CHAPTER 6

COLLOBORATIVE, COMPETENCY BASED ENGINEERING EDUCATION

6.1 INTRODUCTION

From the literature survey, was evident that engineering education in India faced the following constraints:

1. Weak foundation in mathematics and science at school level due to rote learning.
2. Difficulty to manage transition to English medium from their school studies in a vernacular language medium.
3. Lack of aspiration and aptitude of students for engineering.
4. Lack of focus and ownership for learning by the students
5. Limited understanding of industry requirements for talent in a competitive environment.
6. Lack of progressive approach to curriculum and pedagogy design.

7. Lack of alignment between the theory and laboratory/workshop classes.

8. Inadequate laboratory facilities considering an ever increasing student strength.

9. Far too many credits/courses compromising depth, inadequate focus on specialisation by not utilising choice of electives.

10. Inadequate collaboration between industry and academia.

In view of this, the development of engineers coming from the engineering Institutes takes considerable time, efforts and hence the cost. It takes about two years to get them functional in the entry level roles. But there is a wide variation in their development to the target roles depending on the managers and engineers themselves. By the time they are ready for the role, over 50% of them leave organisations for better pastures.

In order to address this challenge, a holistic collaborative, competency based engineering education system was developed with active involvement of the stakeholders in a polytechnic and an engineering college using systems approach as shown in Figure 6.1. A Mission was established for this Collaborative Education Programme (CEP).

"Develop a pool of Aspirational, Highly Engaged, Competent (relevant for life and Career), Industry ready & role ready engineers to excel in engineering and manufacturing best in class automotive products and in their lives"

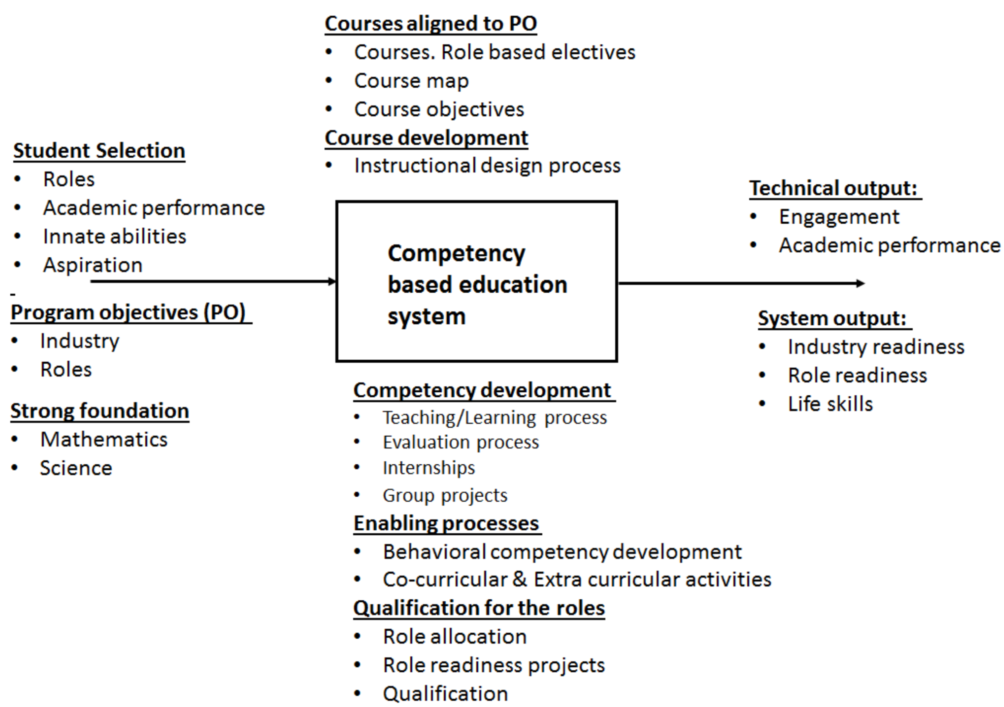


Figure 6.1 Competency based education system

Inputs for this system include:

- Outreach to attract students with right aspiration & Selection based on innate abilities
- Ensuring strong foundation of mathematics and science
- Programme objectives to address the competencies of roles in the corporate

The transformation process consists of three key sub-processes:

- Identification of courses aligned to Program Objectives (PO)

- Developing the courses using instructional design methodology and Bloom's Taxonomy
- Competency development – teaching / learning process, evaluation, internship and group projects
- Enabling processes – behavioural competency/ Professional skills development, co-curricular and extra curricula activities
- Qualification for the roles – role allocation, role readiness projects

Technical output of the system include engagement and academic performance of the students. System output include industry readiness, role readiness and life skills.

6.2 SELECTION OF STUDENTS WITH RIGHT ASPIRATION AND INNATE ABILITY

When the collaborative programme for diploma in mechanical engineering was started in a polytechnic college, there was a challenge in attracting a good pool of students for the programme. The CEP had following merits:

- Reputation of the polytechnic with over 50 years of existence
- Reputation of the automotive company with over 100 years of existence
- Company sponsoring the students by bearing all the expenses for the programme
- Job guarantee on completion of the course

Despite these merits, attracting high quality students for CEP was a challenge. Few meeting with the students and parents revealed the following facts:

- Most of the students apply for the diploma programme after their 10th standard, hail from urban and semi-urban areas. In these areas, most high quality talent have aspiration to pursue undergraduate programme in engineering and hence they join the higher secondary school programme
- Either due to economic conditions or academic performance in their 10th standard, some of the students choose to go to polytechnic.
- Even these students who join diploma programme like to consider lateral admission to undergraduate programme post their diploma education.
- If they don't make it to the undergraduate programme on completion of the diploma, they have an insurance of taking up a job and still keep trying for the undergraduate programme.
- Hence, they hesitate to join CEP which require a commitment for employment on either side.
- In addition, they are driven by the social status that an undergraduate programme offers them.
- Any amount of persuasion with the students and parents did not yield desired results in getting a good number of quality students.

The Chief Education officer (CEO) of the region knowing the merits of the programme, offered to invite the headmasters and presidents of Parent-Teacher associations from over 150 schools in a rural area for an interactive session. The features of the CEP were shared with this group who recommended students interested in considering the programme. In addition, the automotive company was actively engaged in Corporate Social Responsibility (CSR) in the rural areas around their manufacturing plants. The CEP team shortlisted a few locations where large number of good schools were located. CEP team conducted a career guidance program explaining the salient features of CEP programme.

Both the locations responded well for the programme. Initial screening was done in the villages based on consistent academic performance and tests in English, Mathematics and Science. In two years time, the response for this programme had significantly improved. As the response for the CEP was significantly better from a larger catchment area, the quality of the students selected has significantly improved. Also in terms of aspiration, the students and parents coming from rural areas never imagined going to a good polytechnic college on their own and they have no idea about undergraduate engineering programme and about lateral admission after diploma programme. They were delighted with the opportunity offered to them to pursue a diploma programme in such a reputed polytechnic college and getting sponsorship from the automotive company with a job guarantee. The students are highly committed and are better engaged than the earlier batches.

