Curricula and Extension at Engineering Colleges
TEQIP-II
Discussion and Approach Note.

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In this note we present a possible approach note to discuss the above agenda. We structure the agenda as a set of two-three questions in the realm of higher education, especially technical tertiary education. These are as follows:

1. What are the needs of India from the perspective of Engineering Curricula and Extension.

2. How can current curriculum structures and frameworks, and practices of engineering colleges be adapted to address the above needs?

3. What are the threats which need to be kept in mind. How is one to localize and address these threats.

We begin the discussion.

1 Needs of India in the engineering and technical area

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India poses many opportunities for engineers, starting of course, from various government engineering services and the PSUs such as BHEL, ONGC and so on. It also has many sectors which are well developed such as construction, infrastructure, automotive, textiles, chemicals and so on. These have well established channels for recruiting engineers, and generally speaking, engineering colleges have catered to their needs in some form. What we list below are important needs which are not met.

- **Developmental needs.** Thse are best understood as the popular demands for *sadak, bijli, paani*, and also of developmental outcomes in health, livelihoods and so on. Many of these are really demands for engineering services coupled with skills of working in a social and political economy context.

Most government departments are reluctant to hire new staff since it is not clear that the net value is positive. Many roles of monitoring, evaluation, design, implementation are possibly better done by entrepreneurs and small consultancies, but such "knowledge products" are yet to be standardized.

There is also a loss of practice that many departments face. There have been no new standards or research for the variety of design situations which have newly arisen. Largely, there are no significant collaborations between tertiary institutions and line departments of of state governments.

- **Economic needs.** It has been pointed out by many economists that the sectoral composition of our economy, esp. the small share of manufacturing, is not sustainable. There are many reports that our graduates, including engineering graduates are not employable. There is also the lament of very few enterpreneurs (per capita) in our stage of development. The causes of this has also been argued, e.g., poor investment climate and rigid labour laws. Some examples of these deficient sectors are the manufacture of machines, sensors and actuators, medical diagonostic machines, control systems, special components and so on.

  Even within the manufacturing sector, while a large chunk of this is done in the informal sector, very little attention is paid to its knowledge needs. It is well known that formalization brings great productivity benefits, but we do not it reflected in our curricula or our extension. Thus an appreciation of the socio-economics and technical needs of the informal sector and the small and micro-enterprises is an important need.

- **Strategic manufacturing**. This are not only restricted to defense, but also to sectors such as telecommunications, bio-tech, energy and so on. The import of telecommunication equipment itself is a substantial fraction of our current import bill. The nation is facing a balance-of-payment trap which may impact defense, communication and the energy sector, including the solar and wind energy.

  This requires an indigenous production facilities, IP regime, markets and strategic partnerships between institutions and the formation of key companies. It also requires a research and development effort which is focussed on deliverables and not merely journal papers.

- **Strategic and policy research needs** Finally, there are many sectors such as in climate change, water, etc. which are strategically or developmentally important, which need a sustained technology and policy analysis. These demand skills beyond just the high-tech. They demand a nuanced understanding of society, and an ability to talk to experts across many disciplines and an ability of academic articulation.

This research must straddle across many stake-holders, right from elected representatives and bureaucrats, to multilateral funding agencies and international academia in both applied social sciences as well as technology.

Thus we see a broad set of expectations that India has from its engineering institutions in the areas of training and research. These require not merely a different curricula but also a different set of stake-holders and a different level of engagement between institutions and these stake-holders.

For example, the in the development setting, it will require familiarity with flagship programs such as in watersheds or drinking water, the design and implementation of asset creation in the small, working with elected representatives, government agencies, NGOs and civil society organizations. It will also require new business/consultancy models whereby stakeholders such as district administrations will pay for services received.

