Enhanced Learning of Thermal Engineering Courses through Structured Enquiry and Problem Based Approach

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Abstract:
Fluid mechanics and Heat transfer are important application oriented courses taught for Mechanical engineering arena and also allied courses like Automobile Engineering, Aero-space and Chemical Engineering. The pedagogy for thermal engineering courses have undergone paradigm shift over the years through novel ways of industry participation, discussion of applications-driven issues, facilitate problem-solving skills, perform analysis/ design of thermal systems and use of computational tools. The thermal course material is upgraded pertinant with new technology issues as part of the proposed pedagogical initiatives.
In this direction two lab courses of Fluid mechanics and Heat transfer were identified and revamped for enhanced learning of thermal concepts in the backdrop of student aversion towards these courses. The implementation of course delivery based on the Blooms taxanomy has improved the modus-operandi of delivery of these Lab courses. The categorization of the experiements as Demonstration, Exercise, Structured enquiry and open-ended enquiry has given ample opportunity for faculty to address the ABET 3a, 3b, 3c, 3d, 3e, 3g and 3k criterion to a greater extent.

Key words: ABET criteria, Fluid mechanics, Heat transfer, Structured Enquiry and open-ended problems.

I. INTRODUCTION

The technology driven world today demands critical thinking and logical reasoning amongst the gradutes for better career prospects in the industrial sector. The conventional method of teaching is averse to this trend of changes demanded by rapid pace of the technological advancements. In the light of India becoming signatory of Washington accord, there is an urgent need to review the pedagogical practices to suit the needs of tech thirsty student fraternity. The advent of information technologies has lead to knowledge flooding in every field of engineering. The teaching-learning process earlier predominentaly confined to closed class room interaction is much debated issue towards modifications among eductional policy makers.

As early as 1990s several pedagogical innovations and approaches have been reported in different engineering streams with modules designed for interactive learning.[1] These initiatives have borne fruits of delivering greater learning gains than the traditional lecture format. These initiatives were triggered by the observations of poor student attentiveness and performance even to lectures delivered by eminent teachers despite of the good math-skills possessed by the students. The traditional lectures, although excellent for many purposes, did not auger well because of their passive nature of learning. Unbiased fair assessment is an integral part of teaching learning process that ensures high morale and motivation amongst the taught. The meticulously designed and adopted assessment techniques confirm to effectiveness of interactive engagement of students of a range of backgrounds leading to enhanced gains [2].

Energy, materials and information in Engineering profession are amongst the vital resources for overall development and upliftment of mankind that was overlooked in the early day engineering education which imparted very little attention (< 5.2%) to Application-segment. The engineering education in present context has the prime objective to mould students and enable them practice engineering to utilize meaningfully resources of nature. This demands good understanding of nature that goes beyond theoretical knowledge based on traditional educational laboratories [3].

In view of multi parameter optimzation in engineering solutions experimental data and analysis play a pivotal role for practicing Engineers involved in compilation of engineering data and ensure products to perform their intended role. Their performances are compared with supplier specifications to demonstrate compliance or indicate scope for changes to overcome deviations. There is need for "design backed effort" to practice activities towards attainment of excellence in assigned task though the Practicing-engineers by default apply conventional pedagogy concepts.

The present generation engineers operate in a challenging environment and therefore the paradigm shift is mandatory in educating future generation engineers whose components include domain knowledge, work skill-sets and goal driven attitudes. The pedagogical transformations basically aim to equip engineering graduates with the knowledge, skills, and attitudes they need to meet the demands. The problem based learning approaches have been time tested to offer good prospects to future engineering and technology [4].

