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Modification of Mechanical Engineering Laboratory Courses to imbibe Industry Skills

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Abstract : Technology today is into challenging phase with teams built for management, design, research and development. Engineering has undergone change owing to computer tools that contribute exponential rise in productivity. Educators in India have responded on a positive note, with improved pedagogical practices reported. Governments have supported to percolate this change through New Education Policy that mandates institutes to adopt outcome based education. The initiative is part of OBE framework implemented in design and delivery of heat transfer and machine drawing laboratory courses at undergraduate level. The excitement through active delivery and assessment forms the bedrock of this change. The routine recipe lab is substituted by employer focused practice dimensions of obsolescence removal of and relevance factor. KLE Tech follows a dynamic curriculum design and delivery with inputs from all its stakeholders to make it truly responsive to contemporary change.

This gave enriching experience by providing space to gather basic concepts and build on higher order skills. The high weight to continuous learning component (80%) eliminated student anxiety level due to panic in end semester assessment (20%). Overall improvement in student performance in lab courses was reported and scope to address higher learning levels was noticed. The average scores improved as 7- 8 grade pointer for both lab courses investigated with more than 30% score contributed by L3-L4 level task in heat transfer. The student scores were higher in lower level (L2) as compared to performance in demonstration and statistical analysis (L3-L4) due to the change being first experience in their lab conduction. The overall opinion stated the practice to be extended to all lab courses.

Keywords: Engineering Education; Graduate Attributes; Heat transfer, Machine drawing.

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1. Introduction

The role of higher education in building sound economies has taken the centre-stage with close to one eighth of student community being part of it, with an annual outlay of over $ 40 billion. In view of current scenario imposed by the global pandemic and its immediate consequences, Indian educational sector has projected a rise in its higher education segment to 30% by additional 800-1000 universities and over

40,000 institutes to be established in the next 10 years. The engineering education constitutes a major part in the nation's techno-economic development and growth. The engineering education to deliver tangible results towards societal development has to undergo transformations aimed at inculcating professional skill sets apart from the strong technical expertise. Mechanical engineering discipline covers a wide range of functions and activities that find applications that cover major areas of real world situations like, the complex design of Gas turbines to simple combustor in Bunsen burner. The engineer's expertise extends to develop special purpose machines, operate equipment in manufacturing units and manage operation functions in organizations. The mechanical engineering curriculum of UG programme aims to prepare students, to undertake career openings in diverse domains that include management, manufacturing, design and thermal streams. As per the mandate of the top accreditation bodies (like ABET, NAAC and NBA) engineering curriculum should empower graduate engineers, to seek career options with conglomerate of engineering skill sets. The design and operation of myriad thermal/fluid flow components /systems are governed by concepts of heat transfer and machine drawing that are foundation courses in mechanical engineering curriculum. The pedagogical intervention helps in practical implementation.

The design of thermal/ flow component/systems includes-

- Laws governing fluid flow and heat transfer to design system components
- Investigate fluid flow and heat transfer through experiments designed to collect and analyze experimental data using appropriate instrumentation and data acquisition system.
- Error estimation in measurement of physical parameter like temperature, flow velocity, heat transfer rate, heat transfer coefficient through statistical calculations.
- Investigate different modes of heat/fluid transfer and correlate it to practical applications.
- Design and analyze simple thermal equipment to meet the specified thermal requirements.

The heat transfer constitute a vital stream in mechanical engineering studied as theory and laboratory, with latter providing a connect to link myriad thermal systems. The general student perception puts heat transfer in “high risk group” owing to its analytical nature and abstract concepts. There arises need for course instructor to device pedagogical interventions that counter to this misconception. Heat transfer draws prerequisite from thermal engineering courses leading to simulate processes in design and manufacture of devices. This course aids computational fluid dynamics (CFD) tools with career paths in heating-ventilating-and air-conditioning, aviation, automobiles, marine vehicles, defense equipment, energy conversion devices, and environment.

Machine Drawing is communication tool used by engineers in professional practice as part of idea exchange, necessary to demonstrate problem solving. This aids to communicate interconnectivity of different sub-components to build the complete assembly. Engineering drawings help represent geometric dimensions and tolerances of conceived product, vital for conceived product to be translated into functional system. Furthermore, machine drawing concepts are pre-requisites to develop part drawings necessary to next level of investigations based on Finite Element Analysis (FEA) offered in sophomore year of engineering studies. The current engineering studies are entirely based on use of computer tools for drafting and analysis in order to ensure speedy analysis that help reduce the time in evolving products. This course has two components of abstract visualization and tool competence.

The engineering education aims to provide support to resolve existing Industry problems at large to ensure equitable and sustainable development. The world has adequate resources for societal benefit to be used with minimum impact on environment and thereby ensure continuance of equitable practices. Innovative solutions unique to meet expectations within the ambit of available resources are expected from engineering community to function as 'change-agent'. This needs competence to address complex problems that often demands inter-disciplinary effort. The Washington Accord gives important attributes (A to G) associated with complex engineering problem whose solution has features,

