HUMAN RESOURCE DEVELOPMENT TO MEET THE CHALLENGES OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTs)

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Preface

The phenomenal growth of the software industry in India – more so, its export performance – has been defying rational explanations. The hype associated with this growth has been built up into a mystique of some sort. All of us – inside the government and outside – have begun to believe that there is an inevitability underpinning this phenomenon. The industry has been moving from success to success because software is peculiarly matched to the Indian genius. We can't help succeeding doing business in software.

This mystical belief conditions all our thinking and has given rise to a single-minded obsession about promoting software export activities in India. This has also warped our thinking concerning the best way to generate quality software-workforce to meet our present and future requirements.

In this Report I have tried to get behind this mystique and analyze the human resource development (HRD) problem from a broader perspective in terms of actual ground realities. I have tried to formulate a 4-level expertise generation framework based on "desired ideal" criteria. Using the framework I have tried to tackle the implementation problem in going from the "desired ideals" to "plausible actualities".

The formulation of the 4-level framework and the suggested implementation strategies are purely suggestive and call for in-depth discussions on a national scale. I hope sincerely that this report would get widely distributed and would generate constructive discussions among all those concerned with the future of the deployment of Information and Communication Technologies (ICTs) in India to upgrade industrial performance in general, and software activities in particular.

This Report could not have been written without the help and advice of P. Sadanandan and S.P. Mudur of NCST. Clearly, however, they should not be held responsible for the sentiments expressed in the Report. Also, I thank them for contributing Appendix I on the educational and training programmes of NCST. I thank also all the other staff members of NCST who have contributed to the preparation of the Report.

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1. Background

The single most extraordinary development in the Indian industrial scene during the last decade and a half has been the phenomenal growth of the Indian software industry, especially its export performance. It does not seem that in the foreseeable future – say, in the next decade or so —- the growth of the software industry in India would slow down. Software exports of USD 50 billions, from the present level of USD 2.5 billions, are seriously being targeted in 10 years from now. In this context, both within the government and outside, anxieties have been expressed on the ability of our educational system to meet the challenge of producing enough software specialists. Ad-hoc solutions have been proposed: for example, to increase the intake in IITs in the software specializations; to start additional institutes of the caliber of the existing IITs; to up-grade the Regional Engineering Colleges (RECs) to the level of IITs; and so on. Before panicking and rushing off pursuing a variety of disparate solutions, it's worthwhile to pause at this stage and try to understand, from ground up, the nature of the problem that confronts us. In this paper, I attempt an analysis of the software education problem as one facet of a larger problem of human resource development to meet the challenges of a world that is rapidly undergoing change due to the dominance of information and communication technologies (ICTs).

If it is true that technology 'push' is transforming this world into a *global village*, then, the ultimate requirement for survival is to be able to function as a significant *contributing* member of this global village. The skills one equips oneself with, and the knowledge one is able to command of this world (near-by and far-away) are determinants of the kinds of roles one can play in this global village. The skills one acquires, whether as part of in-school training, or through individual initiatives at home, must be *marketable* in this global village. In a world dominated by ICTs, survival demands that one's skills are ICT-friendly, and the products one makes are designed and/or manufactured with ICT-friendly processes.

"This does not imply that everyone should acquire the specialized competencies of a software engineer or a programmer. India's economy needs people specialized in a variety of skills and conversant with the use of modern tools in their own varied specializations. The needs of domestic computerization on a large scale, and new challenges such as e-commerce, can only be met by involving every arts, science, and commerce college — in addition to engineering colleges and institutes of technology — in addressing the relevant educational needs as part of general education."

"Truly multi-disciplinary education is involved in preparing young people to use modern tools in their own fields of expertise, and to compete with others in the world in a global market. For instance, proper exploitation of the WWW-technology demands expertise in commerce, design, arts, advertising and marketing." Meaningful work in such technologies can be undertaken only by interdisciplinary teams.

2. Knowledge Societies[1]

"At the micro-economic level, the 'knowledge intensive' economy is experiencing rapid growth in the information intensive services and manufacturing. The borderlines between manufacturing and services are becoming blurred. For example, inputs of information-processing services have reached 70% or more of the total production cost of automobiles. In this and other manufacturing sectors, 'over ¾ of the value of a typical "manufactured" product is already contributed by service activities such as design, sales and advertising'.... This clearly creates a major challenge for formal and informal education and training systems in the developing countries (DCs): (p.56)

"The formal institutions of education that exist today, and even many of those in the planning stages in the DCs, are becoming less relevant to the requirements of emerging 'knowledge societies". It is important for these countries to reshape educational institutes in a way that is consistent with their developmental priorities". (p.67)

"If international telecommunication costs continue to decline, telecommuting or teleworking could result in a shift of certain jobs away from industrialized countries to lower-cost, high-skilled DCs. Teleworking includes home-working, satellite-centre working (where an office provides facilities for work at a distance from the firm), telecentre-working (where an office is shared by several firms), distance group-working, and teleservices such as telesecretarial and tele-maintenance services". (p.248)

"The teleworking jobs that are being exported involve high-level, creative, and professional skilled work, as well as low-level information-processing and clerical jobs..... It is forecast that new jobs are likely to grow in areas such as bio-medicine, aerospace and semi-conductor design.... Countries in the Caribbean region, for example, are becoming financial services "back-offices" for Wall Street in USA... So far, outsourcing of jobs in the service sector is occurring mainly in accounting, airline ticketing, data-processing, health care record processing, insurance claims processing, credit card handling, toll-free telephone services, and some aspects of software development.... Most strategic decision-making roles are being retained in the industrialized countries." (p.248)

A recent publication of OECD (OECD 1996) claims: "Whatever else may be said about the emerging socio-economic system, it seems clear that more people are required to take economic initiatives and that a much broader view of what "enterprise" means is needed. ......" (p.60)

"The most fundamental requirement is undoubtedly a radical change in education. The industrial revolution required a salaried labour force based on *specific* qualifications which provided the basis for life-time insertion into a mass production economy and the social structure. Now, many more people are required to take economic initiatives and to be responsible for reconstructing their 'human capital' over the life cycle. The fundamental changes needed in education and training ..... are an essential foundation for moving towards a more entrepreneurial culture. They could be succinctly depicted as a move towards life-long learning for self-development through more flexible careers.