In the case of the undergraduate programme in engineering, the admission happens through a single window process by the state technical university. The colleges have little say in admission except for management quota seats. Hence it was decided to select the students at the end of first semester. This is due to the following issues :

- There are students who are rigorously coached in school for two years to crack the examinations just by rote memory. . Such students find it difficult to cope up with engineering education for few semesters.

- Many students, after two years of pressure from parents and the school, take the first semester easy to relax. Such students are unable to pass all the courses in the first semester.

This selection after first semester ensures choice of students with right aspiration and attitude for CEP.

The selection process for the CEP is similar to the one explained in the Section 4.3. Minor variations in the choice of tools, activities and duration between diploma students and undergraduate students. Every year, the qualifying criteria is being revised upwards based on the wider choice of the candidates.

6.3 BRIDGE COURSE FOR GOOD FOUNDATION TO LEARN ENGINEERING

Engineering is about applied Science and Mathematics. For example, brakes in an automobile can only be designed and improved with deeper understanding of the concept of 'friction'. Similarly road induced and engine induced vibrations in automobiles must be tackled to improve the comfort of the passengers. This can be improved only with a deeper understanding of 'damping'. In the absence of such understanding, generally engineers tend to approach the problems on a trial and error basis or by copying from benchmarked vehicles which may not yield desired performance at an optimal cost.

This is due to the fact that the students do not learn Science and Mathematics with clear understanding and lack ideas about application of the concepts in real life. As mentioned in the previous sections, the Indian School education does not have a common framework. There are multiple governance bodies for school education. The State Boards for secondary education which are managed by state governments haven't kept pace with changing realities in the country and in the world. The education system of the state board is generally rote based where students lack understanding and application.

When students follow rote based learning, they tend to forget the concepts soon after the examination. When the students understand the concepts and relate to real life application of the concepts, they do not forget the concepts easily. The technical tests for CEP was prepared on the lines of CBSE pattern which contains 70% of the questions for 'understanding' and 'application', only 30% is towards 'remember'.

In the case of undergraduate students, the Institute is a 60 years old premier institute which attracts within the top 10 percentile of the students from Higher Secondary School Examination in the state. In the single window counselling, the institute's seats get filled up in the first three days. Despite this, the students who score close to 100% in their board examination, mean score is less than 40% in mathematics and Science as shown in Figure 6.2. This proves the point that the students lack understanding of the concepts of physics, chemistry and mathematics.

12th standard marks Cutoff Vs Entrance test marks (2012 batch)

Maths **Physics**

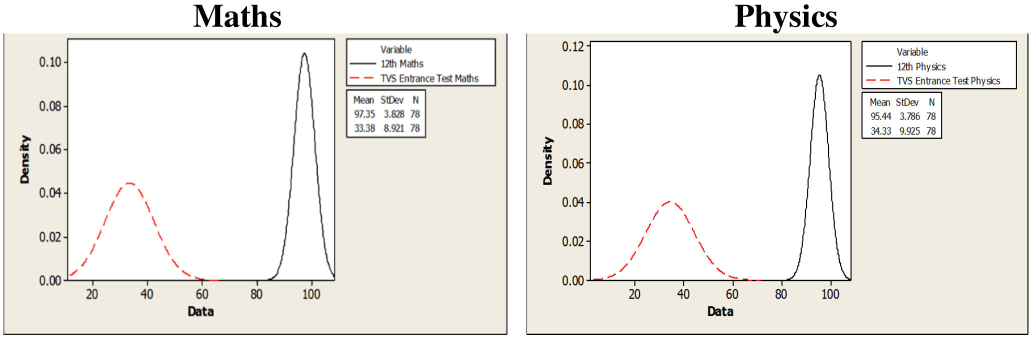


Figure 6.2 Performance of students in 12th standard and in admission test

Similarly, in the polytechnic college, the students who scored more than 80% in their state board secondary school, mean score less than 40% in the selection test. This is shown in the Figure 6.3.

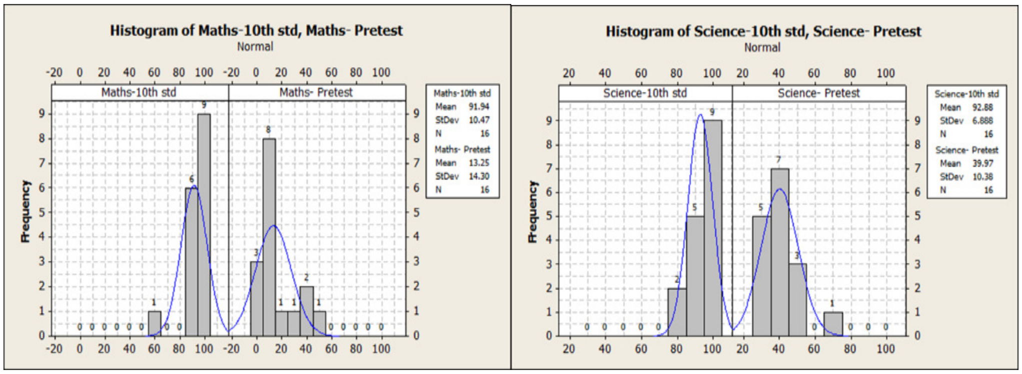


Figure 6.3 Performance of students in 10th standard and in admission test

In both the cases, students also lack proficiency in English as most students did their school education in Tamil medium which is their mother tongue. The polytechnics and engineering institutes teach the programme in English medium. The students have the challenge of suddenly coping with English medium.

A large number of undergraduate students who qualified for admission in the premier institute are unable to pass their examinations in the first few semesters. Generally the students are unable to clear in the first attempt in the following courses:

- Calculus and its application
- Linear Algebra and Fourier series
- Engineering Mechanics
- Fluid Mechanics
- Strength of Materials

- Kinematics of Machinery
- Dynamics of Machinery
- Applied Thermodynamics
- Heat and Mass transfer
- Fluid Mechanics and Gas Dynamics

All these courses involve physics and mathematics. Students find it difficult to assimilate and perform well in the examination.

It was evident that there is a need for a bridge course to strengthen the foundation on mathematics and science to learn engineering better. Team of teachers from a CBSE school, faculty from the colleges mapped the concepts of science and mathematics taught in the school against the engineering courses by each semester. Table 6.1 shows the mapping for physics for the polytechnic. Similarly mapping was done for mathematics and chemistry for polytechnic and engineering college. Based on this mapping, bridge course modules were structured for three semesters. Module 1 is offered prior to starting their course in the first year for the diploma students.