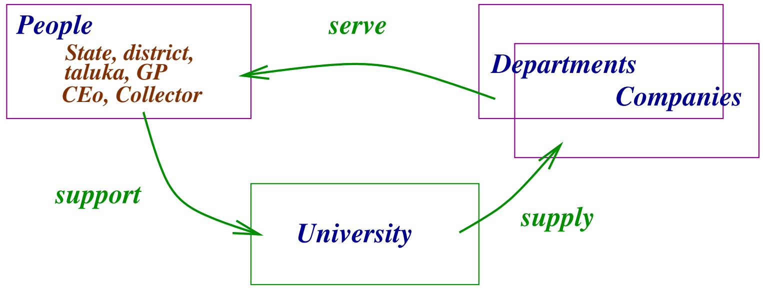
On the other hand, working on the formalization agenda requires understanding how small and micro enterprises operate, their problems and their technical needs, i.e., factors of market as well as the operation of small machinery and processes. The stakeholders here will be different-small enterprises, ITI trained self employed youth and so on.

We also see that the higher strategic needs mirror the local needs, e.g., only if we understand technology generation, management and innovative business models in the small-scale can we migrate to the small high-tech companies which are crucial in the industrialization trajectory. Thus the progression of scale is organic and material.

2 What do we need and what do we have

These composite needs require a structured response where we have a regional, state and national institutions which pursue a layered curriculum and research agenda and work with different stakeholders.

Our current design of engineering colleges is based largely on the old heavy-engineering model of the 1950s and 1960s as shown below:

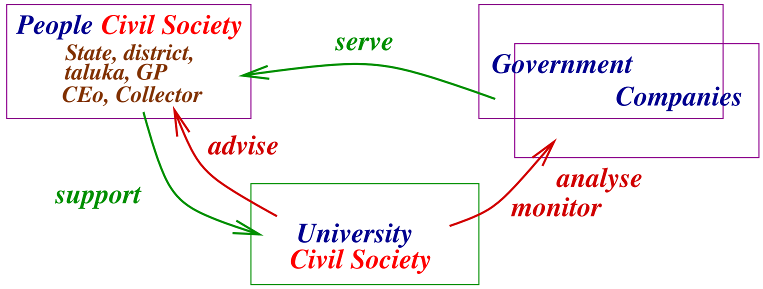


This involves the assumptions of (i) the state machinery and industry serve society effectively, (ii) the employee and research needs of the state and industry will be met by the university, and (iii) an uncritical support of society for our universities. Examples of institutions which were set up with this model are of course the Thomson college (now IIT Rourkee), the IITs and the RECs (now NITs). These involved setting a core "engineering" curricula with largely classroom teaching, some amount of heavy engineering lab-work, and perhaps an apperentice-ship in these industries. See [1] for a detailed analysis on the conduct of teaching and research in our engineering academia.

However, in the past few decades, this model has not served us well. Globalization and liberalization has led to many changes in the economy. One prime example is the emergence of the global service sector and IT which has sucked away core engineers into global service. At the same time, core engineering and manufacturing companies are in retreat. Even in the development sectors such as water, there is very little fresh knowledge inputs or an energetic job market. In sectors such as energy or water, we see international consultancies, multinational companies with a wide variety of skill-sets and multilateral agencies as important players. These now define much of the agenda and create much of the implementation framework.

The second big development is the large number of government programs which demand professionals but are unable to find them or even to define their roles very clearly. This includes programs such as IWMP, NRLM and so on. Increasingly, the government is using NGOs for their manpower needs, which while well meaning is leading to informalization of key engineering activities.

On the whole, we see that the new university or engineering college must be able to work with different stake-holders, including towns, cities and regional administrations. It must develop many roles such as consultancy, design and analysis of public systems, interdisciplinary planning and evaluation and so on. This model is best shown below:



It shows the university as the key nurturer of civil society and a regional resource and knowledge provider. Depending on its strengths, it can also serve as a monitoring and evaluation agency, and also the home for the development of new practices. However, this will need our colleges to treat society as an honest stakeholder and engineering as a skill of spotting opportunities for good practices to emerge and innovation to take root. It will also require colleges to be engaged with stakeholders and be abreast not only of technical knowledge but also of extant policies and programs. See [2] for a possible methodology.

Take for example the development of water meters. It is increasingly clear that efficiency in water use will require metering. However, there are many variables, such as the scale at which these meters will be deployed and also their location, e.g., bulk meters vs. household, the price-point and so on. This will need colleges to be alert to the policy changes in the sector and also the needs of towns and cities.