[1] The early part of this Section consists of paragraphs excerpted from (Mansell & Wehn 1998)

Such radical changes cannot be achieved without more integration between Ministries of Labour and Ministries of Education." (p.60)

Concerning the economic initiative that needs to be taken at the level of individuals, the OECD report says: "The contemporary entrepreneur is not only someone who comes to the market with capital to buy machines and hire labour. More often it is someone with skills and knowledge and the will to attract capital. She/he will often come from a socio-economic background where there is no commercial or entrepreneurial tradition. Success in entering and staying in the market is dependent on a whole range of conditions through which policy can influence both the decision to take the plunge and the capacity to survive." (p.61)

3. Specifying a Desired Ideal

How shall we go about creating well-trained and knowledgeable human resources to meet the challenges posed by ICTs as discussed in the above excerpts? I shall, in this section, formulate a "desired ideal" in terms of a 4-level skills and knowledge acquisition scenario[2]. It must be emphasized that our specification of our 'desired ideal' and the action agenda to get there are entirely tentative. I hope that the articulation of the problem, as well as a plausible mode of tackling it, would generate constructive discussions out of which a consensual implementation strategy for **change** would arise.

Level O : Universal Prerequisites

With ICT becoming a pervasive technology, *to access the full potentials* of an ICT-dominated world *every* person should become ICT-literate. Minimally this means full familiarity with the use of a personal computer, and basic proficiency in the fundamental tools of personal computing such as e-mail, word-processing, spreadsheet, databases, and, of course, the use of the keyboard and the mouse.

Students going through formal education should, in addition, be proficient in:

- ***Communication:*** Oral communication, general and technical writing, and listening skills.
- ***Quantitative and Qualitative Analysis:*** including discrete mathematics, basic introduction to statistics and calculus.
- ***Organization Functions:*** introduction to economics, accounting, finance, human resources, marketing, production, etc.

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[2] We must emphasize that we are here concerned only with the ICT-expertise that make-up the knowledge and skills at each level. We are not spelling out here the *domain knowledge* that relates to student specializations such as 'Physics', 'Chemistry', 'Mathematics', 'Commerce', 'Business Administration', and so on.

It is also important not to confuse the 4-level scenario presented here with the 4-level (O, A, B, C) specification of curricula by DoE in their DoEACC scheme. Our concern here is not with the development of additional degree or diploma courses in Computer Science to meet the needs of the market. We are emphasizing the need for *integrating* training in ICT knowledge and skills with the education system in its entirety. Some modules from DoEACC may be of use in our training scheme, of course.

Ideally, every student passing out of +2 must have acquired these prerequisite skills and foundational knowledge.

Level 1: Entry-level Skills & knowledge in Information Systems (IS)[3]

- Thorough familiarity with Level O skills and foundational knowledge.
- Familiarity with and competence in the use of vendor-delivered products intended for general use. This implies working-level knowledge of similarities and differences between products with overlapping functionalities (e.g., different word-processing packages) and the ability to choose the best product to meet given requirements.
- Similar know-how and skills in the use of products incorporating knowledge in domains one is specializing in (e.g. products like MATHLAB, SPSS, SAS, AUTOCAD, SAP, etc).
- Capability to be trained to use customized (and/or home-grown) products.
- Familiarity with presentational graphics and their use in the generation of appropriate visual aids for popular or technical presentations. This implies the availability of foundational design know-how: layout, lettering, colour contrast, drawing, etc.

Ideally, all first degree holders from liberal arts, science, and commerce colleges must have acquired Level 1 skills and knowledge of Information Systems (IS).

Level 2: Operating with Available Technologies[4]

- Level 1 skills and knowledge are prerequisites.
- *Knowledge of how* Information systems (both hardware & software systems) work rather than *mere skills in using* them.
- Enough knowledge of programming, data-structures, and mathematics, to be able to design and implement application packages in areas in which one has the requisite domain knowledge.
- Advanced technical writing skills to be able to write, and/or supervise the production of, "help" manuals at various levels of detail and complexity. ("help" manuals could be technical maintenance manuals or user manuals.)
- Articulating requirement specifications and/or translating requirement specifications into systems specifications and design.

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[3] Information systems are engineered systems based on ICT with desired input-output specifications. To create such engineered systems (also called 'system integration' usually) both hardware and software skills and knowledge may be needed.

[4] Levels 2 and 3 relate primarily to students majoring in engineering. Level 2 roughly corresponds to students working for a first degree in engineering. Level 3 corresponds to students working for higher degrees (Masters, Doctorate) in engineering, and also those engaged in R&D activities in R&D organizations.

- Enough basic IS expertise to maintain (i.e. debug/rectify) application packages of various levels of complexity.

Level 3: Generating New Technologies

- Full-fledged IS expertise.
- Knowledge in cutting edge aspects of current technology.
- Ability to add to technology or generate new technology in one's specializations: e.g., graphics, networks, database techniques, operating systems, etc.
- Enough technical and user understanding of the markets to judge what product innovations would sell.
- Enough production know-how and grasp of marketing details to assess rationally the cost of product/process innovations.

Figure 1 summarizes our 4-level HRD scenario. It is important to note several implications of this 'flow-chart'. To begin with, the identification of the usual academic degrees (B.A., B.Sc., B.Com., etc) with one or other of the 4 levels, pre-supposes that the formal education leading to these degrees has been 'augmented' through the integration of the ICT skills and knowledge associated with these levels as discussed earlier in this section. We shall discuss later in this paper some options available to achieve this.

