Report on the TEQIP workshop on "Materials and Metallurgy Curriculum" held at NIT Srinagar (8-9 October 2015)

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The primary aim of the workshop was to discuss the undergraduate curriculum of Materials and Metallurgical Engineering and similar disciplines. The emphasis was to understand the structure of curriculum in various institutes and then to have meaningful discussions to evolve a basic structure of the curriculum, which can be recommended to each institute for further implementation. The purpose was evolve a structure which can be uniformly applied across various institutes whilst ensuring sufficient flexibility in the design of courses and content yet retaining core philosophy similar across the institute which will assist in student rotation sharing of resources as well as in ensuring a basic minimum standard of materials and metallurgy education. Details on the need for such as workshop and the program can be seen in the attached document.

This workshop was oragnised by TEQIP programme at IIT Kanpur. It was also supported by the Knowledge Incubation Under TEQIP (TEQIP-KITE) at IIT Bombay. Participants from fifteen institutions in India, including NITs, IITs, IISc, IISET Sibpur and PEC Chandigarh having four year UG or dual degree programs in this discipline attended the workshop, held over two days. Various participants presented the curriculum structure of their respective departments. This was followed by a discussion on evolving the common observations and lacunae of present curriculum across various institutions. Subsequently, session wise discussions took place to evolve a model curriculum for the discipline across various institutions with an emphasis on developing a basic template, which can be adopted to bring a synergy between various institutions, which will help faculty as well as student in imparting the knowledge effectively and efficiently.

Specific role of Prof. N.N. Viswanathan included a presentation on the curriculum at IIT Bombay at the UG and PG levels. His presentation outlined the number of modern concepts that have been integrated into the curriculum by MEMS department of IIT Bombay. Prof. Viswanathan moderated the session that looked at ways and means of inspiring young students of metallurgical and materials engineering. This session was crucial for strategizing towards high impact of the modern curriculum drawn up at the workshop. During sessions moderated by other participants, Prof. Viswanathan actively contributed to the discussion.

Specific role of Prof. Ashutosh S. Gandhi (IIT Bombay) included planning the various sessions in the workshop along with the organizer, Prof. Ashish Garg (IIT Kanpur). During the workshop, Prof. Gandhi was the moderator for the discussion that followed the presentations on the present curricula at various institutions in the country. This discussion set the stage for the next few sessions on the desired features of the curriculum. Prof. Gandhi also moderated the discussion on the professional major core subjects required in the curriculum. During sessions moderated by other participants, Prof. Gandhi actively contributed to the discussion.

The important aspects of the organisers' report on the outcome of the workshop are given below.

General Observations

- Credit counting is not uniform across the Institute (ranges from 131 to 254). By and large, most institutes count a 3- lecture course as 3- credit course. By and large, across most institutions, the contact hours per week are less than 25 hours per week.
- Share of departmental courses varies from one Institute to other (33% to 55%)
- By and large, the course content emphasizes more on the traditional metallurgical engineering with only a few institutes covering various aspects of modern materials.

- Department course content exceeds 50% of the total number of credits in most institutions, particularly the NITs. In a majority of the institutions, there is a serious lack of enough number of electives.
- Generally there is little variety and focus on what kind of engineering and science related core courses should be offered to the students.
- Humanities content across various institutions is too little.
- The distribution of courses is rather haphazard in certain institutions.
- There is a general weakness in imparting mathematical and computational skills to the students. Moreover the curriculum are designed in such a way that even is these skills were provided in the early years, lack of implementation in the subsequent years leads to erosion of skills.
- A few NITs such as NIT Bhopal, NIT Srinagar face severe lack of faculty strength, which may completely defeat the purpose of UG programmes, let alone revamping it. Faculty crunch is hampering the teaching of courses as well as in conduct of laboratories and tutorials.
- Very few metallurgical engineering graduates are pursuing PhD and hence there is serious concern on faculty recruitment for the discipline in the future who can teach traditional conceptual courses.
- A few interesting observations were made
    - PEC University Chandigarh have one semester long industrial training with no course work in that semester.
    - IIEST Sibpur only has a 5 year Dual Degree programme and no four year degree programme
    - NIT Raipur has substantial number of contact hours per week between 30-40 hours per week.
    - IIT Kharagpur has attempted with the idea of grouping of electives under a few broad categories.
- There were points related to Faculty and Student Prospects. Some of these could be “package of UG students”, type of jobs like white collar/blue collar/location of job/ time schedule of work/ flexibility in work environment/ intellectual challenge etc. There can sometimes be a conflict in the career options: for example career choices for UG students can be either a job or Ph.D. or working with NGO or a starts up whereas the faculty have different perspective like career advancements, balance between teaching and research.

Name of the Department/Discipline

- There were discussions on the name of the department on whether it should be “Metallurgical Engineering” or “Materials and Metallurgical Engineering” or “Materials Engineering” or “Materials Science and Engineering”. A few others felt that Metallurgy and Materials should be two different departments. However, most participants countered the idea of having two separate departments, as it was felt that if the fundamentals for the two departments are same, then there is no point in having two departments with different names bur fairly similar content.