Table 6.1 Mapping of physics topics vs Engineering courses

SEMESTER	Engg courses Vs Physics topics	UNITS OF MEASURMENTS- (Develop Content)	STATICS (Content drawn from SBS)	ELASTICITY (Content drawn from SBS)	VISCOSITY (Content drawn from SBS)	SURFACE TENSION (Content drawn from SBS)	PROJECTILE MOTION (Content drawn from SBS)	CIRCULAR MOTION (Content drawn from CBSE)	SIMPLE HARMONIC MOTION (Content drawn from SBS)	ROTATIONAL MOTION OF RIGID BODIES (Content drawn from SBS)	GRAVITATION (Content drawn from CBSE)	SOUND (Content drawn from CBSE)	MAGNETISM (Content drawn from SBS)
		Module - 1											
FIRST YEAR	0104 Engineering Physics – I	X	X	X	X	X	X	X	X	X	X	X	X
	0206/0306Engineering Graphics– I	X											
	0114 Engineering Physics – II												
SEMESTER III	2201 Mechanical of Materials	X	X	X				X		X	X		
	2202 Fluid Mechanics & Fluid Power	X	X		X	X					X		
	2301 Manufacturing Processes	X											X
SEMESTER IV	2205 Applied Thermodynamics	X											
	2206 Electrical & Electronics Engineering	X	X								x		X
	2303 Machine Shop Technology	X											

Pre-test is conducted prior to the bridge course and post test is conducted after the bridge course module is completed. It was found that a significant improvement in the performance of the students post bridge course in all the subjects. Figure 6.4 shows the performance of students in physics in 10th standard, admission test, pre-test, post-test and semester examination. Similarly, the performance in mathematics, chemistry, English is shown in Appendix A.4.20, A.4.21 and A.4.22. This shows that there is a significant improvement in the performance of students in Mathematics, Physics, Chemistry and English after the bridge course. It is not possible to influence the entire school system to create a strong foundation, bridge course provides a fairly good foundation to learn engineering.

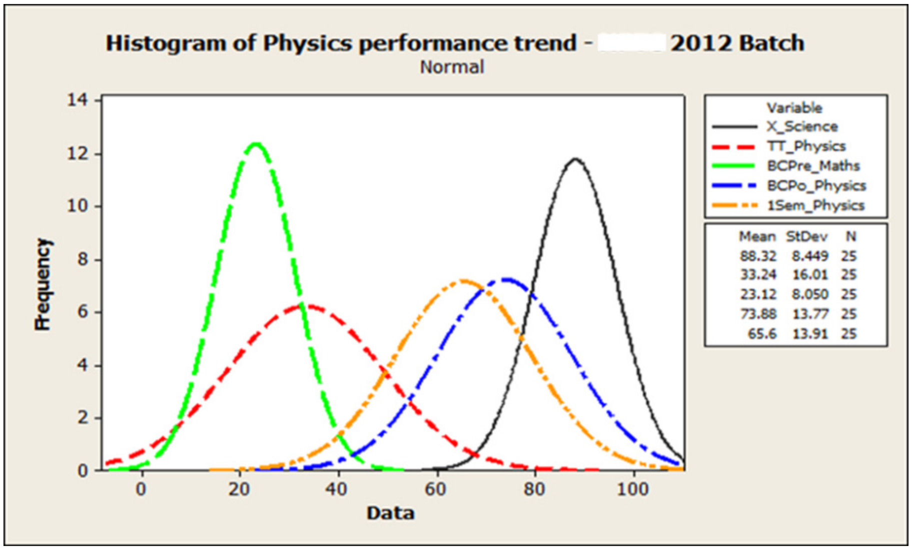


Figure 6.4 Performance in admission test, pre-test and post test of brige course

The CBSE school who conducts the bridge course for the polytechnic has now come forward to develop a bridge course for the undergraduate students in the engineering institute. This would be started in the next academic year 2015 – 16.

6.4 PROGRAMME OBJECTIVES ALIGNED TO TARGET ROLES

A two levels of key roles were chosen in the areas of Product engineering, Production engineering and Production management. The competencies of the roles established in the automotive company were considered for establishing programme objectives. Few examples of the functional competencies include Product awareness, Product engineering, Design verification, Manufacturing processes, Manufacturing systems, Quality control, Quality Assurance, Problem solving, Project management and Product cost management at several levels ranging from level 1 to level 3.

Based on the competencies of the key roles and benchmarking of universities, programme objectives were established for Diploma in mechanical engineering Undergraduate programme in mechanical engineering.

At the end of the Diploma in Mechanical Engineering, the programme students will :

- Apply scientific principles and concepts relating to phenomena of products and processes.
- Design and prepare parts drawings of mechanical elements by modelling / drafting adhering to design guidelines and standards that are fit for purpose
- Plan and prove new production facilities stabilising Quality, Delivery and cost.
- Measure parts using appropriate methods, test parts and sub-systems against engineering standards.
- Check the design of products and processes for DFX – assembly, manufacture, cost, quality, productivity & ergonomics
- Demonstrate working level understanding and appreciation of inter-disciplinary domains that are required for design of mechanical elements.
- Solve problems using appropriate tools and techniques

On successful completion of BE Mechanical programme, a student will be able to:

- Apply scientific principles and concepts relating to development of products and processes

- Design and develop products and processes, that deliver the requirements of the target customer group and related quality functions.

- Use modelling and simulation to analyze systems' behavior and optimize for results

- Demonstrate working level understanding and appreciation of inter- disciplinary domains that are required for design of products and processes.

- Check the design for DFX – assembly, manufacture, cost, quality and reliability, serviceability, re-cyclability, environment, ergonomics

- Choose appropriate quality tools and techniques for problem solving

- Understand the industrial and business environment in which the enterprise operates.

Similarly, objectives for undergraduate programme in Electrical and Electronics programme was established.

6.5 COURSES ALIGNED TO PROGRAMME OBJECTIVES

A matrix was prepared between the programme objectives and the courses offered in each semester with clear relationships as shown in the Table 6.2. Using this relationship, one can establish objectives for each course based on the programme objectives that each course supports. The courses that are not strongly connected to the programme objectives were reviewed. Similarly where a few programme objectives were not supported by adequate courses, certain new courses have been included. The courses required for a deeper specialization in design or manufacturing are included in the list of electives and they were arranged into streams. This check was found to be useful in aligning courses with the functional objectives.

Table 6.2 Programme objectives vs Courses

		Program Objectives								Behavioural Objectives							
CODE	SUBJECTS	Apply scientific principles and concepts relating to phenomena of products and processes	Design and develop products and processes, that deliver requirements of the target group.	Use modeling and simulation to analyze systems' behavior and optimize	Demonstrate working level understanding and appreciation of inter-disciplinary domains.	Check the design of products and processes for DFX –	Solve problems using appropriate tools and techniques	Understand industrial and business environment in which the enterprise operates		Sound health, physical fitness and positive attitude	Adherence to ethics and TVS values	Communication, Interpersonal and team-working skills	Emotional stability	Learning capability and self-reliance	Creative thinking and constructive criticism	Plan and work to time.	Versatility and Adaptability to change
H11	Engineering Mathematics-I	●															
H12	Physics	●															
H13	Chemistry	●															
H14	English											●		●			
H15	Basics of Mech and Civil Engg.	●															
H16	Basics of EEE and ECE				●												
H17	Physics Lab	●															
H18	Chemistry Lab	●															
H19	Engineering Graphics	●															
G21	Engineering Mathematics-II	●															
G22	Free body mechancs-I	●				●											
G23	Material Science	●				●											
G24	Ecology	●						●		●							
G25	Metrology	●	●				●										
G26	Computer Programming			●													
G27	Metrology Lab	●				●											
G28	Computer Programming Lab			●													
G29	Workshop	●	●														
G31	Engineering Mathematics-III	●															
G32	Free body Mechanics-II	●				●											
G33	Applied Materials & Metallurgy		●														
G34	Thermodynamics	●															
G35	MP 1 - Casting & Welding		●			●											
G36	MP 2 - Forming,Joining & Finishing																
G37	Manufacturing Process Lab		●			●											
G38	SoM & Materials Lab		●														
G39	Machine Drawing		●														

Even though electives options are available in all the institutes, they are not arranged in streams to offer role and career focus. Institutes and students lack awareness of roles and career opportunities in the corporate and hence the choice of electives. Despite having 180 credits and over 40 courses in four year undergraduate programmes, students do not take up an adequate number of courses aligned to the roles they will assume in the companies. Hence they do not learn the domain knowledge and skills through a formal academic course and apply them in their work.