Secondly, as earlier indicated, the skills and knowledge training in ICT covers the entire general education system from +2 through post-graduate levels. This enables us to indicate career paths in the ICT industry at suitable levels for those leaving the formal educational stream at any of the 4-levels. Despite the 'augmentation' of formal education, 'Industry Training' at each level is necessary. However, now, these training programmes need not be 'general' but can be more 'particularized'. The human resources available to the industry at each level come with better training in the skills and knowledge associated with that level. Of course, some candidates qualifying at the higher levels might set themselves up as entrepreneurs. This has not been indicated separately in Figure 1.

Lastly, it will be seen that larger numbers of students form part of the general educational system in levels 0, 1 and 2. Consequently, it is cost-effective to ensure adequate ICT training, as specified in the scenario, at these levels first, rather than targeting augmentation of existing IITs to produce more B.Techs and M.Techs, or creating new IITs. We shall consider the relative merits of these alternatives, in detail, in the following sections.

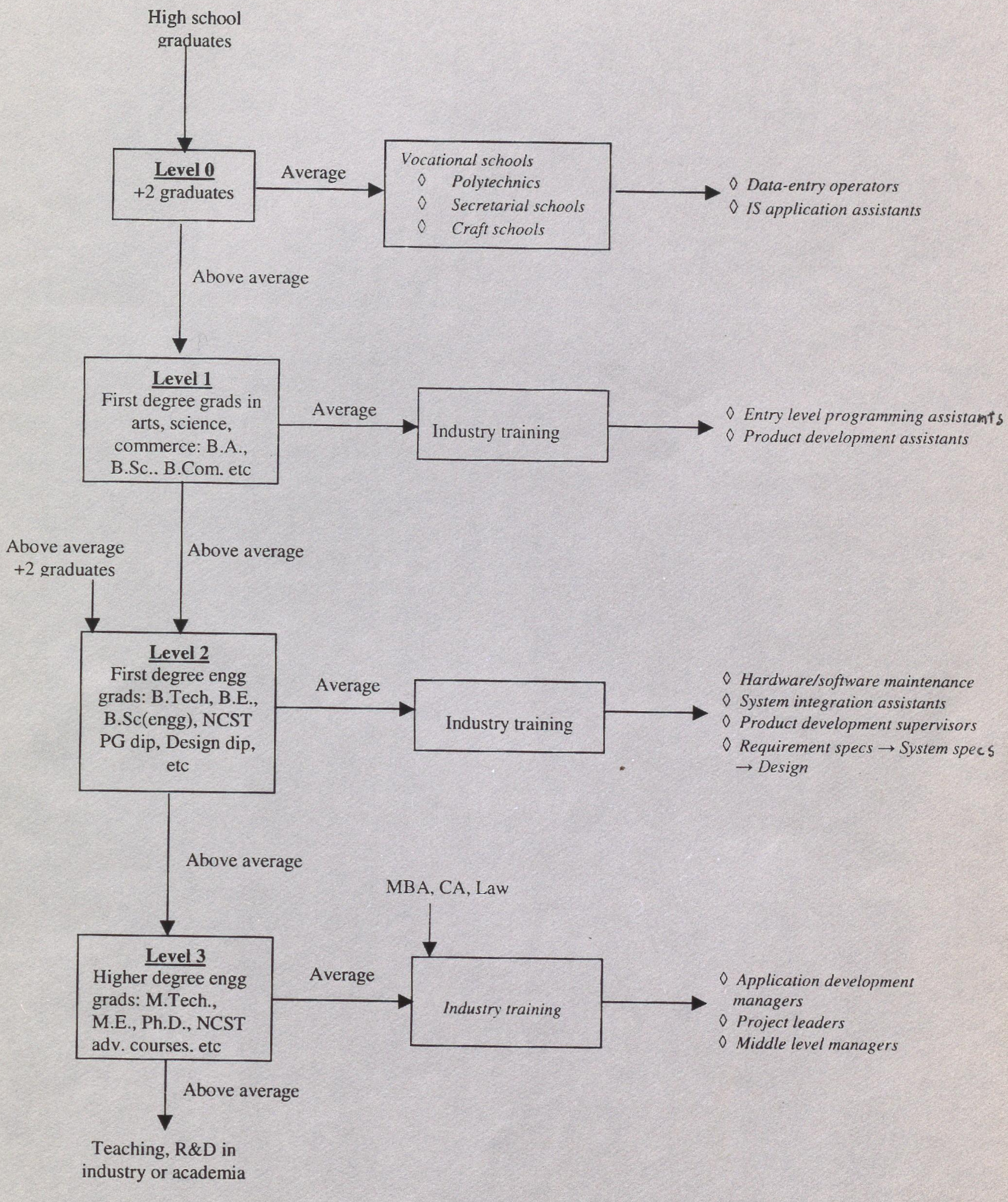

Figure 1: The Four-level HRD Scenario and its Deployment for meeting ICT Requirements

4. Bringing about CHANGE: Opportunities

Our specification of the "desired ideal" in the form of a 4-level scenario, and its summary as a flow-chart in Figure 1 in the last section, raise some fundamental questions about plausible strategies for converting "ideals" into "realities". The 4-level scenario also opens up several opportunities to strengthen the ICT industrial base in India. In this section we shall discuss these opportunities. In the following section we shall look at some strategies for converting "ideals" into "realities".

The ICT industry in India, for all its creditable global performance, suffers from several weaknesses as is well-known to most major actors in this sector. The Prime Minister, while inaugurating the HiTec city in Hyderabad, identified one such major weakness. He is reported to have said, "the benefits of IT could not remain confined to the *well-off* and the *English-educated* ..... I will consider my government's commitment to IT fulfilled only when it improves the life of the poor and the powerless." (Deccan Herald, Bangalore, Nov 23, 1998)

Secondly, although the power of ICTs stems from the coming together of information and communication technologies, the prevalent tendency in India is to talk exclusively about IT, to identify IT with the software industry, and to stress, exclusively again, in all discussions *the export performance* of the Indian software industry. In such discussions one tends to forget that ICT is primarily an enabling technology and an infrastructural one – like electric power technology. **The real benefits of ICT would accrue to a country only to the extent that ICT is deployed to innovate and improve the performance of other industries and services in general.** The absence of such a realization is, again, the prime reason for the almost total absence of an informed domestic market for ICTs in India.