<u>Design of a model curriculum:</u>

Basic Considerations:

- It was felt that first the basic template should be made before the constraints are imposed.
- We need to apply a unified approach, implying that fundamental concepts related to different kinds of materials need to be taught together and not as separate courses. For example, structure of materials can be taught together for both metals and ceramics.
- It was felt that the homogenization of courses across the institutes should be avoided in a model curriculum. Faculty of different institutes should be left to develop the courses as per their interests and strength. However a rather uniform template for core courses can be developed which will ensure a basic level of synergy across various institutes helping students pursuing higher degree.

- The curriculum should be quantitative and based on correlations between structure, property and process. It should discourage mugging of concepts, rather concepts can be delivered via a quantitative, project and assignment based approach along with hands-on experience.
- Sharing of courses with departments should be promoted to ensure that common courses are shared hence enhancing the faculty time utilization and eliminating the duplication.
- Whilst designing manufacturing related courses, one can adopt unit operations approach, which minimizes the number of courses without sacrificing the content.
- Balancing of theory and experiments as well as tutorials is quite critical.
- Computational and mathematical courses need to be enhanced and be organized in such a fashion in conjunction with other courses such that skills are not lost. Also, these courses could be taken up in collaboration with other well-equipped departments.
- There should be adequate emphasis on the process understanding in addition to understanding of materials behavior; former is quite well taken up by Chemical Engineers.
- The total contact hours should be approximately 24-28 hrs per week.
- Innovative ideas need to be applied in teaching such as asking students to do small projects such as finding about a given piece of material (IITB experiment)
- Also, the interdepartmental common courses, the departments can ask their faculty to become tutors such as in Mathematics and Physics.
- We should evolve concept of modular courses where a courses can consist of topics around a theme and can be taught by multiple instructors.

A few key points that were strongly emphasized by various colleagues:

a) Mathematical component needs to be increased in teaching of Materials and Metallurgy
b) Innovative ideas have to be implemented while teaching some ‘too theoretical’ contents
c) Resources need to be utilized in a more effective way and perhaps a unified template will further help this cause

Basic Curriculum Template

(A) Institute Core Courses

These are the list of basic courses which are to be spaced out in eight semesters with most of them being taught in first two years.

(A1) Mathematics related courses (5-6)

1. Numerical Methods	(2L+1T)
2. Probability & Statistics	(2L+1T)
3. Linear Algebra	(3L)
4. Ordinary and Partial differential equations.	(3L)
5. Vector Calculus	(3L)

Above courses should be spaced out over four years and are complemented with appropriate exercises in the departmental courses so that concepts are retained.

(A2) Physics related courses (3)

1. Physics I: Engineering Mechanics	(3L)
2. Physics II: Electricity/ Magnetism/ Quantum Mechanics	(3L+1P)

(A3) Chemistry related courses (2)

1. Physical Chemistry	(3L)
2. Analytical Chemistry/ Inorganic Chemistry/ Metallurgical Analysis	(2L+1P)

(A4) Biology and Life Sciences (1)

1. Basic Biology	(2L)

(B) Other Institute Core courses/topics related to Science and Engineering (10-12)

1.	Engineering Drawing and Design	(3L+1T)
2.	Programming and Computational Skills	(2L+1T/P)
3.	Manufacturing Process	(2L+1P)
4.	Solid Mechanics and Rigid Body Mechanics (Statics and Dynamics)	(3L)
5.	Fluid Mechanics/ Transport Phenomena	(2L+1T)
6.	Basic electrical engineering, electronics, and instrumentation	(2L+1P)
7.	Introduction to Materials	(2L)
8.	Humanities and Social Sciences (**2 to 4 courses**)	(3L)
9.	Ethical and Environmental issues	(2L)

(C) Departmental Courses (40-50%)

It was decided that departmental core courses can be listed in terms of topics and various Institutes can decide on how much weightage to be given to various topics, depending on their strengths. The overall department course content was divided into four broad categories

C1: Departmental Core Courses (11)

Course or topic	Lectures	Tutorial	Laboratory/Project
1. Materials Thermodynamics and Phase Equilibrium	3L	1 T	--
2. Reaction kinetics, Diffusion and Phase Transformations	3L	1 T	--
3. Structure of Materials	3L		1 P
4. Unified Course on Mechanical Properties	3L		1 P
5. Phase transformations, Microstructures and Heat Treatment	3L		1 P
6. Electronic, Magnetic and Functional Properties	3L		1 P
7. Chemical and Thermal Processing of Materials	3L		1 P
8. Mechanical Processing of Materials	3L		1 P
9. Materials degradation	2L		
10. Design and selection of Materials	3L		1 mini project
11. Iron and Steel Making **(Can be moved as Departmental soft core)**	3L		