A streams of electives using option of eight elective courses offered in the undergraduate programme as shown in the Table 6.3. While the programme is still in Mechanical engineering, the streams of electives were carefully chosen to bring automotive focus and role focus. Three courses such as automotive fundamentals & manufacturing, Systems Approach for Engineers and Project management are considered to be ‘Automotive Core’ which every student as a part of CEP has to go through. The next two courses each are used to offer ‘Design Core’ and ‘Manufacturing Core’. ‘Design Core’ contains automotive engines and systems and another in vehicle design and engineering. ‘Manufacturing’ stream contains Manufacturing Systems Engineering and Logistics engineering.

Within the Design stream, there are two streams namely Powertrain design and Testing and Vehicle design and Testing with three courses in each. Similarly there are three streams within manufacturing stream namely Assembly Engineering, Forming and Joining, and Metal Cutting with three courses each. These courses were developed with experts who are practitioners in the respective field and delivered by them. These streams focus the students for specific roles in design or manufacturing.

Table 6.3 Streams of electives leading to roles

6	Automotive Fundamentals and Manufacturing				
	Project Management				
7	Systems Approach for Engineers				
	Automotive Engine and Systems		Logistics Engineering		
	Vehicle Design and Engineering		Manufacturing Systems Engineering		
8	Fundamentals of spark ignition engines	Vehicle Design Engineering (Static Systems)	Assembly Processes & Tools	Weld joint design & process engineering	Metal Cutting Process Engineering
	IC Engines - Design & Engineering	Vehicle Design Engineering (Dynamic Systems)	Assembly Engineering	Press tool design & welding fixture design	Metal Finishing Process Engineering
	Powertrain Testing & Instrumentation	Vehicle Testing & Instrumentation	Assembly Testing & Assurance of Performance	Forming & tube bending	Tool Engineering
ROLE	PART DESIGN ENGINEER/TESTING ENGINEER	PART DESIGN ENGINEER/TESTING ENGINEER	PROVING ENGINEER - ASSY	PROVING ENGINEER - FABRICATION	PROVING ENGINEER - TCM/ECM

Another challenge in learning engineering is understanding the connection between several courses that the students learn over three or four years. Practicing engineering would involve synthesising the several disciplines and concepts that they learn over time. For example, if we have to prepare a 'delicious dish' what we need is the content and recipe to prepare it. If we collect the high quality contents and put it in a bowl it does not become a dish unless they are prepared and cooked using a recipe. Similarly, the undergraduate students learning of over forty courses over four years and passing in each of the courses does not make them good engineers. Hence a course map is established with connections between the courses which can be considered as 'Recipe' for learning engineering.

For example, in the first semester, the students in mechanical engineering learn physics and chemistry in which they learn about the physical properties of materials, atoms, molecules, etc. When they learn material science in the second semester, they need to understand how a particular chemical composition impacts the physical properties. When the carbon content is low in iron, it is called low carbon steel and the alloy has property of ductility and malleability. If the carbon is very high in iron, it becomes cast iron and it becomes brittle but strong in compression and has good damping properties. These concepts will be useful in choosing the right material in design of machine elements and choosing the right manufacturing processes. In the case of low carbon steel where ductility is good, forming, bending can be used to manufacture the parts. In the case of cast iron, casting process is the best choice to manufacture parts.

Hence a course map, shown in Figure - 6.5 was prepared to establish relationships between the various courses. Prior to starting every course, the student's understanding of concepts learnt in the previous courses must be verified. Wherever required, revision and refreshing would be useful.

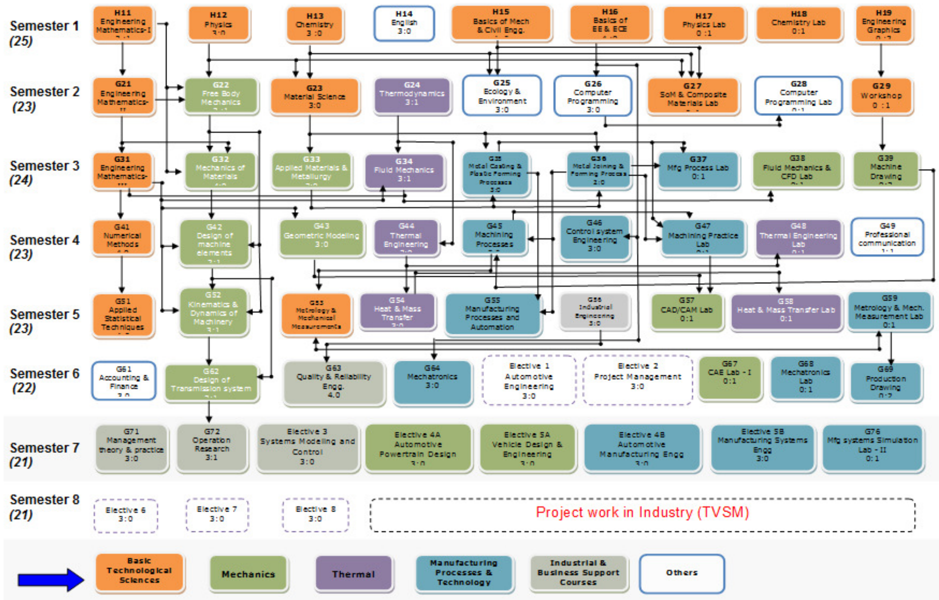


Figure 6.5 Course map showing linkages between courses

Appendix A.4.23 shows an example how course map can be managed by establishing relationship between the courses while developing AC Machines course in undergraduate program of Electrical and Electronics Engineering.

