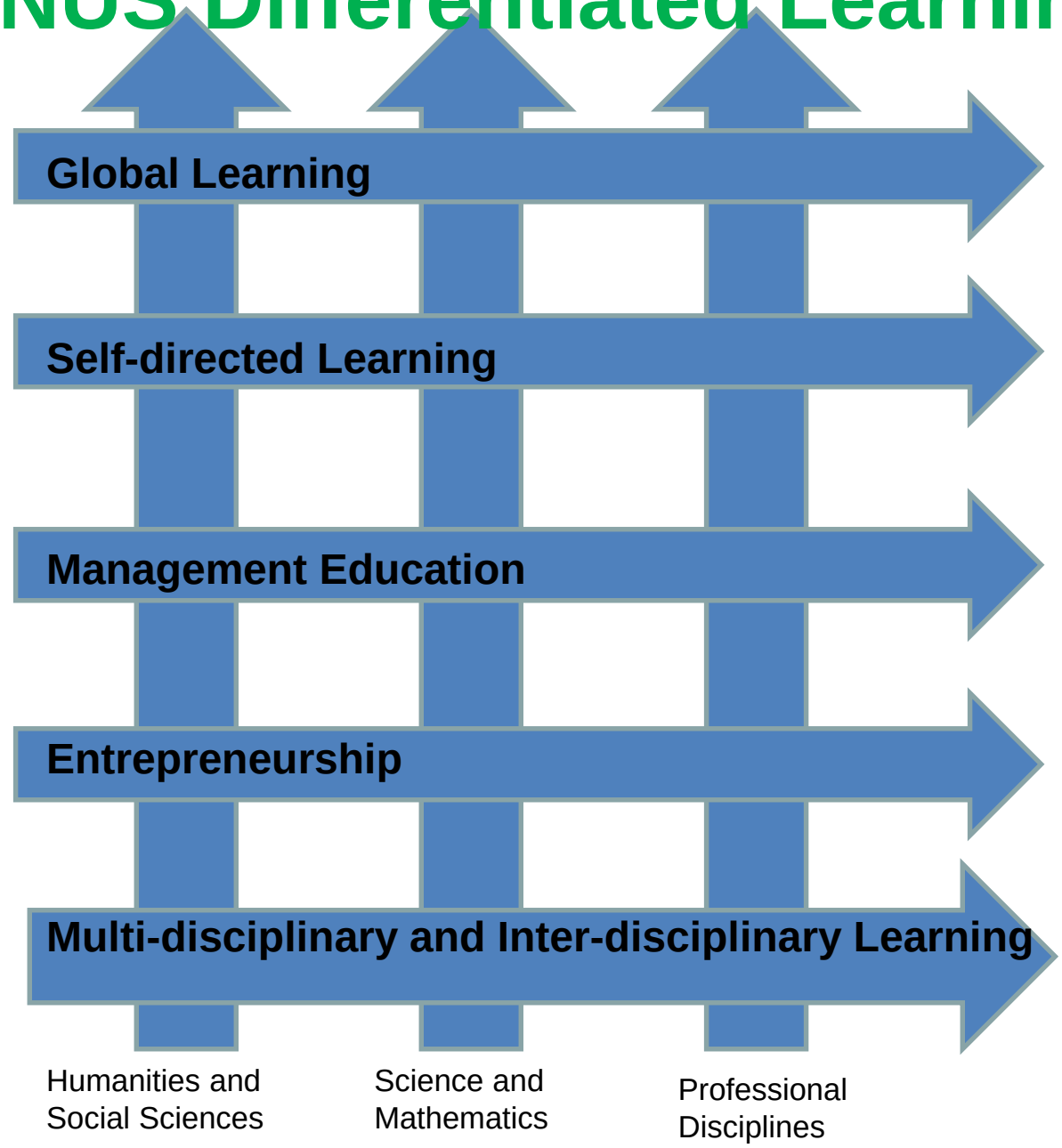
- Only 10% of tertiary education institutions (~20,000) worldwide are active in research & innovation
- Bench mark nationally and internationally
- New pedagogy for glocal education
- Actively seek out collaborations with society, businesses & industry
- Bring facts to the policy makers, philanthropists, and public
- Recognize and incentivise faculty members
- Facilitate exchange of students, faculty members, researchers
- Host diversity of talents

National University of Singapore



GRU(creative institution) facilitates new knowledge, technologies, talents, industries, and ultimately wealth for society

NUS Differentiated Learning



1. Local and/or overseas Internships and Attachments
2. Student Exchange Program
3. Summer Program

1. Undergraduate Research Opportunities Program
2. Project-based Modules
3. Honors Projects
4. Independent Study Modules
5. Residential learning in Halls
6. Service Learning

1. Minor in Management
2. Second Major in Management
3. Double Degree in Business
4. Masters in Management
5. Masters in Public Policy

1. Modules offered by Centre for Technopreneurship
2. Minor in Technopreneurship
3. Project in Startup
4. NUS Overseas Colleges
5. NUS Entrepreneurship Society

1. USP Core Curriculum
2. University Requirements
3. Faculty Requirements
4. Minor
5. Second Major
6. Double or Concurrent Degree

Engineering curriculum, pedagogy ?