The single-minded obsession with exports — both on the part of the government and of the industry — has resulted inevitably in a situation where, in 1998, the top 20 exporters accounted for 61% of the total revenue of the industry. The industry is not only top-heavy, but due to the failure to open up a viable domestic market, there has been no evolution of a long-term strategy to grow and nurture small and medium-scale enterprises in ICT-based activities.

The Indian software industry, as structured at present, has been a relatively poor employment generator. "Employment in the mid-90s represent about 8% of the total electronics industry employment, and just 0.5% of the total manufacturing employment in India. It is estimated that there are 20,000 people actively employed in software export services. Contrast this with the 3 million registered unemployed graduates in the 90s." (Heeks 1996)

Since 1996 when Heeks wrote this, undoubtedly the employment figures in the software industry have grown significantly. Nevertheless, the thrust of Heeks' criticism continues to remain valid. While on the one side the industry is clamouring for *well-trained, immediately employable engineering graduates*, the number of educated unemployed has been growing out of control. It is worth pondering how this discrepancy arises. Even a superficial analysis of figures 2 and 3 would show that students who leave the formal educational stream at the +2 level, or with degrees in arts and science (B.A., B.Sc.) enter the employment market essentially with no applicable professional skill, or applicable professional knowledge. It is not unusual, in a city like Bangalore, to come across B.Sc. degree holders opting to drive autorikshaws or taxis because those jobs are more remunerative. The real challenge – a massive one by any reckoning – is to equip these students with the relevant applicable skills and knowledge *BEFORE* they enter the employment market.

The Indian software industry has also been suffering from rapid staff turnover, rapid escalation of staff salaries, and a serious dearth of middle-level project management and professional supervisory staff.

An analysis of Figure 1 would show that most of the current weaknesses of the Indian software industry would be made less serious by promoting our 4-level scenario. At present the software industry tends to recruit the major part of its input from levels 3 and 4, that is, from the high-end of the ICT skill and knowledge spectrum. Because of the small numbers available for recruitment at these levels, the competition turns out to be keen and, as a result, the salaries demanded and offered unnaturally high. In spite of this, because the subsequent task challenges do not match the professional expectations of the recruited candidates, the staff turnover tends to be high. Much of the brain-drain stems from these levels.

On the other hand, most entry level recruitment should address itself to candidates who qualify for recruitment at levels 0 and 1or, at most, 0, 1 and 2. Notice that the candidates qualifying at these levels satisfy two desirable prerequisites: their numbers are large, and their geographical spread covers most of the country – urban and rural. In addition, they are not all likely to be exclusively English-oriented. Also, if properly trained in leadership and entrepreneurship qualities, small- and medium-sized ICT enterprises should be capable of being established in various parts of the country involving these candidates. These establishments should be able to provide ICT-based services *within* the country[5]. These SMEs (small and medium enterprises) should thus become constituents of a much-needed *domestic market* for ICT services. These SMEs should be capable of providing a variety of services to the middle-class households and the trade and business establishments such households interact with.

One other long-term disservice done to the country by opting to recruit – with unnaturally high compensation packages – over-qualified engineering graduates to execute fairly routine tasks, is to deplete teaching institutions and R&D laboratories of potential middle-level leadership and, often, of high-level leadership.

Figures 2 and 3 identify a wide variety of production industries and service industries that are part of the Indian industrial scene which should benefit through the ICT services capable of being provided by the SMEs indicated above. Note that currently ICT

[5] These SMEs should also be able to handle outsourced ICT-enabled services (transcription, back-office data processing, etc.) which are generally acknowledged to be a market worth several hundred billions of USD. Clearly, there is a vast scope for providing such services within the country. Because of the current obsession with exports, these internal markets remain totally ignored.

penetration into the Indian industrial scene (identified in Figures 2 and 3) is, to say the least, very superficial.

5. From "Ideals" to "Realities"

In Section 3, a 4-level scenario was outlined for equipping students, at various levels in the educational system, with ICT skills and knowledge of marketable value. The essential requirement was that this equipping process should be *integrated* with the normal educational process. The outcomes of the equipping process – that is, the skills and knowledge acquired as a result – were listed earlier in terms of desired "ideal" end-conditions. The task confronting us now, in trying to go from specified ideals to actual realities, is to spell out implementable ways of dealing with the following issues:

1. In order to arrive at the desired end-results at each level, specify the additional modules that have to be incorporated in the teaching/training programme. This is essentially a matter of curriculum development. Assessment procedures and the identification of (or generation of) appropriate reading material should also be specified.
2. Who will teach these additional modules? If new teachers are to be recruited, where will we find them? If existing teachers are to handle these additional modules, how will we train them?
3. What are the infrastructural requirements?
   i) Typically, in our case, how many PCs are needed? (That is, what is the minimum admissible PC-student ratio?)
   ii) What are the student-student, student-teacher and teacher-teacher connectivity requirements?

Clearly, one cannot expect to find ready-made, implementable solutions to each of these issues. These are precisely the aspects of the overall problem which require constructive discussions in depth. I hope such constructive discussions would follow the articulation of the problem attempted here. In the rest of this section, I shall confine myself to making a few remarks and comments which, hopefully, would be of value in initiating and sustaining such discussions.

To begin with, for our present purposes of converting ideals to realities, I shall reduce the levels to two by combining together levels 0 and 1, and levels 2 and 3. Let me first consider the second of the two cases.