II. Evolution of pedagogy for Student Centric learning Practice

The Mechanical Engineering Undergraduate students as part of curriculum learn several Thermal courses prominent amongst them are Fluid mechanics and Heat transfer as part of the four year Programme. These courses addresses questions that emphasize underlying principles of fluid flow and heat transfer that are prominent in solution of myraid types of real world engineering problems. The underlining concepts mastered through these courses facititate hands-on exposure to principles that relate to conduction, convection, radiation, boiling and condensation. The present section of the reported pedagogical ordeal provides insights into the experiences of stakeholders undergoing two methodologies of teaching learning with reference to thermal engineering courses at UG Programme in Mechanical Engineering. The brief comparative account of two divergent approaches are dealt at lenght in context of course delivery, learning process, evaluation criteria and benefits realized with reference to thermal engineering courses of fluid mechanics and heat transfer.

A. Teacher centric course design

The traditional approach of course delivery in Fluid mechanics and Heat transfer course was based on execution of the prescribed set of course modules designed and delivered with the Course-Instructor at the epicentre of pedagogy system. This approach is also refered as "Teacher centric: follow the Instruction-method" that specified steps to be executed to get expected final result for any problem defined. The students based on varying degree of their involvement in the course sessions were logically grouped between exquisite to repulsive student. The aforesaid traditional teaching-learning approach did make a limited impact on major segment of the class while a meager segment of the class involved thoroughly in the proceedings of the teaching-learning ordeal. This lead to serious concerns on the remainder part that was left into disillusion due to monotony of step-by-step procedure. The students as part of the course delivery in this traditional route were to follow the specified instruction set on dealt chapters and evaluated through an equally tiring and monotonous work out that decided performance grade in the course.

The evaluation front of thermal engineering courses in fluid mechanics and heat transfer course posed challenges to Instructors for fool-proof methodology that would investigate the depth of student understanding. The traditional assessment practice included gaguing student performance through Minor exam and Assignments based on stereotyped questionnaire. This approach lead to an overall exercise that was a mere memory teaser rather than honing skillsets and knowledge exploration as the course provided no room for student thinking beyond the prescribed set of exercises.

The thermal courses of Fluid mechanics and Heat transfer involving design based numerical calculations was not well recieved by a major chunck of students and obvoiously turned out to be a nightmare for a substantial part of the class. The student performance at end of semester examination reflected an agonizing scenario of lack of ingenuity in their performance due to improper assimilation of the course content. The courses though with a wide scope for practical applications turned out to be a "tough-to-digest courses". These courses were able to reach only the Exquisite student layer leaving the Intermediate and Repulsive student layers puzzled about the wide ranging application of thermal engineering aspects to practising Mechanical engineer. This annhilated the student's quest for knowledge leading to student dislike for the otherwise important courses for a Mechanical engineering professional domain. The teacher centric traditional approach kept student comfort level too low with a drooping learning curve that lead to a phobia towards thermal engineering courses.

B. Disciple centric course design

The central theme of this improvised pedagogy practices shifts the concern from the teacher to the taught otherwise referred as Disciple in traditional Indian jargon of teaching-learning. This approach of delivery finds roots in the Guru-shishya parampara practised in ancient Indian Eduation system before the advent of English into the educational arena. This proposed methodology is based on flexible learning that has no rigid prescribed set of recipe making it more student participative "Student centric: Do it yourself method". The approach stressed on knowledge exploration through team work and practical experimentation without barriers on student thought process.

The sessions were conducted to promote better learning through group learning activities that fostered group dynamics apart from learning the course content. The activities were designed to promote active student participation through group tasks that promoted better conceptual grasp on the course content. The study was not limited to memory teasing but promoted higher levels of learning skills that included problem solving and critical analyis. The prominent teaching-learning activities initiated in thermal engineering course that witnessed wide acceptance by students are briefly indicated as follows.

The Fluid mechanics and heat transfer laboratory course experiments were modified to include structured enquiry and open-ended type experiments.