- Technical competence
- Problem solving skills
- Work and communicate effectively in national and international context
- Character, ethics

National University of Singapore

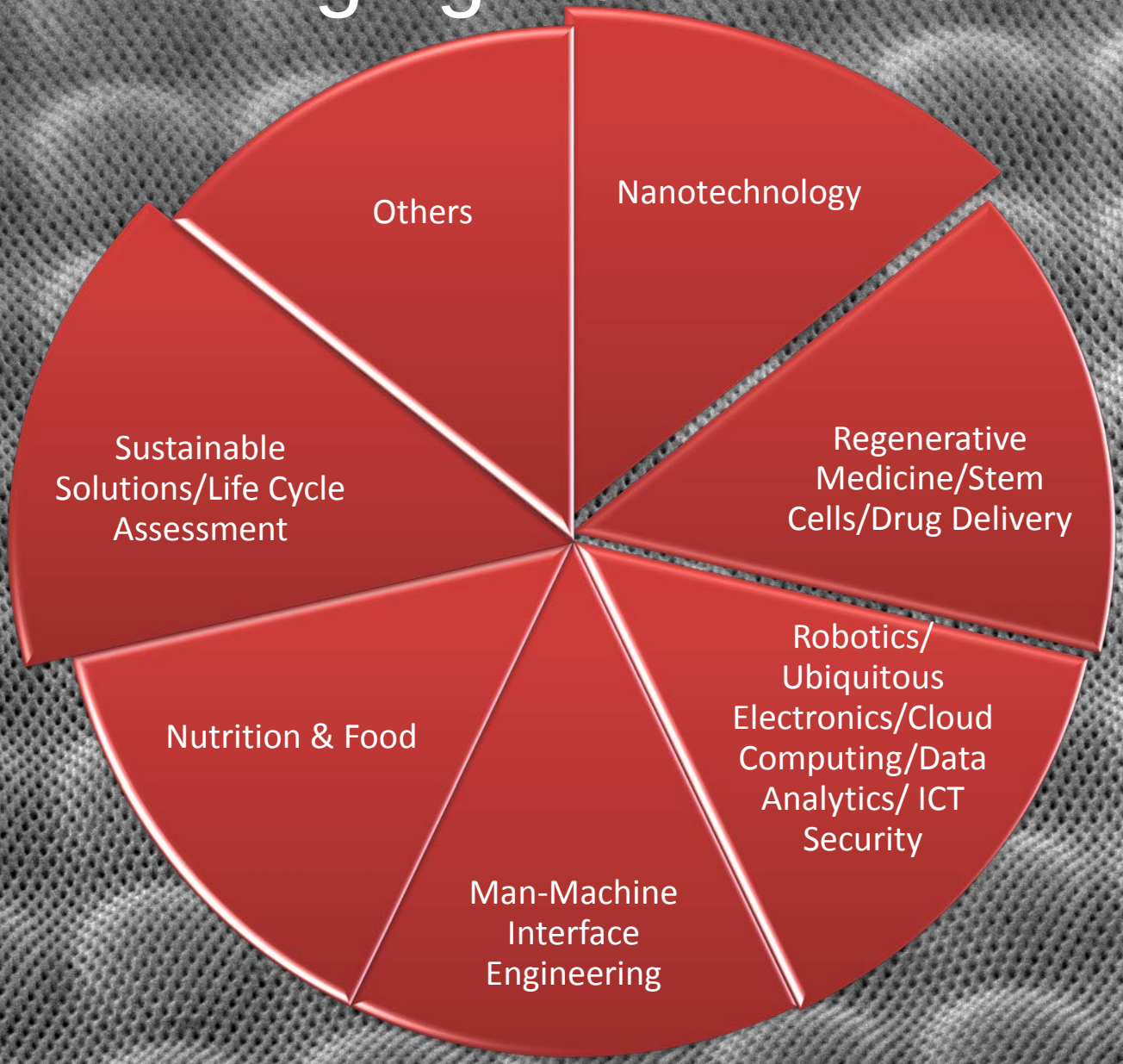
No 1 in Asia

Top 30 in the world

What an academic can do?

- At world-class research intensive university ~80% of the faculty are research active. This drops to ~0% for teaching only institutions
- Be visible nationally and internationally
- Collaborate within and beyond borders
- Design projects with students & community
- Consult & test bed projects with businesses & government
- Mentor students