<table>
<tr><td rowspan="9">ENERGY
Wood
Biogas
Wind
Oil
Electricity
Thermal
Hydel
Nuclear
Fusion
Solar</td><td>FISHERY</td><td>FOOD, BEVERAGES, TOBACCO</td><td rowspan="3">CHEMICALS PETROLEUM & COAL PRODUCTS
• Basic Chemicals Fertilizer
• Paints, Inks, Explosives Pesticides, Soaps, Pharmaceuticals, Cosmetics
• Liquid Fuels, Lubricants</td><td rowspan="3">VEHICLE MANUFACTURE
• Road
• Rail
• Sea
• Waterways
• Air</td></tr>
<tr><td rowspan="2">AGRICULTURE
Food Crops
Cash Crops
Livestock
Meat
Poultry
Dairy</td><td>TEXTILES, CLOTHING FOOTWEAR</td></tr>
<tr><td>WOOD, WOOD PRODUCTS</td></tr>
<tr><td rowspan="2">FORESTRY</td><td>PAPER , PAPER PRODUCTS</td><td>WOOD & METAL CRAFT - WORK</td><td rowspan="2">ELECTRICAL GOODS
Components
Equipment</td></tr>
<tr><td>IRON & STEEL NONFERROUS METAL</td><td>PRINTING & PUBLISHING</td></tr>
<tr><td>MINING</td><td rowspan="3">NON METALIC MINERAL PRODUCTS
Glass, glass products
Bricks, Ceramics
Cement, Concrete
Plaster, Stoneware</td><td rowspan="2">FABRICATED METAL PRODUCTS
Metal Containers,
Tools, Nuts & Bolts
Spring & Wire Products</td><td rowspan="2">ELECTRONIC GOODS
Components
Equipment</td></tr>
<tr><td rowspan="2">QUARRYING</td></tr>
<tr><td>RUBBER & PLASTIC PRODUCTS</td><td>ELECTRONIC SYSTEMS
Communications
Computers</td></tr>
<tr><td></td><td></td><td colspan="2">PRODUCTION TECHNOLOGY GOODS
Machine Tools
Manual
NC
CAM
ROBOTICS</td></tr>
</table>

Figure 2. Primary and Secondary Production Sector Industries

CONSTRUCTION
• Building
• Water Supply
• Sewerage
• Roads
• Rail Tracks
• Canals & Waterways
	MANAGEMENT
	• Planning & Research
	• Administration
	• Marketing
	    |____Advertising
	    |____Other Promotion
	• Sales
	    |____Wholesale
	    |____Retail
		FINANCE
		• Banks
		• Insurance
		• Real Estate
		• Stock Exchange

TRANSPORTATION & STORAGE
• Rail, Road, Sea, Air,
Inland Waterways
Vehicle
    |_____Operation
    |_____Maintenance
Warehousing
		COMMUNICATIONS
		• Post, Telegraph, Telex
		Telephones, Digital Data
		• Space
		• Equipment
		    |_____Operation
		    |_____Maintenance

RECREATION &TOURISM
• Cinema, TV, Radio,
Audio, Sports, Racing,
Clubs, Hotels, Restaurants,
Travel Agencies
	SOCIAL OVERHEADS
	• Government
	National, State, Local
	    |__City
	    |__Ward
	    |__Village
	• Law & Order
	Police _____Prevention
	    |___Detection
	Justice, Legal services
	• Defence
		COMMUNITY SERVICES
		• Education & Basic Research
		• Health : Human, Veterinary
		    |____Paramedical
		    |____Testing & Diagnosis
		    |____Hospital Care
		• Libraries, Museums, Galleries
		• Weather Services
		• Personal Artisan Services

Figure 3. Service Sector "Industries". ICT-based industry is not shown as a separate "service industry" since it is pervasive and infrastructural in nature. It underpins all industries shown here and in Figure 2.

5.1 Levels 2 and 3: NCST (National Centre for Software Technology) has been conducting, for over two decades, part-time and full-time training programmes in software technology. Over this period, they have finely honed the teaching/training process so that:

1. Large classes of students are handled at one time (50 to 100 or more students);
2. Teacher requirements are reduced to an absolute minimum;
3. Training is learning-centred rather than teaching-centred;
4. Learning is self-motivated and self-paced;
5. Training is based on individual assignments and group projects;
6. Grading is largely automated.

Reading material is carefully selected and distributed so that, at the termination of the training programme, each student ends up with a private library of state-of-the-art books. This is an essential requirement if learning based on self-study is to guarantee quality.

In Appendix I, the NCST educational programme is described in considerable detail. I think it can well serve as a replicable model for structuring training programmes in software technology meeting the ideal end-condition needs of Figure 1. The specific modules evolved by NCST can be readily integrated with B.E. level (i.e. our level 2) training of engineering colleges. NCST also conducts advanced level courses on a similar basis on specific topics in software technology. These modules are capable of being integrated with M.E./M.Tech. level (i.e. our level 3) programmes of engineering colleges. NCST is currently beginning to explore the feasibility of offering web-based versions of the modules evolved by them. They expect to increase the student strength from the present 700 (including franchised operations) to 4000 annually.

Since I am best informed about the NCST training programmes, I have been dealing with them exclusively. There are several other private and public groups specializing in training programmes at some or all of our 4-levels. Clearly, they should all be assessed as to their acceptability to serve as models for our purpose.

5.2 Levels 0 and 1: Coming now to our first two levels, the problems relating to infrastructural requirements and teacher training (issue 2 and 3 outlined at the start of this section) turn out to be especially critical ones to handle. To begin with, take for instance the connectivity issue. The prevailing view within the educational system – whether private or public – seems to be that all that is needed to meet this issue head-on is to make PCs and Internet connection available to every school. However, a few minutes of sober thinking would convince anyone that providing connectivity through Internet at these levels of our educational system is not a solution to providing student-teacher, or student-student connectivity. By doing this we would be merely shifting the problem to a different level instead of solving it, for the following reasons.

Firstly, the Internet is rapidly getting commercialized. It is becoming a "dot-com" network. It is ceasing to be of academic value to schools and arts & science colleges. Also, the network is expanding at such a phenomenal rate that already bandwidth problems are making it unacceptably slow for accessing relevant information by schools and colleges.

Secondly, content-creation is a major issue so far as India is concerned. This problem is magnified many-fold by the need to make content available in regional languages. We do not have, at present, any long-term, national level, programme for tackling the content and language issues.

Thirdly, content on the Internet — to whatever extent it is accessible – is of little value to our schools and colleges unless it is localized (i.e. made relevant to indigenous interests and also to Indian norms and values). We shall discuss this localization issue again later.