1. Materials Thermodynamics and Phase Equilibria (3L + 1T)
2. Reaction kinetics, Diffusion and Phase Transformations (3L)
3. Structure of Materials (3L+1T)
    - Bonding, Crystalline and non-crystalline solids, Defects, Microstructure and basic characterization such as XRD, OM and SEM
4. Unified Course on Mechanical Properties (I) (3L+1P)
    - Mechanical behavior of materials (elasticity, plasticity, creep, fracture)
5. Unified Course on Functional Properties (II) (3L+1P)
    - Functional properties (electrical, dielectric, magnetic, optical , thermal)
6. Chemical and Thermal Processing of Materials (3L+1P)
    - Chemical (Extraction of various types of materials)
    - Thermal (Solidification, Casting, Welding)
7. Mechanical Processing of Materials (3L+1P)
    - Deformation processing and particulate processing of various types of materials
8. Materials degradation (2L)
    - Corrosion, oxidation, fatigue, wear
9. Design and selection of Materials (2L)
    - Couple with a mini project

10. Phase transformations & Microstructure (Heat Treatment) (3L+1T/P)
11. Iron and Steel Making (Can be moved as Departmental soft core)

C2: Laboratories (6)
1. Structure and characterization of materials
2. Mechanical properties of materials
3. Functional Properties of Materials
4. Phase Transformations and Microstructures
5. Thermal and Chemical Processing of Materials
6. Mechanical Processing of Materials

C3: Mini-Projects (minimum 2)
1. Design and selection of materials
2. Structure-property-process correlations

C4: Departmental Electives (Dependent on faculty strength and interests)

Physical and Mechanical Metallurgy	**Modeling and Simulation**	**Extractive and Process Metallurgy**	**Advanced Functional Materials**	**Processing and Manufacturing**
Dislocation theory	Computational methods in materials engineering	Nonferrous extraction	Smart materials	Welding and joining
Microstructural engineering	Modeling and simulation (FEM/FDM/CV)	Secondary steel making	Thin films and device fabrications	Powder metallurgy
Advanced phase transformation	Numerical analysis for metallurgical problems	Electro and hydro metallurgy	Electrical, optical and magnetic ceramics	Solidification processing
Diffusion in materials	Mechatronics	Plant design and economics	Nuclear metallurgy	Surface engineering
Alloy design	Computational materials science		Biomaterials	Nondestructive testing
Advanced metal forming			Polymers and composites	Environmental issues of materials
Interfaces in materials			Advanced ceramics and composites	

C5: Institute Open Electives
To be determined by availability in the institute and relevance

C6: UG Project
It was felt that the issues of evaluation and plagiarism were quite important in the UG project. While it is an important exercise, it should be conducted in such as manner so that its purpose is achieved. It was felt that it can be made optional if the departments desire so.

One model can be to replace the UG project with 2-3 elective courses.

Another model can be to make students do two or more mini projects focusing on various aspects of materials which could be more relevant and interesting such as one on design and selection of material, another or structure property correlations in materials and so on.

C7: Industrial visit/training
The institute should facilitate this activity so that students compulsorily spend a month in summer or winter at an industry. For this, faculty members should not be loaded with responsibility and it should be taken care by training and placement department. For example, PEC Chandigarh has taken an unique initiative in this direction where students are expected to spend 16 week (a semester) in an industry.

Summary over eight semesters

Institute core and HSS courses	18-20 Courses
Departmental Core	10-12 Courses
Departmental and Open Electives	6-8 Courses
Laboratories	6 (Department) 3-4 (Institute)
Mini Projects	2+

A few suggestions on curriculum:
- A few participants suggested that course on "Numerical Methods" needs to be taught by the department instead of being taught by Mathematician in order to give more application based problems to students. It was also suggested that theory part of this course needs to be condensed. Others suggested that this course needs to be replaced by "Modeling & Simulation" which deals with Finite-element finite-volume calculations and then these can be used for solving various problems in linear algebra, PDE etc.

- A lot of debate took place on what should be the content of analytical chemistry. Some believed it should be called "Metallurgical Analysis". One point everyone seemed to agree on is that the number of courses in Chemistry needs to be reduced.

- Fluid Mechanics and Transport Phenomenon: It was again pointed out that this course can be followed in 2L +2T mode where lectures are taken by one department for students from various streams like Materials Engineering, Mechanical Engineering, Chemical Engineering. While tutorials can be taken by specific departments so that relevant examples can be provided to students)

How to excite the undergraduate students
It was felt that one of the biggest challenges in materials and metallurgy education is the how to motivate and excite the young undergraduate students over the course of four years. There were various suggestions such asL

- Faculty can use recent technology to update with students.
- We should help to improve the job opportunities in the core sector and should excite them about it.
- Facilities (labs and softwares) can be shared with UG students to improve their motivation. IIT must share facility with NIT students.
- Industry leaders should be invited periodically to motivate the students.
- Faculty must themselves be excited to create excitation in student. There has to be balance and synergy between the career aspirations of students and the faculty.
- More hands-on and project related approach can enthuse the students
- Technical festivals can be utilized to showcase his/her skills.
- Sharing of course material and question bank can be done between IIT and NIT as well as online resources can be shared.

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