Emerging R&D Platforms



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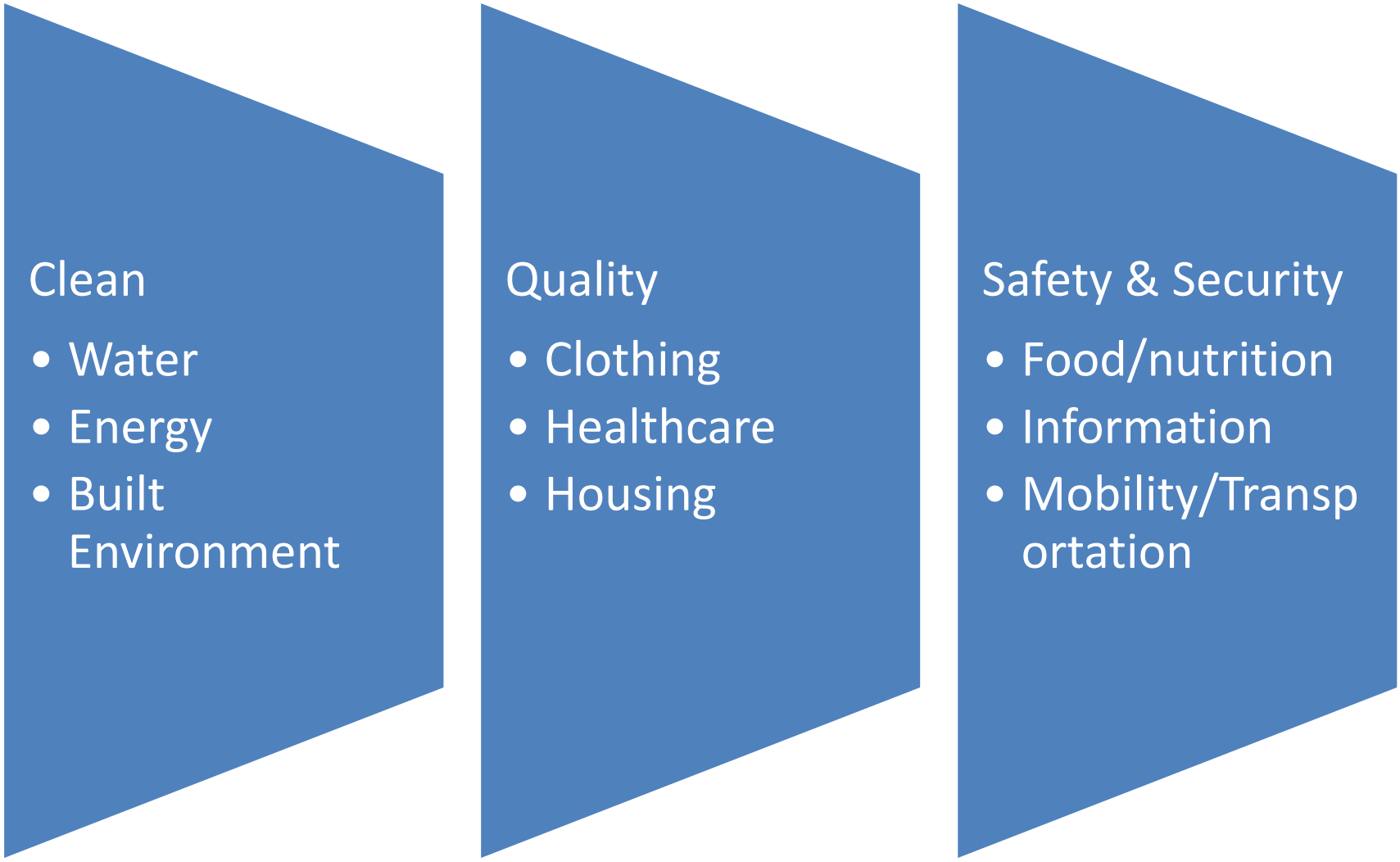
Societal challenges (Global Challenges)

While societal challenges are common across the world they are specific to the local conditions



Materials Today (2013) 16(4), 102-103

China to invest $349b in curbing air pollution

Plan highlights concern over public discontent

BEIJING – China plans to invest 1.7 trillion yuan (S$349 billion) to combat air pollution over the next five years, state media said yesterday, underscoring the new government's concerns about addressing a key source of social discontent.

The money is to be spent primarily in regions that have heavy air pollution and high levels of PM2.5, the state-run China Daily newspaper quoted Mr Wang Jinnan, vice-president of the Chinese Academy for Environmental Planning, as saying. Mr Wang helped to draft the plan.

Tiny floating particles, measuring 2.5 micrometres or less in diameter, are especially hazardous as they can settle in the lungs and cause respiratory problems and other illnesses.

The plan specifically targets northern China, particularly Beijing, Tianjin and Hebei province, where air pollution is especially serious, the paper said.

The government plans to reduce air emissions by 25 per cent by 2017 compared with last year's levels in those areas, according to the report.

"The thick smog and haze that covered large areas of the country in January has focused public attention on this issue," said Mr Zhao Hualin, a senior official at the Ministry of Environmental Protection.

China's State Council, its Cabinet, approved the plan last month, Mr Zhao said.

The newspaper said it was China's "most comprehensive and toughest plan to control, and in some regions reduce, air pollution by the year 2017".

A man wearing a mask on a street in Beijing. China's plan to combat air pollution specifically targets northern China, particularly Beijing, Tianjin and Hebei province, where pollution is especially serious. PHOTO: REUTERS

Mr Zhao said more details would be released later this month, at the earliest.

The government intends to issue two more plans to address water pollution and improvements to the rural environment over the next five years, the report said.

In December last year, China said it would spend 350 billion yuan by 2015 to curb air pollution in major cities.

Mr Chai Fahe, vice-president of the Chinese Research Academy of Environmental Sciences, said that China's leaders realised, after releasing the plan last year, that a tougher approach against air pollution was needed.

Smog over northern cities in January generated widespread public anger, as did the discovery of thousands of pig carcasses in March in a river that supplies Shanghai's water.

Social unrest over environmental complaints is becoming common across China, to the government's alarm.

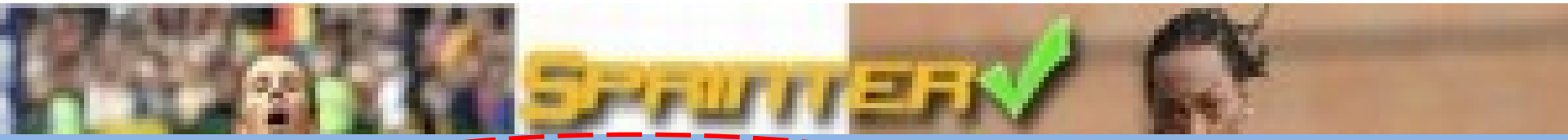
The authorities have tried to assuage anger with measures that included empowering courts to mete out the death penalty in serious pollution cases. But results so far have been mixed.

REUTERS

Healthcare is a growing sector in all countries

@GARDINER HARRIS

What a student can do?