3 A possible approach

How is one to approach such a multi-faceted and interdisciplinary requirement from our engineering college *while ensuring that these changes are not disruptive*. Here are some key suggestions:

- **Develop a pre-engineering core**. This will be compulsory and should deal with real situations and real data. A possible design is (i) a **Data Analysis** course (see a sample output in [5]), and (ii) a **Measurements** course besides the usual battery of PCM and workshops. The workshop course could be made more up-to-date with a regional bias. For example, in Surat, it could also involve visiting weaving mills, diamond industrial units and so on.

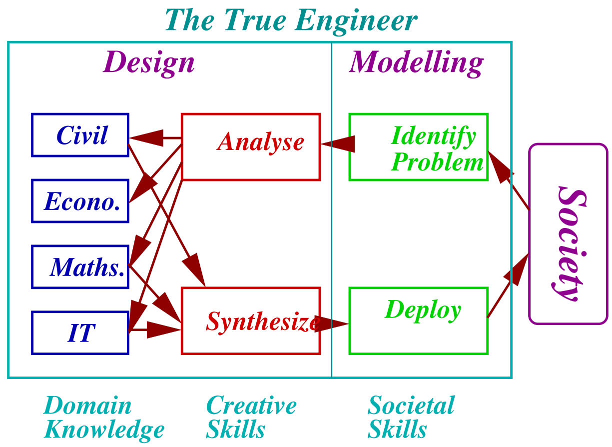
- **Build disciplinary bridge courses** (DBCs). These course are to be taught by department faculty but attempt show its relevance in society. For example, in Computer Science, it could be the optmization and representation problems at the local Bus Depot and station. This will present many opportunities for students and faculty to interact with stakeholders and to se how real problems arise and how they may be solved.

- **Build stake-holder rapport**. This can be done by various means and at various levels. The simplest is possibly a pan-institution seminar series which brings the collector, the MLA or MP, the industrialist, the social worker, the women's group leader, community leader and even the leader of the auto-rickshaw union. Many of these speakers will need to coached into giving a public presentation. Another option is to report work done in a *stakeholder workshop* which calls all stakeholders and presents the research/analysis before them. For example, if the study involved a a section of a main road, its construction, its problems, traffic on it, costs of maintenance, past contracts and so on, then the stakeholders would be the municipal council, residents, contractors and so on.

- **Develop an inter-disciplinary project platform**. The basic objective here is to allow faculty members to float projects of an interdisciplinary nature but which have concrete stakeholders. This could be in the form of a framework for credited student projects. An example is the **Technology and Development Supervised Learning** (TDSL) platform at IIT Bombay (`www.ctara.iitb.ac.in/tdsl/`) which is run by CTARA with a developmental focus. The webpage lists the motivation, guidelines and sample projects. TDSL allows any faculty member to float a stake-holder driven project for students to take. It is administered by a speacialised staff and a faculty coordinator.

- **Develop an inter-disciplinary minor**. This must be done after sufficent experience has been otained and interdisciplinary bridge courses (IDBCs) have been formulated successfully run. This should encapuslate the basic interdisciplinary and stakeholder experience of the institution and should be a point of pride for the institution. It should also be used to strengthen the Humanities and Social Sciences departments in the institution and their relevance to engineering.

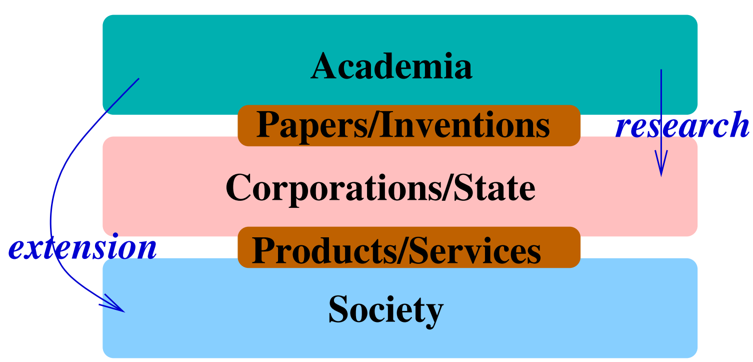
The key methodology in the whole process of developing the requisite skills for an engineer is to think of him/her as a problem solver who can interact with society directly and who has the inter-disciplinary skills to be able to see the full picture. This is illustrated in the picture below:



As we see, there are three types of skills that we must develop, (i) *societal skills* of observation and of deployment, (ii) creative skills of problem parametrization and decomposition and then of synthesis, and finally (iii) domain skills and their organization.