6.5.1 Course Objectives

Course objectives are established for each of the courses of the programme which become the learning outcomes of the course. The objectives established for each course must enable the student to demonstrate the overall programme objectives. Hence course objectives must be derived from programme objectives and not from the existing curriculum. This is an iterative process and the objectives are reviewed during development of the course and after the delivery. Examples of objectives derived for two of the courses is as follows:

At the end of the course in Physics, the students will

1. Explain what influences the physical properties
2. Explain influence of physical properties on the product functionality
3. Explain the concepts of simple machine, equilibrium and mechanical advantage in real life applications
4. Explain the influence of pressure, velocity, temperature on flow of matter
5. Solve simple problems by applying fundamentals of physics

At the end of the course in Mechanics of materials, the students will

1. Determine the stress and strain relationship, strain energy, yield stress and explain the failure theory
2. Solve numerical problems related to mechanical deformation and properties of materials
3. Explain the concept of different supports and determine the bending moment, shear force, bending stress and deflections
4. Explain theory of torsion and equations to solids and hollow shafts to derive numerical solutions for transmissions
5. Selection criteria with numerical examples and solutions for typical gears and drives
6. Solve simple problems by applying the above concepts and thereby demonstrate comprehension of strength and stiffness of machine elements

Articulating the course objectives is a iterative and creative work and need to visualize the role of engineers and how such course objectives would help the engineer to practice in the specific task which is aligned to programme objectives. The Table 6.4 shows how the linkage between the course objectives with programme objectives can be verified.

Table 6.4 Programme objectives vs course objectives

	CO1	CO2	CO3	CO4	CO5
PO1	●	●	●	●	●
PO2	○	○	○	○	●
PO3	○	○	○	○	
PO4					
PO5	○	○	○	○	●
PO6					
PO7					

6.6 COURSE DEVELOPMENT

Course development is carried out using instructional design process explained in section 5.3. Course development was carried out by a team of faculty and Subject Matter Experts (SME). To start with, a design document is prepared as shown in Table 6.5. The course objectives established are used as the terminal objectives which is nothing but learning outcome to be accomplished at the end of the course. Enabling objectives required to accomplish the course objectives are identified at one or two levels. The objectives are classified into cognitive process and knowledge dimensions. Content and pedagogy is determined using guidelines shown in Table 5.7. This serves as a guideline for choosing appropriate methodology by the team.

Table 6.5 Design document for course development

Terminal Objectives (TO) (What the participant will be able to do at the end of this training program)		Enabling Objectives (EO) Level 1 (What the participant should be able to do if he has to do the relevant TO)		Enabling Objectives (EO) Level 2 (What the participant should be able to do if he has to do the relevant EO level 1)		Content (The content that needs to be covered if the participant has to do the relevant EO)	Bloom's taxonomy of Objectives	
							Type of knowledge	Cognitive dimension
By the end of the training program, participants will:		By the end of the training program, participants will:		By the end of the training program, participants will:				
1	Solve the problems in engineering systems using the concept of static equilibrium	1.1	Represent the force system, moment and couples	1.1.1	Explain the concept of vector and scalar and the importance of both	Explaination the concept of vector and scalar and the importance of both	Conceptual	Understand
				1.1.5	resolve the force system in three dimension	Resolution of the given force system in three dimensions and expalin the difference in each component	Conceptual	Apply
				1.2.4	Find the reactions of supports in two dimensions	Determination of the reactions of supports in two dimensions	Conceptual	Apply
				1.2.5	Explain the types of supports in three dimensions	Discussion of the various types of supports in three dimensions	Conceptual	Understand

In view of standardization of the course development process across institutes, the company and multiple teams, a portal was established which is shared between the CEP team, SMEs and Faculty in the institutes. This also ensured only one version of the design document and course material and any corrections are carried out on one master. Table 6.5 shows several methodologies for teaching/learning, advantages, disadvantages and guidelines to make use of the merits. The methodologies include lectures followed by question based discussion, small group discussion, case studies, video and audio, role plays, activities and exercises.

Table 6.6 Evaluation of teaching/learning methodologies

Methodology	Advantages	Disadvantages	Preparation
Lecture	Factual material is presented in a direct, logical manner. May provide experiences that inspire. Useful for large groups	Good presentation skills needed. Audience is often passive. Learning is difficult to gauge. One-way communication	There should be a clear design. Using audience specific-examples, anecdotes increases effectiveness
Lecture followed by discussion	Involves students, at least after the lecture. Students can question, clarify and challenge.	Time constraints may affect opportunities. Effectiveness depends upon appropriate questions and discussion.	Faculty need to listen, encourage questions. Need skills to manage monopolization, flagging down of interest.
Questions Based Discussion	Pools ideas and experiences from group. Opportunity for everyone to participate.	Cannot be applied if more than 20 students. May lead to limited participation Time consuming and require energy	Requires careful planning by faculty to guide discussion. Requires careful wording of questions.
Small Group Discussion	Encourage participation of everyone in small groups Groups can reach consensus.	Group dynamics. May get side-tracked.	Needs preparation and moderation.
Case Studies	Develop problem solving skills in exploring solutions Opportunity to apply new knowledge and skills.	Sometimes may not be able to relate to own situation. Insufficient information can lead to inappropriate outcome .	Case must be clearly defined and prepared with appropriate context.
Video and Audio	Entertaining way of introducing content Keeps group's attention. Stimulates the concepts for students to relate to	Probability of different interpretation	Need to obtain clips and set up equipment. Effective only if discussion follows
Role Plays	Opportunity for students to assume roles and appreciate another point of view. Allows for exploration of solutions.	Some participants may be too self-conscious, feel threatened Not appropriate for large groups.	Need to define the problem situation and roles clearly. Must give very clear guidelines.
Activities and Exercises	Introduces problem situation indirectly. Breaks monotony. Wide range to choose from/prepare - only check is creativity.	Some participants may be unwilling to share.	Needs to be chosen carefully Must give very clear instructions. No value without debriefing.

The Table 6.7 shows one share of tutorial for few courses for which the structured tutorial system is planned.

Table 6.7 Share of lecture and tutorial for a course

	COl		CO2		CO3		CO4		CO5		CO6		Total	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T
AC Machines (E42)													33	12
Microprocessors & Microcontrollers (E43)													30	15
Control Systems(E44)													30	15
Digital Signal Processing (E45)													35	10
Electrical and Electronic Measurements (E46)													30	15

6.7 COMPETENCY DEVELOPMENT

In most engineering institutes in India, teaching is through lectures. Engineering programmes need to develop professional practitioners. This can happen only when a significant portion of the teaching and learning is focused on practice. In this regard, most universities have a judicious mix of lecture, tutorials, assignments, laboratory work and projects which are well integrated towards learning objectives. While lectures are delivered in the large lecture theatres for over 100-200 students, the tutorial is offered to a smaller group of 20 students. This is a major reform to be implemented in India and this would require infra-structure and a large number of tutors. It is possible for students pursuing their master's programme or doctoral programme to be trained as a tutors, which is practiced in a few western universities. This was tried for a few courses as an experiment and based on the merits, this can be extended to more courses. The institute has agreed to align this requirement with the new buildings that will be built in the next few years to have larger lecture theatres and smaller tutorial class rooms.

In most engineering institutes, the faculty are not trained on content development and delivery of the programme for greater effectiveness. In this regard, a formal workshops were organised for competency based curriculum development and for train the trainer programme.

In a competency or outcome based curriculum, the evaluation of learning is a challenging task as the evaluation must be around the competencies or outcomes that have been defined for the programme and courses. Currently, evaluation is not focused on learning outcomes. The higher the cognitive process level of the outcome, the more difficult it is to assess the competency. For example, framing questions for the examination for higher level cognitive process dimension requires the faculty to have a good understanding of the application of the engineering concepts. Moreover, the response to questions relating to higher level cognitive processes can widely vary from student to student depending upon their creativity and understanding. The response, which if not familiar to the faculty who is evaluating, may result in the student not being given the right score.