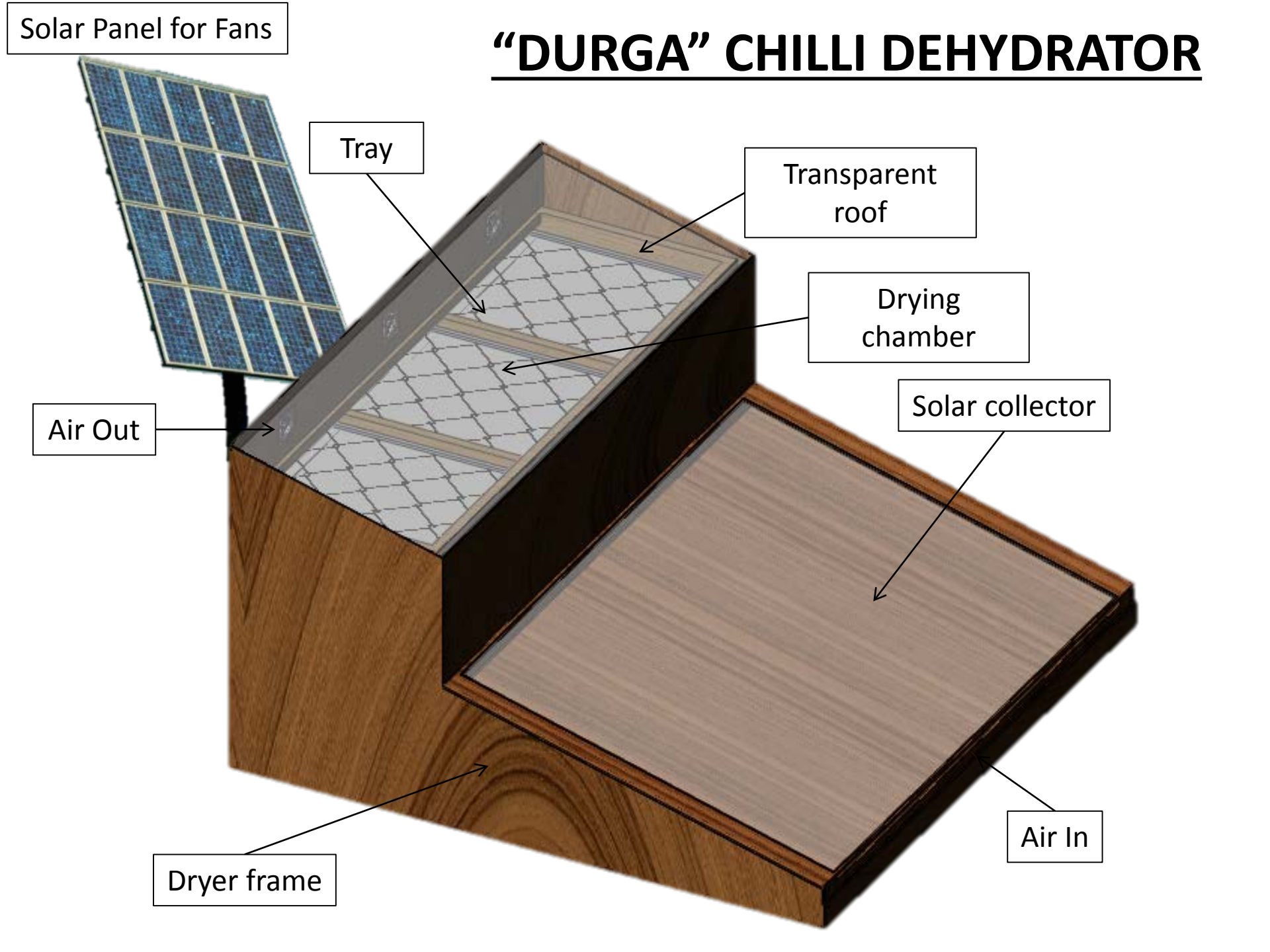
- ICT skills & communication skills
- T-skills
- Life long learning skills
- Overseas internships
- Attachments with businesses
- Team based experimental learning & projects