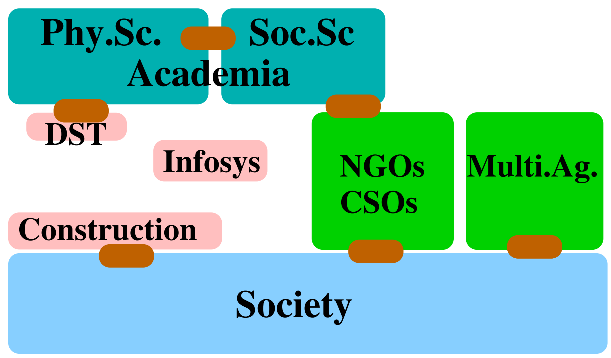
4 Extension and its project cycle

In our framework, extension is an important activity for an institution for it supports the core objective of it working as a regional resource and as a nucleus for civil society. *Extension* and *Research* are two mechanisms of reaching to society which remains the ultimate beneficiary of both mechanisms. The basis of this is 3-way sandwich that we see in the developed world, from which this concept is copied.



In the developed world, the university the company and the state are the effective in meeting the needs of its people and the role of the university to supply knowledge inputs to the state but mostly to the insudtry. Such inputs may be termed as research. Frequently though, based on the funding agency of the university, the state may want the outputs of the academia to be directly accessible to society. Such output is called *extension*. There are fairly well developed metrics to measure research, e.g., as the number of papers, or in the industry case, in the number of patents and their value. Compared to this, the measurement of extension is not as advanced, and certainly not in India. All the same, extension has proved itself extremely useful in the developed world. The extension problem is also usually posed differently from the research problem and is more direct and usually in the public domain. Contrary to what is believed, extension constitutues a substantial chunk of the transfer of knowledge in developed countries from the university to the people.

The situation in India and other developing countries is very different and is illustrated as follows:



We see a disconnect between the academia along disciplinary lines. Next, we see very few companies which actually straddle both the acadamia and society. Finally, we see important players, viz., the consultancies, the multilateral agencies and the NGOs and CSOs of which only a few have connections with academia. In this set-up it is all the more important for institutions to develop, measure and incentivize extension. In fact, extension is an important research activity which could follow a three stage cycle:

1. **The problem of value creation**. This is to do understand how value is to be created. For example, in the Bus Depot problem, it may be the correct identification of the issues that will generate value for the Bus company, e.g., better utilization of crew or assets.

2. **Research**. This is the activity of doing the theoretical and experimental work of producing a solution or a framework for the same. In the Bus depot problem, it may involve databases, linear programming, IT and also research in traffic and costs, subsidies and so on.

3. **Courseware.** This is the final phase of understanding, The research done is assimilated and used as case-study in UG/PG level courses. This will help produce professionals who can understand and solve societal problems.

The extension model above may be used effectively to develop core research areas for which there are no business models but which deliver value, e.g., in the core development sectors such as drinking water, cooking energy, town planning and so on. This work may help in analysing events such as droughts, developing good practices, engaging with government departments and improving outcomes. See `www.cse.iitb.ac.in/ sohoni/water` for an example of our work in the drinking water problem. It can also help develop new courses in particular problem areas which may serve as electives and also help in CEPs for the sector people. See the water course at CTARA at `www.cse.iitb.ac.in/ sohoni/TD603`.

One important role for extension is to nudge the region in an appropriate development trajectory. This may require guiding regional agencies in designing knowledge requirements and products and preparing manpower for the same. For example, one such position could be the District Watershed Manager. The precise job description, roles and activities, the knowledge and practice requirements, the data sets and so on, may need to be formulated by the regional institution. Thus definition of the roles and also preparing people for the same is also an important extension activity.