One solution to circumvent all the above problems is not to depend on Internet as the main provider of connectivity to Indian communities for **internal use**. We must create community networks to provide connectivity to homogenous groups within the country with academically and professionally common interests. Thus, we must create a variety of educational networks which would cater to the needs of (i.e. to the educational and informational needs of) schools, colleges, hospitals, libraries, museums, and so on. Some of these have already been set up in India and are functioning. After all, ERNET was originally (still?) envisaged primarily as a community network to service education and research needs within the country.

Clearly, for schools and colleges (arts and science colleges), school networks and college networks are the solution to tackle the connectivity problem. Taking language requirements into account, we would probably have to create regional school and college networks. Like STD and ISD networks, our first priority should be to create analogues of STD networks for data for internal use. Internet (ISD) connectivity can be provided strategically as the traffic in the educational system demands.

We are still left with the very major problem of content creation. I do not have an easy solution to suggest. There, probably, aren't any easy solutions.

In a recently published book, Gates (Gates 1999) has a highly readable and informative chapter on school networks titled "Creating connected learning communities". It is made up mostly of case-studies of actually functioning school networks in North America, U.K., Australia, Japan, etc. Design and performance information from these networks, although they may not be immediately transferable to the Indian context, should provide valuable inputs to the planning of analogous networks in India. I am giving below a few excerpts from this chapter which seem to have applicable value.

"The success of PCs as educational tools requires teacher involvement. Without teacher training and integration into the curriculum, PCs will not have a big impact. Many PCs have gone into computer "labs" where they sit, seldom used. Schools need to shift [from teaching technology to teaching with technology]." (p.388)

"Students [from Western Heights School District in Oklahoma] have used the video-conferencing system to take virtual field-trips to the Eastern Coast, to England, and to other places in Europe, visiting museums, studying with sister schools. Students throughout the district watched the space shuttle launch with John Glenn in late 1998 live over their PCs." (p.390)

Here is a good illustration of what localization and content creation are all about. Surely, Indian students would want to visit museums and cultural centers in India and not in Boston or England? Who will create the relevant multimedia modules to make such virtual visits possible by our students? Also, when will we have in our schools the necessary network links to watch our own space shuttle launches live?

"Highdown School [in Reading, UK] connects more than 100 PCs in the school with interactive CDs and *filtered* content from Internet ......"

(emphasis added, p.392)

"Even in the best of schools, the ratio of PCs to students is often no better than 7 students to every PC ...." (p.395)

At levels 0 and 1, where the student numbers involved are very large, the problem of affordability tends to become a very serious issue. How does one bridge the gulf between the "Haves" who have home computers, and "Have-nots" who do not have home computers? This has been engaging the serious attention of school authorities and communities at large. Gates discusses several innovative solutions that are being experimented with in Australia and other countries.

We are still left with the vexing problem of teacher training. There may not be an easy solution to tackle this. To some extent, outsourcing the training responsibility to independent training schools may help. But in levels 0 and 1, the essential requirement is to integrate ICT-usage in the classroom with subject-matter teaching. It is doubtful whether independent training institutions would be able to cope with this. Some mix of solutions, including setting up of Resource Centres may help. Perhaps one can learn from the successes and failures of a programme such as the "CLASS Project". Discussion at a national level is clearly indicated in coming to grips with this problem.

6. Concluding Remarks

Is it necessary that our educational system (or, for that matter, any educational system) should be primarily concerned with equipping its students with skills and knowledge to meet the requirements of the market? Perhaps not. The educational system might function on the basis of an entirely different value system, with focus on culture, aesthetics, moral values and so on. But my contention is that *minimally* the students of an educational system must be equipped with *marketable* skills and knowledge. If, at the end of one's education, one finds oneself unemployable for lack of marketable skills and knowledge, it is difficult to justify the time and money spent in acquiring such an education. My primary concern in this paper has been with the need for spelling out minimal sets of study modules which, if integrated with the normal training programme, would equip the students with at least minimal employable skills and knowledge. I have tried to articulate this thesis within a 4-level scenario taking into account the fact that the market is rapidly changing and getting increasingly dominated by ICT skills and knowledge.

The Indian educational system trains hundreds of thousands of students annually at each of the 4 levels of our scenario. Students leaving the educational stream in levels 0 and 1, to a very large extent, are unable to find any employment consistent with their educational training. They have to take recourse to additional market-oriented training.

On the other hand, students graduating out of levels 2 and 3 find themselves wooed by the software industry with offers of unnaturally high compensation packages. Despite this, very soon, the majority of them form part of the brain drain to the industrialized countries – mostly to U.S.A.

My argument is that such an anomalous situation prevails: (i) because of the lack of market-orientedness of our educational system and its ignorance of the rapidly changing market requirements; and (ii) because of our exclusive obsession with the software industry and its export orientation. An essential need to contain this anomaly is to develop rapidly a domestic market for ICT-based services which would generate meaningful job opportunities for students coming out of each of the four levels of our scenario.

Our obsession with the software industry as our ultimate, and only, saviour must give place to a more balanced assessment of ICTs in their entirety and their applicability to the various sectors of our industry and the benefits that would accrue thereby. Also, a determined attempt should be made to encourage the development of SMEs, across the entire industry, to provide a variety of these ICT-based services.

7. References

1. Bill Gates (1999): *Business @ The Speed of Thought*; Warner Books
2. R. Heeks (1996): *India's Software Industry*; SAGE Publications (India)
3. Robin Mansell & Uta Wehn (1998): *Knowledge Societies: Information Technology for Sustainable Development*; UN Commission on S&T for Development; Oxford University Press
4. OECD (1996): *Reconciling Economy & Society*; OECD Publication
5. AnnaLee Saxenian (1994/96): *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*; Harvard University Press, 1994. Pbk.1996

Appendix 1

NCST's Educational Programmes in Software Technology

About NCST (National Centre for Software Technology)

- NCST is a national laboratory for software technology of the Ministry of Information Technology (MIT), Govt. of India
- It operates as a centre of excellence, emphasizing quality over quantity
- It has five laboratories located in the cities of Mumbai and Bangalore.