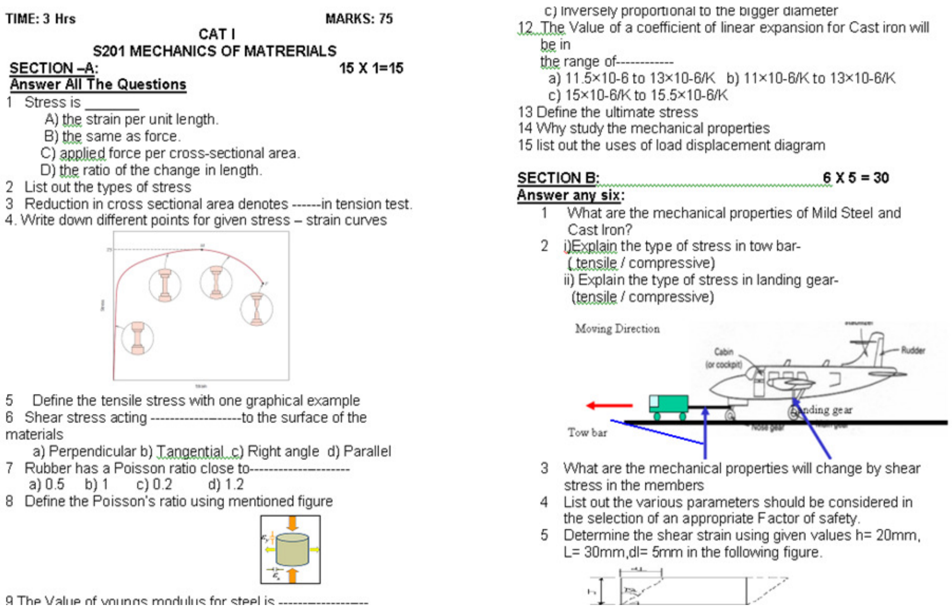
It is possible to use the evaluation methodology developed by (Kirkpatrick & James 2008). The first level is collecting feedback from the students on several aspects such as objectives or outcomes, content, delivery, duration, understanding, ambience and learning materials. Learning is measured through assignments, continuous assessment tests and semester examinations. Application of learning can be measured in laboratory exercises and projects. Outcome can be measured in laboratory exercises and projects. Getting such a systematic way of designing the evaluation process in an academic system will require the right perspectives, maturity, initiative and efforts on the part of the administrators and faculty. Experiments were carried out in this direction with faculty for few of the courses. As the electives were developed and delivered with experts and expert institutes, the company had a greater influence on the elective courses to experiment with new delivery methods, tutorials, activities.

An evaluation framework was established with guidelines for Continuous Assessment Tests (CAT), semester examination aligning to course objectives and enabling objectives (Table 6.8). This framework contains the cognitive process dimension on the columns with the continuous assessment tests and semester examination on the rows. For each of the tests and depending upon the course objectives and enabling objectives covered, the weightages of questions for cognitive process dimensions have been finalized. Based on the weightages, the types of questions and the number of questions are decided. Question banks are created for each of the cognitive process dimensions and type of questions. Based on the algorithm defined for each test or examinations, comprehensive question paper is generated on the portal by random generation. The question bank is prepared by the team of SMEs from the company and the faculty.

Table 6.8 Evaluation framework

Name	Total Marks	Course Objectives	Remember			Understand			Apply			Analyze			Evaluate			Create		
			%	No. of Qns	Marks	%	No. of Qns	Marks	%	No. of Qns	Marks	%	No. of Qns	Marks	%	No. of Qns	Marks	%	No. of Qns	Marks
CAT 1	50	1,2,3	20	5	2	20	2	5	60	2	15									
CAT 2	50	4,5,6	20	5	2	20	2	5	60	2	15									
CAT 3 / End Semester	100	1,2,3,4,5,6,7, 8,9	10	5	2	15	3	5	75	5	15									
# - There is either or choice for apply																				

A question paper for CAT-1 for Mechanics of materials is shown in the Figure 6.6. Similarly question paper for CAT-2 and CAT3 and Semester examination can be prepared from the question bank.



TIME: 3 Hrs MARKS: 75

CAT I

S201 MECHANICS OF MATRERIALS

SECTION –A: 15 X 1=15

Answer All The Questions

1 Stress is _______

A) the strain per unit length.

B) the same as force.

C) applied force per cross-sectional area.

D) the ratio of the change in length.

2 List out the types of stress

3 Reduction in cross sectional area denotes ------in tension test.

4. Write down different points for given stress – strain curves

5 Define the tensile stress with one graphical example

6 Shear stress acting -------------------to the surface of the materials

a) Perpendicular b) Tangential c) Right angle d) Parallel

7 Rubber has a Poisson ratio close to--------------------

a) 0.5 b) 1 c) 0.2 d) 1.2

8 Define the Poisson's ratio using mentioned figure

9 The Value of youngs modulus for steel is ------------------

c) inversely proportional to the bigger diameter

12 The Value of a coefficient of linear expansion for Cast iron will be in the range of------------

a) 11.5×10-6 to 13×10-6/K b) 11×10-6/K to 13×10-6/K

c) 15×10-6/K to 15.5×10-6/K

13 Define the ultimate stress

14 Why study the mechanical properties

15 list out the uses of load displacement diagram

SECTION B: 6 X 5 = 30

Answer any six:

1 What are the mechanical properties of Mild Steel and Cast Iron?

2 i)Explain the type of stress in tow bar- (tensile / compressive)

ii) Explain the type of stress in landing gear- (tensile / compressive)

3 What are the mechanical properties will change by shear stress in the members

4 List out the various parameters should be considered in the selection of an appropriate Factor of safety.

5 Determine the shear strain using given values h= 20mm, L= 30mm,dl= 5mm in the following figure.

Figure 6.6 CAT-1 question paper

After each test and examination, an analysis is carried out to understand how the class as a whole had performed and how each student had fared. The assignable causes such as content not adequate, teaching methodology not appropriate - for poor performances were identified and addressed by appropriate actions on the content or methodology. If there are slow learners, they are given some extra attention either by the teacher or by the peers.

6.7.1 Internships

Apart from competency based curriculum being implemented in the institutes, internships are offered to the students who are part of the CEP, during each of their semester holidays. Based on the courses learnt during each semester and the competency for the target role, the internship assignments and projects are arranged in order to acquire an understanding of the industry environment in terms of work-culture, products, manufacturing processes, manufacturing systems, safety orientation, quality orientation, team working etc. The CEP team has prepared a structured calendar for the internship programme for every semester (Table 6.9).