Green Tech Humanism Award
Green Tech Highest Popularity Award

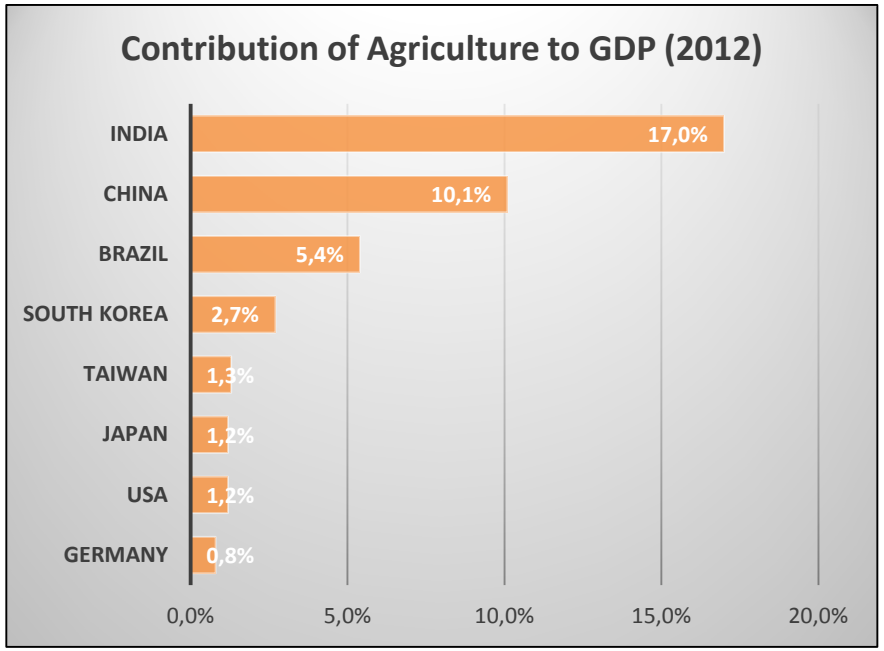
NUS
National University
of Singapore

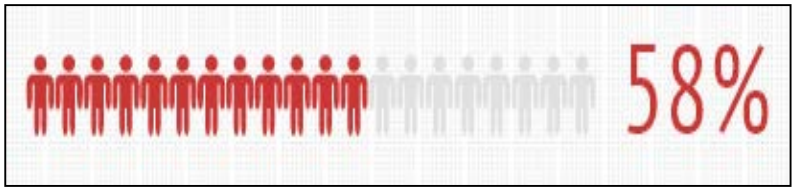
Low Cost Solar Chilli Dehydrator

“DURGA” CHILLI DEHYDRATOR



INDIAN AGRICULTURE



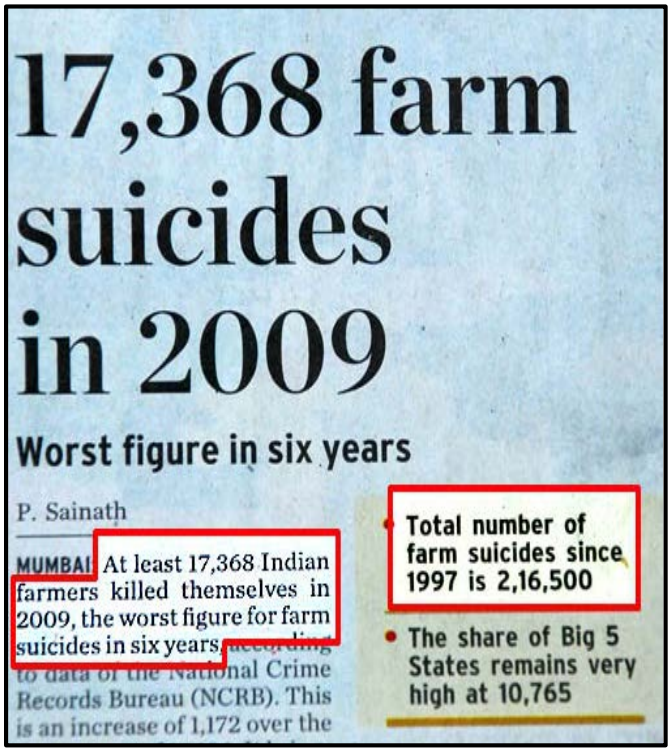


Of India's population is employed by Agriculture

Access to Technology → Distribution → Irrigation facilities → Harvest Spoilage → Skilled Labor Shortage → Corruption

Challenges in Agricultural Sector

DAILY CHALLENGES OF THE FARMER



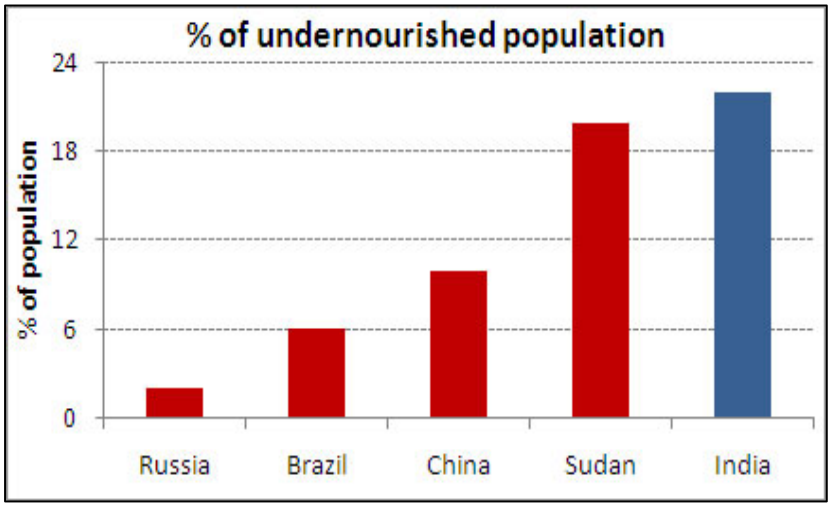
17,368 farm suicides in 2009

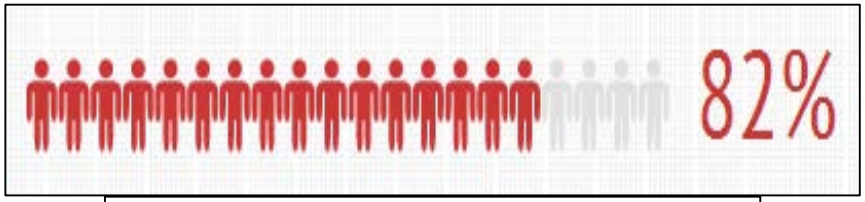
Worst figure in six years

P. Sainath

MUMBAI At least 17,368 Indian farmers killed themselves in 2009, the worst figure for farm suicides in six years, according to data of the National Crime Records Bureau (NCRB). This is an increase of 1,172 over the

- Total number of farm suicides since 1997 is 2,16,500
- The share of Big 5 States remains very high at 10,765