Primary objectives are to:

- Carry out research and development in software technology,
- Carry out educational and training activities

Areas of current interest:

- Computer Networks and Internet Engineering
- Data and Knowledge Engineering
- Graphics and Computer Aided Design
- Knowledge Based Computer Systems
- Software Engineering

Educational Programmes:

- Largely in continuing education in the form of post graduate diploma programmes in software technology and also in the form of short term intensive courses on advanced topics of relevance to the industry.
- NCST's postgraduate diploma programme in software technology started over 20 years back through the initiative of Dr. S. Ramani, when NCST was operating as the National Centre for Software Development and Computing Techniques at the Tata Institute of Fundamental Research in Mumbai.
- Keeping in view the changing trends in computing and the industry demand, the diploma has been restructured often to enable optimal imparting of education and training in the field of software technology.
- Broad structure
  - ❖ part-time post graduate course (PGDST) which is of one year duration
  - ❖ provides a good foundation in programming, along with a strong foundation in key computer science areas including database management, object oriented programming, and computer networking.

- Those who finish the PGDST, may optionally do the Advanced PGDST (APGDST), which is also a part-time one year course. This allows the candidates to specialize in specific areas of interest. Areas offered in the APGDST include: digital imaging, expert systems, parallel computing, software engineering, computer graphics, multimedia technology, component based software development, programming paradigms, etc.

Eligibility and Admission Process

- Candidates have to be graduates in order to join the course. The type of degree or subjects taken do not matter for eligibility. Candidates entering the course are assumed to have some general familiarity with computers though no programming knowledge is expected.
- Admission to PGDST and FPGDST (Full-time Post-graduate Diploma in Advanced Software Technology) is through a nation-wide Competence in Software Technology (CST) examination, held once a year. The examination has two papers -- general aptitude and computer concepts. The aptitude paper assesses the candidate's analytical and problem solving abilities.
- Admission to APGDST requires successful completion of the PGDST course. A few seats are kept open for direct admission to candidates who possess a degree in computer science. These candidates are also selected through a different level of the CST examination. This test, in addition to having a paper on general aptitude, tests the candidates' computer science knowledge in different subjects at the degree level.
- Admission to PGDIT (Post-graduate Diploma in Internet Technology) is also through the CST examination, but again at a different level. In addition to having a paper on general aptitude, this level tests their programming and fundamental computer science knowledge at an engineering degree level.
- The CST examination results are also currently being used for selection of students for admission to the post graduate courses of the following universities:
  - ❖ Goa University (MCA)
  - ❖ Mumbai University (VJTI's MCA)
  - ❖ SNDT Women's University (MCA and PGDCSA – Post-graduate Diploma in Computer Science and Applications))
  - ❖ IIT Bombay (School of Information Technology's M.Tech in IT and DIIT – Post-graduate Diploma of IIT in Information Technology)

CST, some statistics:

- About 8000 candidates have been appearing for the test every year. About 50% of these are engineering graduates in different disciplines and the remaining are graduates and postgraduates in other subjects like science, commerce, arts, medicine, etc. Approximately 10% of the candidates get selected for admission to the various courses. Engineering graduates appear to have a slight edge in performance.

Methodology of Training:

- Typically, there are five modules covered in a part-time diploma programme and ten modules in a full-time programme. These modules are covered during the course of one year.
- Examples of topics covered are given below:

PGDST:

- Computer Programming fundamentals
- Data Structures
- Algorithms
- Computer organization
- Operating system fundamentals
- Database fundamentals
- Computer networks and Internet
- Object-oriented programming and C++

FPGDST:

- Computer programming fundamentals
- Data structures
- Algorithms
- Computer organization
- Operating system fundamentals
- Database fundamentals
- Computer networks and Internet
- Object-oriented programming and C++
- Software engineering
- Web programming
- Component object modeling technology
- Electronic commerce

PGDIT:

- ❖ Computer internetworking
- ❖ LAN technologies
- ❖ Network management
- ❖ WAN technologies
- ❖ Network programming
- ❖ Internet programming
- ❖ Network security

APGDST: (Five options to be chosen)

- ❖ Object oriented analysis and design
- ❖ 3D computer graphics
- ❖ Programming paradigms
- ❖ GUI development
- ❖ Software engineering practices
- ❖ AI programming
- ❖ Advanced Database techniques
- ❖ Distributed computing
- ❖ Parallel computing
- ❖ Multimedia technology
- ❖ Digital imaging
- ❖ Web programming
- ❖ Network programming
- ❖ Expert systems
- ❖ Natural language technology
- ❖ COM technology
- ❖ E-Commerce technology
- ❖ Algorithmic theory and applications

Assessment Process

- The course is designed to be learning centric and less teaching centric. In addition to course handouts, textbooks are included as part of course material to each student. Typically, in any one-year course, there are only about three hours of faculty-student contact sessions per week. However, the courses are highly self-instructional, practice-oriented with emphasis on software development through teamwork. Students have to put in fifteen to twenty hours per week of effort on their own to succeed. The assessment for the modules emphasizes good understanding of the concepts as well as practical skills in applying them. The former is largely tested by written tests and the latter by having to complete a mini-project for each module, done by a team of three to four students from the same batch.

- Knowing a programming language does not imply an ability to write correct programs. One of the requirements for completion of the first module is to demonstrate the ability to go from a problem statement to a working program. This is tested in the PGDST using machine graded programming tests.
- The courses provide a sound blend of academic rigour and practical skills. The academic content ensures that the knowledge learnt is usable over a long period, allowing participants to move among different tools/systems quite easily. The rigorous entrance examination coupled with the regular and detailed assessment during the course is an important part of assuring quality.