- The experiment on Centrifugal blower performance the effect of blade shape was studied by fabricating vanes of Backward, Radial and Forward types. These vanes were mounted on the machine in turn to investigate the influence of blade geometry on the performance of blower that was earlier investigated with respect to only the backward curved vane. The student learning on working of centrifugal blower with different blade shapes improved on account of exhaustive experimentation done on all three vane types to obtain a comparative result on the blade geometry.
- The Centrifugal blower experiment also involved air flow measurement using available venturimeter fitted to the experimental set-up. As part of flow measurement studies students were exposed to the concepts of design and fabrication of alternate flow devices like Orifice plate and the subsequent comparison with existing venturimeter. This exercise enhanced the student learning giving a comparative measure of the two measuring devices.
- The experiment was also designed for (coflow measurement involving manometer to accommodate measurement of large and very low pressures using suitable manometric fluid and manometer configurations. This task exposed the students to real time application of the principles of manometry.
- The experiment involving measurement of incompressible fluid flow was modified to accommodate application of first principles for design and fabrication of venturimeter. The flow measurement tests on the fabricated venturimeter were conducted with reference to discharge supplied by a pump operating at maximum pressure.
- The concepts of Pump design was introduced through an open-ended experiment specifically designed to provide a real world feeling to the students. The task assigned to the students involved selection of a suitable pump for application involving water requirements of a Residential Apartment. The expected deliverables through the student driven task included a detailed design, fabrication methodology and selection of appropriate pump for the specified input parameters gathered from the site.
- To provide a learning experience on operation of Hydraulic Turbines the student groups were assigned task for selection of a suitable Hydraulic turbine to harness the available hydro-resource. The expected outcomes of the task included a thorough justification for the selected type and rating of turbine based on the estimated discharge and available head.
- Use of computational tools for thermal engineering concepts of fluid mechanics and heat transfer through simple illustrations
- Investigate applications of different modes of heat transfer
- Perform heat transfer analysis of thermal systems such as hot box, refrigerator systems and 2-D heat transfer analysis.
- Deliver course seminar on contemporary fluid flow and heat transfer issues

The course delivery lead to realization of higher levels of learning as evidenced through a better student performance. The redesigned experiments in the thermal engineering lab coursesincluded Demonstration, Exercises, Structured Enquiry and Open Ended experiment as indicated in Annexure I. The proposed course delivery has a proper blend of teacher driven tasks to provide the fundamental knowledge followed by application oriented student driven tasks. This redefined modus operandi in conduct of thermal enginering lead to active student participation thereby realizing higher level of learning as per the ABET criterion. The mapping of Course Learning Outcomes with ABET a to k criteria indicated encouraging attainments in thermal engineering courses covering a, b, d, e, g and k- ABET criteria to medium realization level.

This revision in Fluid mechanics and heat transfer lab-courses gave better learning ambience than “stepwise procedure based experiments”. The student perception assessment was based on a scale of 10 that with Excellent (9-10), High (7-8), Good (5-6), Average (3-4) and Low (0-2) for technical (a, b, c and e) and attitudinal (d, g and k) attributes. The student feedback indicated in figures 1a and 1b shows that 70.8% and 72.6% student responses in case of technical and attitudinal attributes averaged above 8 on a scale of 10.

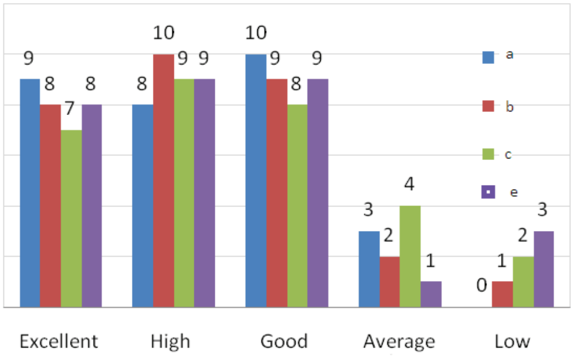

Fig. 1a: Attainment of technical attributes in thermal course (a, b, c and e ABET criteria)