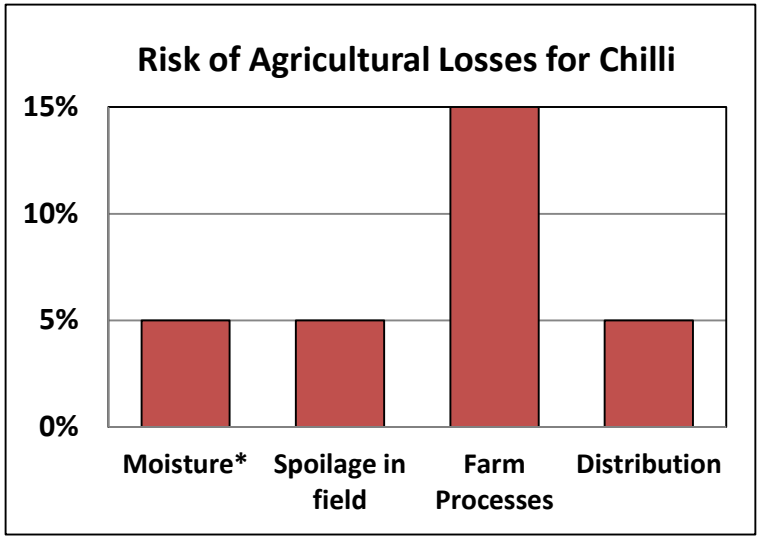
Farmers in Andhra Pradesh are indebted

Live on less than 2$ a day

CHILLI CULTIVATION

India is the largest producer & consumer in world

Andhra Pradesh contributes to 75% of exports




Harvesting

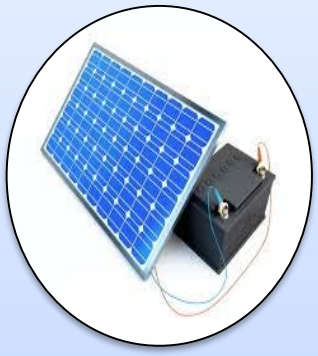

Open Sun Drying


Grading


Packaging

ENVIRONMENTAL FEASIBILITY

Powered by Renewable Energy



Independent of electricity from the grid

No Production of greenhouse gases

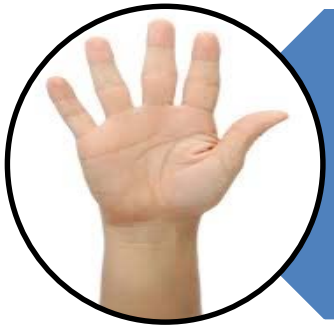
Easily available and locally sourced materials