Educational Partners:

NCST's PGDST programme is run at ten different centers spread over the country. This is done through NCST's educational partners. NCST chooses its educational partners based on a number of criteria. These include:

- demand based geographic spread
- location
- past track record of organization in education & training activities
- faculty
- sustainability
- space and infrastructure
- commitment to NCST's educational quality standards
- Quality is ensured by adopting a tight-coupled model for educational collaboration. All centers adhere to a uniform course syllabus and course schedule. Faculty material includes, transparencies, PowerPoint presentations with voice-overs, video tapes, assignment and project idea banks. All admissions are centralized through NCST's CST examination. All intermediate assignments, tests, quizzes, project evaluations and examinations are carried out strictly under NCST's supervision.

Infrastructure requirements:

For a part-time course with about 60 students, a LAN consisting of:

- two medium-sized servers – one Unix and one Windows NT
- fifteen client workstations – Windows 98 or 2000
- Web server software
- Relational database backend
- DB front-end development tools
- Object-oriented software development environment

For a full-time course with about 60 students, a LAN consisting of:

- two medium-sized servers – one Unix and one Windows NT
- thirty client workstations – Windows 98 or 2000
- Web server software
- Relational database backend
- DB front-end development tools
- Object-oriented software development environment
- Other software tools as required by the individual modules

Placement:

While, NCST does not have a formal placement mechanism, almost all NCST students have so far been very well placed. Many have become leaders of the IT and software industry.

NCST's CST examination is also used to create a software professionals database, which is accessible by the industry for their staffing requirements.

Appendix 2

Silicon Valley (SV) : Some Facts [6]

In discussions dealing with IT in India, "Silicon Valley" has become an overused adulatory term. However, few of us have a real understanding of what Silicon Valley (namely, the *Original* one in California) is all about. Here are some facts which should enable us to compare, in a more informed manner, the Indian situation with Silicon Valley.

SV is now home to a geographic concentration of more than 7000 technology-based companies. Its geography extends across 30 cities and parts of 4 counties, covering an area of 1500 square miles. Some additional statistics are as follows:

Population	2.3 million
Jobs	1.25 million
Ethnic Composition	• White - 50% • Hispanic - 23% • Asian & Pacific Islanders - 23% • Afro-American - 4%
Foreign Born	23% residents born outside USA
Age Distribution	0 - 9 : 16% 10 - 19 : 12% 20 - 44 : 43% 45 - 64 : 20% 65 + : 9%
Educational Background	High School Grads : 82% Bachelor's Degree : 33%

SV industries fall into a variety of Industrial *clusters*. A cluster is a geographical concentration of *interdependent firms in related industries*. A significant number sell their products outside the region. Clusters in SV fall into the following classes:

- Computers & communications

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[6] Abstracted from **Joint Venture's** *1999 Index of Silicon Valley*

- Semi-conductors/IC Equipment.
- Software[1]
- Bio-sciences
- Defence/ space
- Innovation Related industries[2]
- Professional services[3]

These 7 classes account for 40% of all non- government jobs in SV

Average wage in SV (1998)	USD 49,060
US Average	USD 30,860
Venture Capital Input (1998)	USD 3.3 billion
R&D-related employment	15% of work force
US Average	5% of work force
Value -added per employee	USD 113,000

1
- Computer programming
- Pre-packaged software
- Systems integration
- Data-preparation and processing services
- Information retrieval services

2
- Wholesale Trade of computers, peripherals & software
- Electronic Parts & Equipment
- Facilities Management
- Computer Rental & Leasing
- Computer Maintenance & Repair

3
- Printing
- Service industries for printing trade
- Manifold business forms
- Advertising
- Mailing, reproduction, commercial art & photography, stenographic services
- Personnel supply services
- Surveying services

In contrast to the above positive aspects, some negative aspects of life in SV are the following:

- Cost of living 37% more than in USA
- SV job-growth is slowing down
- Income distribution widening

  Top 20% average : USD 130,755

  Bottom 20% average : USD 34,752
- High school graduation rate continues to fall
- Wide ethnic disparity in meeting basic college requirements
- Fewer engineering graduates produced by local universities since 1994 (including Stanford & Berkeley)

A large consortium of local business, government, educational institutions and concerned citizens, called *Joint Venture: Silicon Valley Network* (JV:SVN), was formed in 1992 to address shared regional problems. There were 209 corporate investors between 1992 and 1996.

JV:SVN has committed itself to fostering educational change through its *21st Century Educational Initiative : Challenge 2000 project*. The strategy for change is based on the Venture Capital model. This initiative invests cash, human resources, and technology in a team of schools to improve math, science, or literacy instruction. The return on investment is improved student performance. Schools which want to participate in the project, form themselves into teams and put up a well-articulated project proposal and compete for venture capital. A committee made up of industry leaders, parents and educators evaluates proposals received. Progress is closely monitored by "Challenge 2000" project staff. A total of USD 12.2 millions has been distributed over 3 years from 1995 to 1998 by way of cash, equipment, and human resources (i.e., the participation, on a full-time basis, of experts from industry).

What is unique about the Silicon Valley is not the geographical concentration of a variety of ICT-related industries but the *horizontal networking* of these industries. This has been persuasively argued by Saxenian in her book (Saxenian 1994/1996) contrasting the culture of SV with that of the Boston-area in USA. The following assessment by a study commissioned by DEC (quoted by Saxenian) highlights this networking aspect:

> *"... the region possesses a special kind of infrastructure that has in effect institutionalized innovation in technical fields across the board....*
>
> *The Bay area is unrivalled in sheer variety of companies and the level of formal and informal networking among companies in the technical field.*
>
> *.... Prototype development and engineering are particularly strong .... It is this cross-cutting strength .... that makes Northern California a magnet for top engineering talent, innovative start-ups, and major breakthroughs in technical fields across the board. "* (pp.113-114)

Precisely this kind of horizontal, professional networking is missing in India's software industrial scene. Taking, for example, a city like Bangalore, there is little or no interaction between the very large number of software houses that have located themselves here. There is even less interaction between the software industry and the teaching schools and colleges, or citizens at large, on a routine basis. Consequently, there is no significant sense in which one can talk about the existence of a *software community of professionals* in Bangalore. Interactions – if any exist at all –are all of a commercial nature.