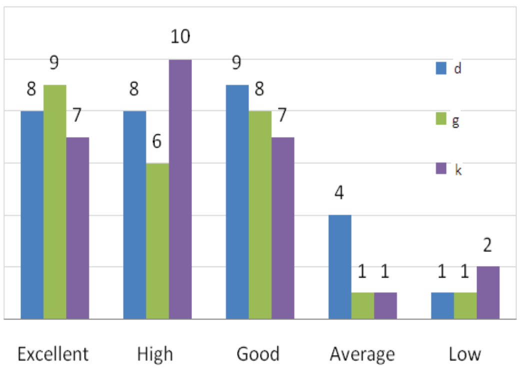

Fig. 1b: Attainment of attitudinal attributes in thermal course (d, g and k ABET criteria)

The students assimilated course content in thermal engineering with computational skills as against traditional approach that made very little room for independent thinking or learning. The next level envisages the implementation of Computational Fluid Dynamics (CFD) aspects in the study thereby strengthening employability of the engineering graduates.

III. Comparative studies on Pedagogical approaches

The comparison of Teacher centric approach and Student centric approach with reference to Thermal engineering courses is presented in terms of content, delivery and evaluation strategies taught as part of UG Programme in Mechanical Engineering.[5,6]

A. *Content*

The syllabus as per the Teacher centric approach was designed to perform stereotyped experiments that did not provide impetus on use of computational tools to make detailed analysis of experimental results. The Annexures AI and AII provide syllabus of Heat transfer and Fluid mechanics Lab courses designed as per Student centric approach. The course content was quite encouragingly received by the students and gave adequate scope for the students to participate actively in the deliberations. The component of self study increases to a greater extent in the student centric approach compared to teacher centric method..However this does not undermine the role of the teacher in teaching-learning process but emphasizes the changing trends in present higher education sector where student should be prepared for self learning.

B. *Course Delivery*

The comparison between course deliveries through the two approaches clearly revealed that the student centric approach created better ambience for assimilation and retention of the course content. It alleviated teaching-learning process to higher levels of ABET graduate attributes when marked against the traditional teacher centric method. It had students to strictly follow the Instructions and obtain the results while proposed method provides 50% (15 hrs) duration for the course instructor to provide the necessary technical support while the remainder of the allotted duration is utilized to develop competency through self learning component.

C. Course Evaluation.

The evaluation process in the teaching learning process is a vital component that develops the ambience for productive teacher-student engagement. The unbiased assessment of student performance is essential mandate of any pedagogical ordeal. The evaluation should promote higher level learning inculcating the necessary skill sets and knowledge base for the students. At times the evaluation process needs innovative participation by the teacher that makes teaching learning productive as well as critically metered. One approaches of fair an unbiased evaluation involves the description or formulation of criteria based on sound rubrics that makes the exercise transparent and effective. The teacher centric approaches involved lesser degree of student involvement due to limited assessment levels that were memory dominated rather than honing skill sets of students. On the contrary the student centric evaluation scheme provided myriad milestones for the evaluation as it included computational skills and also addressed contemporary issues for which the student may be motivated to read research publications from reputed journals in the discipline of thermal engineering. The evaluation of teaching-learning process followed in two approaches clearly distinguishes student centric approach from its counterpart as being more effective leading to better performance and satisfaction for the student.

IV. Associated benefit through Padagogical reforms

The passive lecture mode was transformed into an intense, active, personalized and highly collaborative active learning. The more flexible mode of learning stimulate discovery and improve understanding of conceptual material. The student centric teaching practice resulted in better clarity in concepts amongst students as well as a higher level of realization in the Bloom's taxonomical levels.

The Activity based teaching learning process is an absorbing activity that sharpens the skill and technical know-how of the students apart from elevating the personalities of teachers to make them ready to take up R & D / Consultancy work sponsored by Industry. The immediate effect of implementation of Active learning techniques will lead towards channelizing the capabilities of tech-savvy students and the strong first principle based knowledge domain of the Faculty. The conglomeration of these two unique forces of the academia will lead towards meaningful win-win situations for both students and teachers.

The students will mould into better quality technocrats and teachers would be freed from the monotony of repeatedly teaching through the generation of yellow-page notes prepared for the generation. The active learning ensures greater student participation in the teaching learning process. The evolved experience through implementation of Blooms taxonomy over the years improved modus-operandi of delivering this course as a theory and practical course.