Materials can be recycled or reused

VISION

Education

- An open University focusing on practical Engineering and Craftsmanship



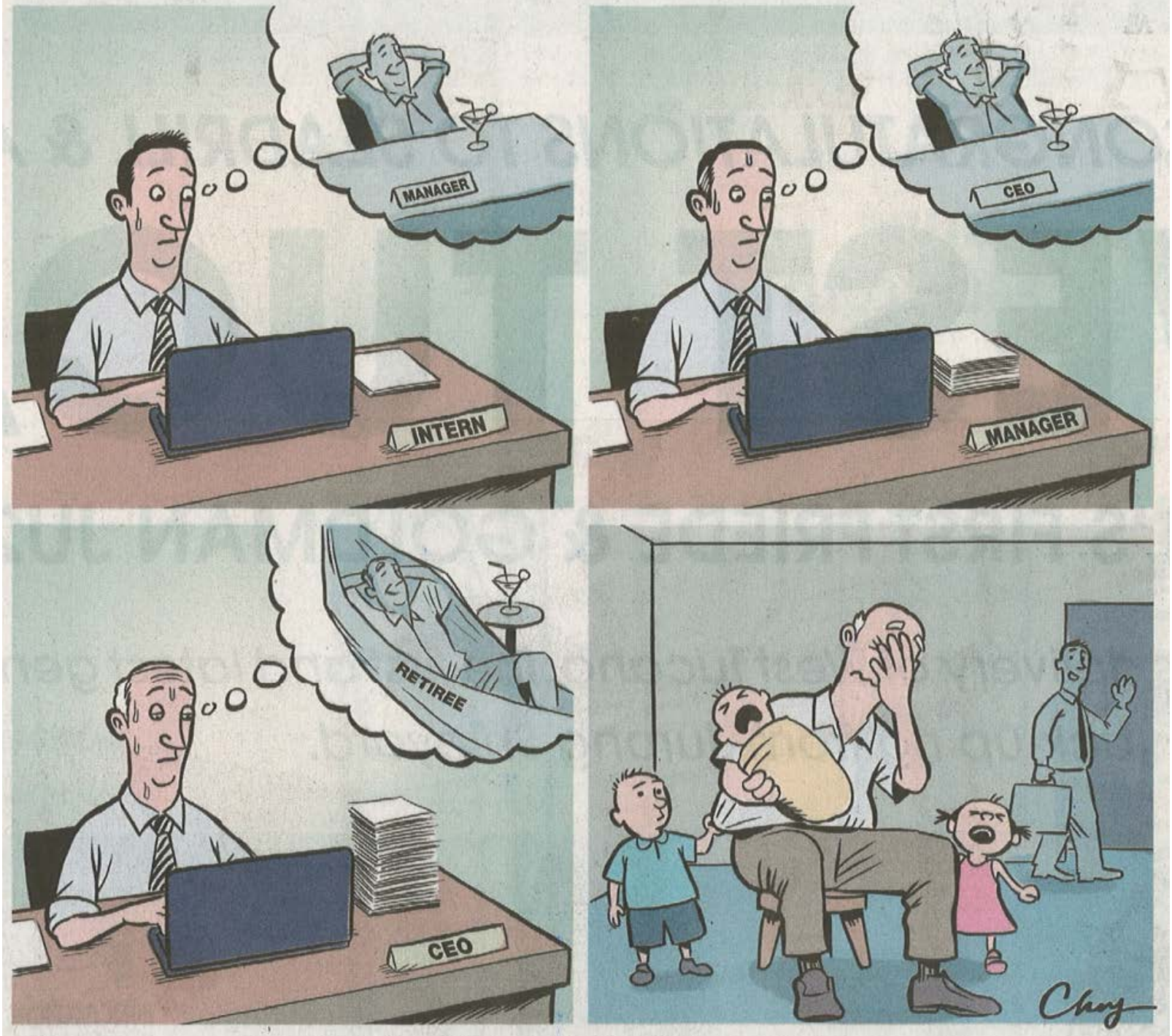
Empowerment

- Empowering local economies and uplifting poverty through micro-networks

Entrepreneurship

- Leading development by encouraging micro-entrepreneurship


CHANGE


MANAGER
INTERN
CEO
MANAGER
RETIREE
CEO

What businesses can do?

- ❑ Facilitate skills learning at tertiary institutions
- ❑ Invest in research & innovation projects at tertiary institutions
- ❑ Invest for long-term
- ❑ Co-locate infrastructure

Way Forward : Education

- Proficient in the use of ICT
- Problem solving skills & communication skills
- Life long learning
- Knowledge of diverse cultures & laws
- Real world experience
- Good mentors are even more necessary given the information & marketing over load

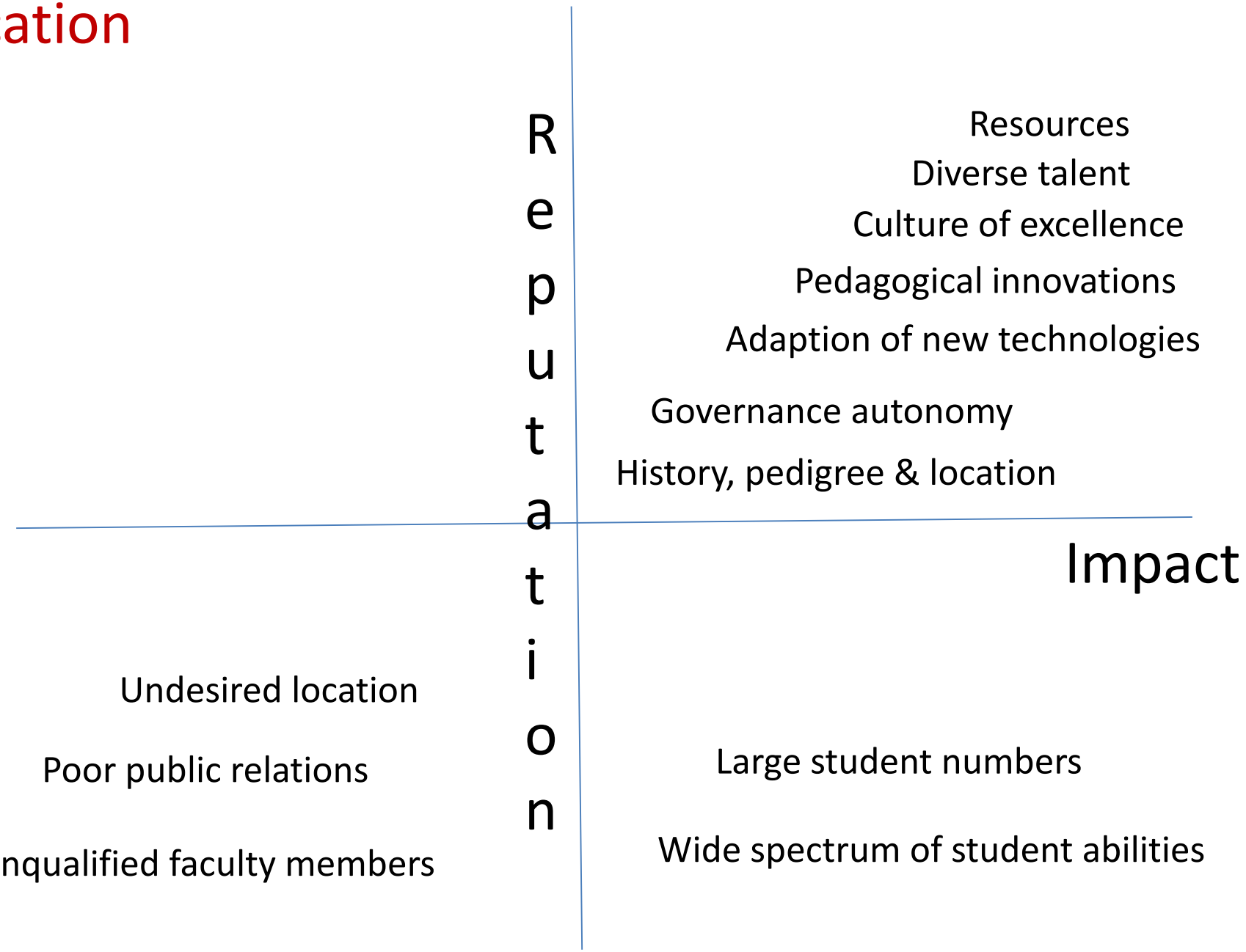
Way Forward : Research & Innovation

- Address societal challenges
- Customization to the glocal markets
- Innovations facilitated by super-disciplinary approaches
- Leverage global cooperation and networks