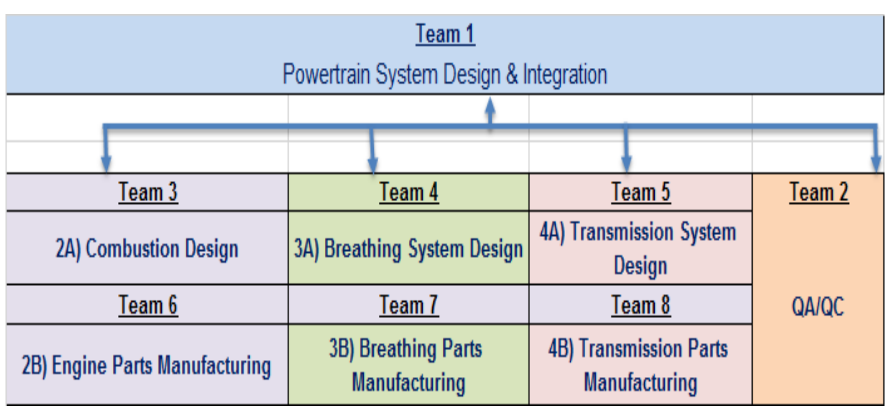
Table 6.9 Internship framework

S. No	Topic	Content	Semesters							
			I	II	III	IV	V	VI	VII	VIII
1	Acculturisation	Industry practices		●						
		History & Values		●						
		EHS		●						
		OHSAS		●						
2	Setting the context	Activities to be planned		●						
3	Company Way	Values		●						
		Principles		●						
		Mgnt processes		●						
4	Skill Development	Skill training, assy training, troubleshooting			●					
		Interpretation of drawings & Visualization			●					
5	Functional Competency development	Derived from CO/PO		●	●	●	●	●	●	
6	Behavioral Competencies			●	●	●	●	●	●	
7	Academic project								●	
8	Industry visit			●	●	●	●	●	●	
9	BAJA Project								●	

6.7.2 Group Industry Project

A project in the final year of the programme is the earliest opportunity to verify realization of programme objectives. In the industry, the projects are carried out in a collaborative manner. New product development is such a complex process that cuts across functions, roles, customers and suppliers. If engineers have to effectively contribute in such an environment, their projects in the engineering programme need to be designed with similar rigor. Group project was conceived for the first batch of undergraduate students to be carried out in a collaborative manner.

Table 6.10 Group project for undergraduate students



Twenty four students were assigned to eight teams to improve power train of a two wheeler as shown in Table 6.10. Each team had a distinct role and scope to play in the group project as shown below:

1. Power system integration – to improve power train performance in terms of fuel efficiency, emission and NVH (Noise, Vibration and Harshness)
2. Combustion design – contributes to the power train objectives with improvement in combustion
3. Breathing system design – contributes to power train objectives with improvements in breathing system
4. Transmission system design – contributes to power train objectives with improvements in transmission system
5. Manufacture of combustion parts – contributes to combustion improvements by manufacturing parts for new specifications
6. Manufacture of breathing system parts - contributes to breathing system improvements by manufacturing parts for new specifications
7. Manufacture of transmission system parts - contributes to transmission system improvements by manufacturing parts for new specifications

The teams have defined objectives in discussions with their faculty guide and industry mentor. The evaluation criteria and stage wise review system was revamped along with the faculty and industry mentors. Towards this, project charters are prepared (Appendix A.4.24 and A.4.25) with clear objectives, scope, stages, review points, evaluation criteria, list of reviewers and examiners.

6.8 ENABLING PROCESSES

Academic processes is one part of the competency development, which is necessary but not sufficient to develop industry ready, role ready and life ready people. Following insights from the literature survey is useful to create opportunities for students to develop on multiple dimensions in addition to academic performance :

- Education needs to be holistic with focus on body, senses, intellect, sprit, nature, cultivation of feeling, extension of self.
- Education is a manifestation of the perfection already in man and hence must focus on life-building, man-making, character-making, concentration of mind and assimilation of ideas.
- Education needs to combine ancient tradition with modern knowledge and be context sensitive.
- Students need to acquire knowledge from multiple sources including the subconscious.

Holistic development can be achieved by carefully designing programmes for development of behavioural competencies, actively engaging the students in co-curricular and extra-curricular activities aligned to their aspiration.

Close to half of the engineering graduates are not employable due to a lack of soft skills like communication and interpersonal skills. In India, getting into Tier-1 and Tier-2 professional colleges is extremely difficult as it is highly competitive. Students go through extensive hard work during their 11^{th} and 12^{th} standard with pressure from parents, school and peers.

Once they secure admission to their dream institutes, they face several challenges. Some of the schools coach students to secure high marks in the qualifying examinations for engineering courses in Tier-1 institutes. They crack the examinations without an understanding of the courses. Such students struggle to cope with the engineering course. Another group of students having worked very hard for two years, like to relax for a few months. All these lead to failure of almost 20-30% of the students in a few courses during the first few semesters. The students catch up in the subsequent semesters. The students who are aware of their limitations do not stretch a little by hard work. Looking at those who take their life easy, they are also tempted to follow them until they fail in the first semester. In most of the first rung engineering institutes, the placement is almost 100%. A single IT company selects about 250-500 students in a single day, which is close to 50% of an Institute's strength. Hence, getting a placement in the campus is also not difficult. Thus, the students gets into a stereotypic life in the campus with a single focus on placement without any serious learning and prepare themselves for their career. While a large number of students join the first year with great aspiration and a desire to work hard, the environment discourages such serious efforts and they fall in line with others very quickly.

In order to understand the challenges, the students in the first year go through, a focus group discussion (FGD) was organized with a cross section of students. The study has shown several challenges they encounter and they were grouped into few clusters (Appendix A.4.26), few themes and examples areas are given below:

- Hesitation: Hesitation to do/ask, doubt if the answer I have is right
- Laziness: Laziness to wake up, study and do assignments

- Peer Pressure: Pressure to follow stereotypes, criticize taking initiative
- Motivation: No motivation to do anything well, difficulty in studying regularly
- Communication: Hesitate to speak in English, Afraid of group discussion
- Interpersonal relationship: Unable to make impact on others, unable to control my anger, unable to get friendly with faculty
- Goal Setting, Planning and Prioritization: Friends demand time, afraid of losing friendship and hence unable to cope with studies, unable to engage in sports, attempt to plan but unable to follow due to multiple priorities

Based on the above inputs collected from the students, insights from literature survey, list of behavioural companies for the entry level employees in the automotive company, a set of behavioural objectives were established for the CEP, with specific goals.

At the end of the programme, the students would have developed:

- Positive health
- Adherence to ethics and company values
- Responsible citizens with a positive attitude
- Communication, interpersonal and team-working skills
- Learning capability and self-reliance
- Planning and work to time

The behavioural objectives were defined and behavioural indicators relevant to the context of the institute and automotive company were identified for designing the programmes (Appendix A.4.27, A.4.28 and A.4.29). Structured workshops and calendar was established for the students. The sequence in which the programmes (Appendix A.4.30 and A.4.31) were conducted is as follows:

- Programme for positive health: Health measurement was carried out using the tools described in Appendix A.4.32. This was followed by practices like yoga, meditation on week days early in the morning and sports in the evening.
- CEP orientation workshop – Share the context, mission and structure of the overall programme, awareness on innate abilities, sensitising the students the need to take ownership for their development.
- Introduction about the company – Share the history, customers, markets, products, manufacturing processes and plants.
- DISHA 1 Workshop– Enable articulating aspiration in terms of career and life goals aligned to their innate ability.
- Ethics and Values workshop– Sensitise students about ethics and values, share code of conduct and create value behaviours as shown in Appendix A.4.33.
- Me and Mine workshop – Create an awareness and understanding about communication, interpersonal and team working, Time management and learnability. Provide framework for practice.