5 How do we fit this in

Finally, we have to see how this fits in with TEQIP and other institutional norms. At this point I must quote the *rationale* for the CBSE curriculum for XI-XII Physics (at `http://www.ncert.nic.in/rightside/links/pdf/syllabus/syllabus/desm_s_physics.pdf`) as an example of contestable priorities.

> *The higher secondary stage is crucial and challenging stage of school education as it is a transition from general science to discipline-based curriculum. Physics is being offered as an elective subject at the higher secondary stage of school education. At this stage, the students take up Physics, as a discipline, with a purpose of pursuing their future careers in basic sciences or professional courses like medicine, engineering, technology and studying courses in applied areas of science and technology at tertiary level. There is a need to provide the learners with sufficient conceptual background of Physics which would eventually make them competent to meet the challenges of academic and professional courses after the higher secondary stage.*
>
> *The present effort of reforming and updating the Physics curriculum is an exercise based on the feedback received from the school system about existing syllabus and curricular material, large expansion of Physics knowledge, and also the edu-*

> *cational and curricular concerns and issues provided in the National Curriculum Framework-2005.*
>
> *The recommendations of National Curriculum Framework-2005 have been followed, keeping the disciplinary approach with rigour and depth, appropriate to the comprehension level of learners. Due care has been taken that the syllabus is not heavy and at the same time, it is comparable to the international standards. Also, it is essential to develop linkages with other disciplines for better learning of Physics concepts and establishing relationship with daily-life situations and life-skills.*

Thus we see **upward compatability**, i.e., of not inconveniencing the few students who go on beyond 12th standard, as the first priority, while the **downward accountability** of helping students interpret daily-life situations comes out as the last priority. We should avoid this trap in the engineering curriculum. The first priority should of course be the developmental needs of the people, followed by the industrial, needs of the region. However, we should see that this does not compromise the aspirations of students for "*higher studies*". Furthermore, guidance should be given to engineering colleges which want to work in "aspirational" areas. This will require the state administration to recognize and reward regional research objectives as equally important as "aspirational" research.

This brings us to the concrete requirements that our curriculum be upward compatibile, i.e., enable our graduates to write and succeed at GATE, the final certifying agency of engineering education in India and now increasingly used by PSUs for hiring of fresh graduates. The second upward compatibility are the stated objectives of TEQIP, esp. in the conduct of research and the motivations for teaching. We recommend the following:

1. Review TEQIP-II extension and research guidelines. Develop institution-specific guidelines to measure extension and provide a robust alternative to *international journal paper* requirement to measuring faculty performance. Set a judicious mix as a target for extension and paper-oriented research.

2. Develop an extension and practice research program spanning 2-3 areas. These could be industrial (such as ceramics), service oriented (such as public transport) or developmental (such as watersheds). Develop stake-holder rapport and engagement and also funding sources as close to the beneficiary as possible. This could be from various state and national programs themselves which now have a evaluation, assessment and research budget.

3. For each engineering discipline, develop a 5-6 course core and teach it well. Push back on GATE and request them to consider a reduced core for disciplinary papers. Supplement these with electives which include the bridge courses and case-study based courses which have arisen out of in-house research.

6 Conclusion

In conclusion, the TEQIP project has given us a remarkable opportunity for reviewing engineering education nation-wide and certainly for the state of Gujarat. We should utilize this window to perform the due diligence and arrive at key conclusions. Perhaps, these conclusions should be shared with other stake-holders in wider civil society, such as industry bodies, civic leaders and so on.

A judicious mix of (i) downward and upward compatibility for curriculum design, and (ii) paper-oriented research metrics and research by extension activities are some key suggestions.

References

[1] Engineering Teaching and Research in IITs and its impact on India, by Milind Sohoni, in Current Science, June 2012.

[2] You-tube lecture on the role of engineering in development, by Milind Sohoni, `http://www.youtube.com/watch?v=G71maumVZ1A`

[3] Water course, `www.cse.iitb.ac.in/ sohoni/TD603/`

[4] A GIS based interface to monitor and study drinking water in Thane district. http://www.gise.cse.iitb.ac.in/upload/thanedb.html

[5] A sample output for IC102, a data analysis course at IIT Bombay. http://www.cse.iitb.ac.in/ sohoni/taluka1.pdf