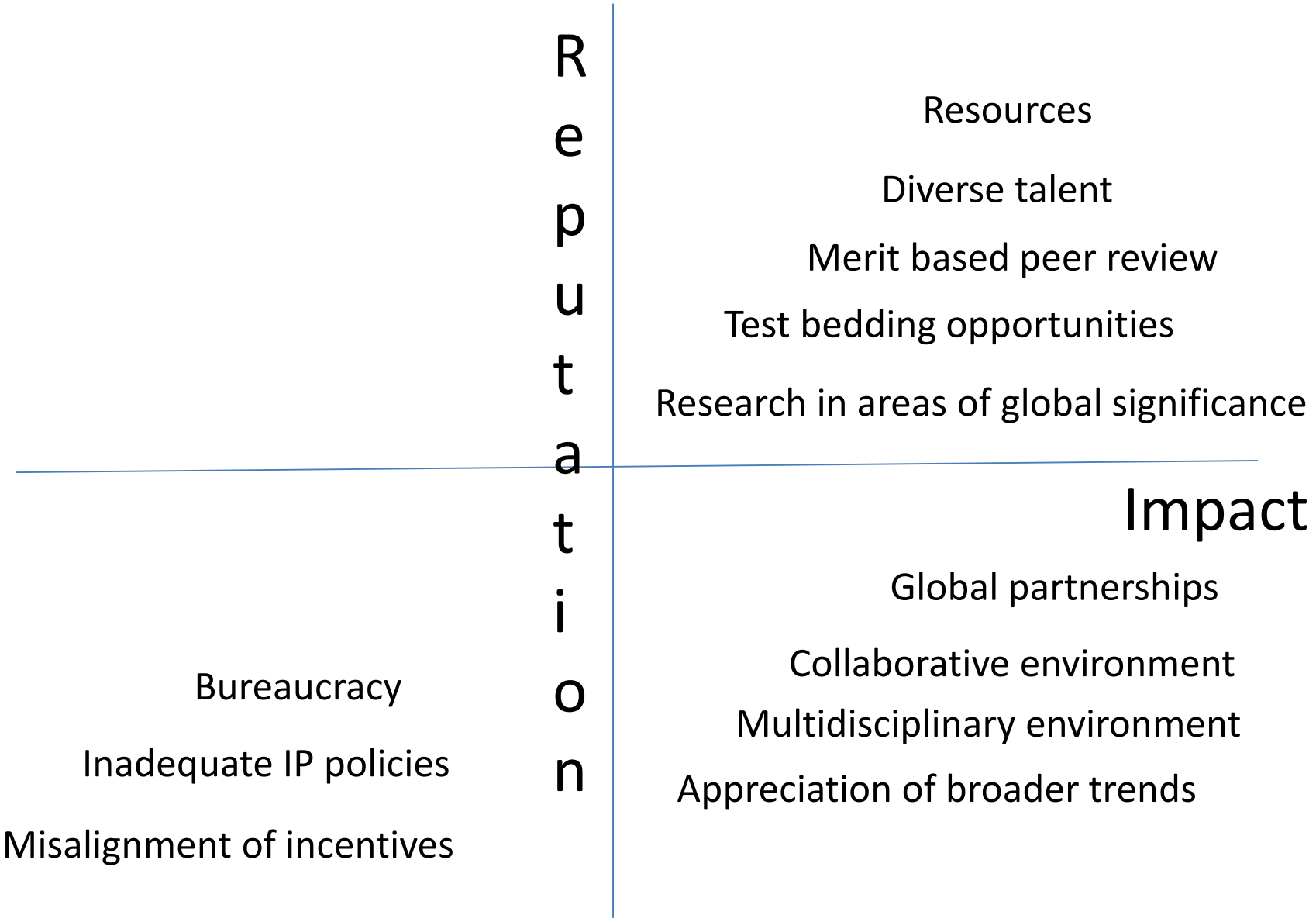
Conclusions

- Innovation is fostered by the spread and democratization of information
- Innovation is fostered by the educational opportunities while tolerating failure

Education


Reputation
Impact
Resources
Diverse talent
Culture of excellence
Pedagogical innovations
Adaption of new technologies
Governance autonomy
History, pedigree & location
Undesired location
Poor public relations
Unqualified faculty members
Large student numbers
Wide spectrum of student abilities

Research & Innovation



- Scientists can do the fundamentals, but..
- Only the engineers can translate ideas into scalable products & real-life applications
- Democratization of education, research and innovation enables social mobility

If everything else is equal, the key differentiators of competitiveness of nations are education & skills of people, scientific research capacity & new knowledge generated, and ability to innovate products, services & governance. Since the World War II democratization of tertiary education happened in USA, followed by Europe and rest of the world. This has been realized via growing the number of universities, expansion of enrollments, allowing variety of education providers (public, private & combinations), embracing distance education programs & life-long learning programs, and more recently on-line education. With the tertiary education as the backdrop, the democratization of scientific research & new knowledge occurred over the past decade. Many countries around the world facilitated scientific research on their shores. Globalization of trade, finance & talents, and availability of modern information & communication technologies accelerated the process. The democratization of innovation is in embryonic stage. Glocalization of products & services, and strategic partnerships will accelerate the process of democratization of innovation. What is next in education, scientific research, and innovation in order to be competitive?