Conclusions

The current scenario of globalization has opened doors for global employment opportunities to engineering graduates worldwide that has made the adoption of higher level learning into the Engineering curriculum a mandatory requirement. The ABET criteria that periodically gauges the changing trends in Engineering and technology has scientifically defined student learning objectives and attributes to make them globally employable. In this regard the adoptions of innovative teaching learning methodologies are the urgent requirements for the growing engineering academia to keep abreast with Industry. The presented pedagogical ordeal to address Thermal engineering courses were very enriching and thought provoking to both student as well as the Course instructor. The student responses clearly reflect on positive effects of implementation of the innovative teaching learning methodology. The ABET criterion if religiously implemented can bring revolutionary changes in the field of Engineering and technology to address the Global Millennium Challenges.

The appropriate changes brought in the identified thermal engineering lab courses (Fluid mechanics and Heat transfer courses) provided adequate scope for students to independently design experiments (open ended experiments) and address most of the 3a-3k criteria specified by ABET to a higher level of attainment.

Acknowledgements

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Table A-I: Redefined Curriculum structures of Lab courses

Course Code: MEL318 Course Title: **Fluid Mechanics Lab**.
L-T-P: 0-0-1 Credits: 1 Contact Hrs: 02 hrs/week
CIE Marks: 80 SEE Marks: 20 Total Marks: 100
Teaching Hrs: 30 Hrs. Exam Duration: 3 hrs

A. **Demonstration** (2 sessions)

1. Introduction to the Laboratory- Overview of Fluid, Classification and its properties
2. Flow measurements- use of rotameter, venturimeter, orifice plate, V-notches

B. **Exercise**(4 sessions)

3. Calibration of flow measuring devices-V notch, venturimeter, Orifice plate
4. Losses in pipes-major and minor pipe flow losses

C. **Structured Enquiry** (6-Sessions)

1. Study effect of speed on performance of Centrifugal pump and Reciprocating pump
2. Study effect of gate opening on performance of Pelton Turbine and Francis Turbine
3. Study the effect of gate opening on the performance of Centrifugal blower

D. **Open Ended Enquiry** (6-Sessions)

1. To design and develop a flow measuring device for a given fluid flow
2. Design a hydraulic turbine for a given operating condition with detailed drawings

Evaluation scheme for C.I.E. and S.E.E.

Assessments	Weight-age (C.I.E.)	Weight-age (SEE.)
Section A	10	05
Section B	20	05
Section C	30	10
Section D	20	10
Total	**80**	**20**

Course Code: MEL610 Course Title: **Heat Transfer Lab**.
L-T-P: 0-0-1 Credits: 1 Contact Hrs: 02 hrs/week
CIE Marks: 80 SEE Marks: 20 Total Marks: 100
Teaching Hrs: 30 Hrs. Exam Duration: 3 hrs

A **Demonstration** (2 sessions)

1. Construction and calibration of thermocouple junctions
2. Air and water flow measurements
3. Thermal conductivity of metals, Insulating materials and liquids
4. Determination of Free and Forced Heat transfer coefficient
5. Determination of Emissivity of a surface

B **Exercise**(4 sessions)

1. Temperature dependence of thermal conductivity.
2. Investigation of free /forced convection on fin effectiveness.
3. Flow dependence of heat transfer coefficient
4. Investigation of fluid dependence on heat transfer in HEs

C **Structured Enquiry** (6-Sessions)

1. Design “cylindrical container insulation” to minimize heat loss
2. Investigation of combined modes of heat transfer
3. Experimental investigation of 2D temperature distribution in a heated plate and comparison with analytical solution

D **Open Ended Enquiry** (6-Sessions)

1. Analyze different designs available for exhaust gas re-circulation and Radiators in passenger cars

Evaluation scheme for C.I.E. and S.E.E.

Assessments	Weight-age (C.I.E.)	Weight-age (SEE)
Section A	10	05
Section B	20	05
Section C	30	10
Section D	20	10
Total	**80**	**20**