- Group coaching – Periodical review of the progress of demonstrating the behaviours relating to competencies to pick up challenges and provide coaching.

Engagement activities: CEP students are encouraged to actively participate in curricular, co-curricular and extra-curricular activities like National Cadet Corps (NCC), National Social Service (NSS), Society of Automotive Engineers (SAE), Institution of Electrical and Electronics Engineers (IEEE), Sports, Kitchen garden, hostel maintenance, daily knowledge sharing, hobby projects etc. The engagement index is worked out based on these activities (Figure 6.7). CEP students are engaged significantly better than the students of the peer group.

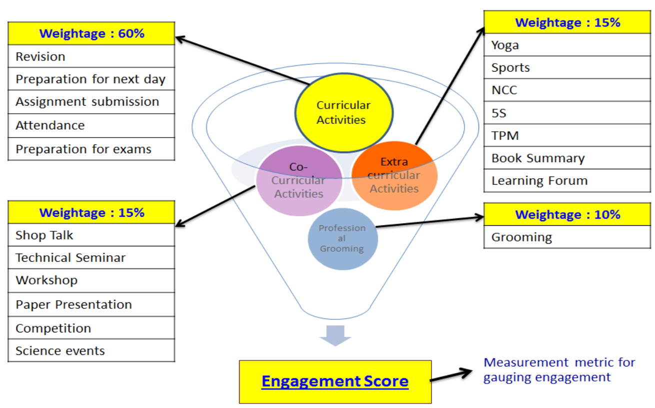


Figure 6.7 Engagement score

6.9 QUALIFICATION FOR THE ROLES

Roles for the engineers were identified and allocated based on assessment of innate abilities during selection process. This was communicated during beginning of third year of undergraduate programme and during last semester of diploma programme. The students are suggested to opt for streams of electives based on the identified roles.

During the last semester or soon after completion of the programme, three projects were established to demonstrate the competencies required for the target role and to qualify the students for the role. There are two types of roles for which the students are prepared for. The first type is a project based role like CAD/Design Engineer and Proving/Process planning engineer where their assignments are project based. While the tasks they perform may be similar, they will work for different projects and hence the scope and time may vary. On the other hand, the role based on standardized daily management like the team leader in the shop floor are fairly standardized.

Three role readiness projects for project based assignment is planned with varying scope of complexity. For example, a CAD engineer in their first project, may modify an existing model, dimension, tolerance and release the drawing. In the second project, they may prepare a new CAD model, dimension, tolerance and release drawing for a simple part. The third project may be to prepare a CAD model, dimension, tolerance and release drawing for a complex part. By these three projects, they are oriented to a range of projects that they will come across in their role.

In the case of Team leader who manages manufacturing operations in the shop floor, role readiness is developed over three phases scoped based on their role and responsibility. In the first phase, they manage Safety and Quality in the assigned manufacturing cell. In the second phase, in addition to managing Safety and Quality they manage delivery and Cost for the assigned manufacturing cell. In the third phase, they manage Morale or Engagement and productivity in addition to Safety, Quality, Delivery and Cost. Thus at the end of the three phases they are qualified as Team Leader.

Based on the target roles for which the students are being prepared, managers of respective sections were chosen as mentors for role readiness projects. During these projects, the students are assessed on two aspects - their ability to understand and follow the standards and processes in sprit and the accomplishment of the outcomes or results expected out of each project. An example of role readiness projects of one of the roles, CAD engineer is shown in the Table 6.11.

Table 6.11 Role readiness projects

Name : XXXXXXXXXXXXXXX Section : R&D/ Fit and finish	Manager : YYYYYY Mento		
Job Description - CAD Engineer	P1 - 3D modeling,drawing of Back plate mgneto casting & machining	P2 - ECR - New variant release - rear fender CKD requ.	P3 - Prepare 3D Cad modeling for U162 Cover clutch
Study and understand requirements from design inputs			x
Prepare CAD model using design guidelines and relevant SOPs	x	x	x
Check and achieve target for cost drivers including weight and Quality			
Conduct packaging and interfacing checks			
Check the design against known failure modes (failure mode directory, DFMEA) along with part design engineer			x
Prepare 2D drawings and incorporate special characteristics derived from AQ/MBQ and DFMEA	x		x
Incorporate the dimensioning and tolerances in line with GD&T standards			x
Support release of drawings and documentation		x	x
Period	4 Weeks	2 Weeks	6 Weeks
Project Deliverable	Q - Error free drawing C - Cost target plan D - 2D Drawing Release - as per time plan	Q - Error free drawing C - Cost target plan D - ECR Release - as per time plan	Q - Error free drawing C - Cost target plan D - 2D Drawing Release - as per time plan
Adherence to SOP	Qdesign Guideline Past product problem DFMEA	QSW for ECR ECO	Qdesign Guideline Past product problem DFMEA
Situational Issues	Availability of workstation	Availability of workstation, requirement from other dept Testing	Availability of workstation
Background	CAD Modeling practice	Rear fender CKD Requirement for exports	CAD Modeling practice
Pre requisites	Basics of ProE Basics of Plastics DFA,DFM,DFS	QSW for ECR ECO DFA ,DFM, DFS,DFMEA	Basics of ProE Basics of Plastics DFA,DFM,DFS
At the end of the project student will be	Prepare errror free 3D model	Release ECR - rear fender CKD requ.	Prepare errror free 3D model

The job description is listed in the first column and three projects are listed on the next three columns. Each task is checked for each project. It can be seen that as we move from the first project to the third project the checks are more which shows that the third project is more complex and it represents almost close to real life tasks of the CAD engineer. The students are oriented to the SOP prior to assigning the projects.

Most of students were qualified for the roles scoring 70% ready for the target roles barring few who had do to further projects and get qualified. Three batches of students from the polytechnic have gone through role qualification and were deployed in their roles.

Progress of the engineers deployed from CEP are reviewed every quarter with the engineers and their managers. The bar for their performance is raised to deliver better than their peer group. A development plan is prepared to get them fully ready for the role. Once they become functional in their current role, they are encouraged to undergo the programmes for the next roles.

6.10 SUMMARY

Developing engineers who are industry-ready, and role ready requires significant efforts such as:

- Outreach to attract people with right aspiration, selection for innate abilities and foundation of mathematics and science to learn engineering.
- Programme objectives (both functional and behavioural) are derived from the target roles in the industry.
- Courses and their relationships are important. Course objectives need to align with programme objectives.
- Course development using structured instructional design process, delivery and evaluation aligned to competency development

- Streams of electives, roles in group projects, role readiness projects aligned to identified roles and internships are very important.
- Programmes for developing behavioural competencies, active engagement in curricular, co-curricular and extra-curricular activities are essential for holistic development of students.