A. Use of in-depth engineering knowledge.

B. Wide conflicting technical, engineering and other issues.

C. No obvious solution and require abstract thinking and originality in analysis to formulate suitable models.

D. Involve infrequently encountered issues.

E. Outside problems encompassed by standards and codes of practice for professional engineering.

F. Involve diverse stakeholders with widely varying needs.

G. Higher level with many component parts or sub-problems.

The well designed complex engineering problem should necessarily include attribute A with one or more features from attributes B to G listed. The effort of instructors to train new generation of engineers should lay emphasis on imparting knowledge that has depth (connect to real world) as against the width or vastness of information propounded by traditional approach. The new pedagogical practices must make teaching-learning process more engaging by incorporation of attributes to develop stronger competence to solve complex engineering problems. The courses of heat transfer and machine drawing involve analytical co-relations, abstractness and computation compatibility necessary for adoption of complex engineering problem solving. The present work aims to formulate a basis to make laboratory courses in mechanical engineering more effective, leading to higher level attainment of programme outcomes on basis of defined course outcomes. [1]

2. Literature Review

The escalating population growth world-wide has created a situation of resource scarcity in terms of basic amenities for sustenance of life and human society. The reported literature on engineering pedagogy strongly recommends outcome based education tailored to appeal the new generation learners. The new generation engineering is more aligned towards knowledge base creation that opens space for creativity. The delivery mode needs a shift to real world tasks that bring practice orientation to replace pure theory-based concepts.

Engineering education must partner development and growth being responsive to global changes, preparing students to solve complex engineering problems on basis of sustainability. The knowledge integration of various engineering streams forms bedrock of next generation reforms aimed at holistic-teaching to substitute teaching-in-isolation. However, any new change is resisted as reported by the trans-discipline study that focuses on lethargy towards implementation of path breaking reforms in engineering education. The deterrent to changes in pedagogy has predominantly been lack of full fledge faculty acceptance to new practice. Hence need to take confidence of all stake holders of policy change needs utmost prominence in transition to new educational reforms. The need to organize 'faculty conclave' to share good practices and success stories can catalyze the wider reach of education reforms [2].

The education transformations have been globally investigated with successful pedagogical practices aiding congenial space to student community. The proactive teacher performs the role as change maker based on acquired pre-service and in-service duration. The exhaustive data built a strong case that stated faculty commitment to teaching roles strongly influenced by self belief in teachers. The higher confidence levels before introducing 'new practice' in pedagogy was essential to its successful implementation. The change policy demands clarity in understanding among teacher and student community catalyzed by motivational feedbacks at initial level [3].

The corporate world demands team work, unlike academics ruled by 'excellence in isolation' in majority of its assessment. The courses with scope to engage students collaboratively with faculty and peers helped experience team building- the bedrock for success in corporate, academic or research career. The research is the drive engine backed by inter-disciplinary activity fuelled by collaborative team work in word and spirit. The student-teacher interactions proved beneficial to learning cycle as 'win-win situation' to both student and teacher aiding active research along with routine teaching. The strong emphasis to imbibe research in academics is widely stressed by science and technology policy. Future engineering schools should play proactive role to nurture society for their effective solution building, thereby contributing to nation building [4].

The use of electronic gadget has created space to 'inquiry' through simulations that optimize systems. The industry has adopted computer based design to optimize its products and services consequently leading to academic pedagogy adopt computers. The "orient-conceive-investigate-conclude-discuss" cycle of Inquiry involves thorough questioning, hypothesis generation and process realization. The importance of inquiry learning, systematic implementation stages and efficacy enhancement of learning has been reported [5].

Engineering education today targets to solve UN grand-challenges and hence demand unique pedagogical attributes. The new route stresses multi-disciplinary teams to facilitate complex problem solving and its effective communication to enhance societal benefits. The education has power to bring in major transformations in "social thought", backed by effective teaching-learning to support local needs in conjunction with global concern for humanity at large. The generation next needs hand-holding to transit from intelligence economy to empathy driven economy that stresses global wellness [6].

The rapid development of web and cloud technology has opened new business options due to high speed connectivity that defeated barriers to development. The remote control of machine tool and 3-D printing has opened new development vistas. The rapid technology advances require responsive teaching-learning that ensures faster adoption of new concepts or unlearning obsolete ones. There is an urgent need to adopt e-learning that promises better efficacy over traditional route. The learning needs shift from data exchange to experiential learning that marks depth against volume of knowledge. The pros and cons of digital learning includes its larger reach and effective learning with efforts needed to develop facility [7].

The student community today has new set of opportunities opening excellent and challenging career options. However, technology changes put student community into a continuous path of updating and creative thinking. The innovations and smart solutions help optimize resources, generate out-of-box thought making education an enriching experience. The decline in engineering education standard leading to economic losses and occupational safety at work place is reported. The motivational drive to prepare graduates for successful career in Industry or research oriented higher studies helps to generate the future pool of engineering educators [8].

The technical drawing courses are primarily required for a mechanical engineering graduate. To teach the drawing language, problem based learning (PBL) approach and out of classroom activity approach was adopted. In case of online delivery of the drawing laboratory courses, there is a need for a structured virtual laboratory plan [9, 10].

The summarized literature clearly highlights adoption of new ways to engage students and attainment of higher levels of course outcomes. The adoption of teaching that excites students yields better results due the following reasons,

- Insolated studies without connecting to the whole do not lead to beneficial designs of engineering products.
- Pro-active efforts and motivational support is essential in new pedagogical initiatives to emerge successful.
- The highest level of attainment of learning process is the research practice that emerges into new scientific domain.
- Corporate sector is fuelled by innovation arising from academia that is catalyzed by digital revolution.
- Sustainability being the focal point of all decisions has lead to higher expectations from academia-industry dual.

Thus, the above literature survey concludes that new initiatives or good practices are essential to improve teaching-learning process in mechanical engineering programme. This work builds on identified gaps to fill short comings of existing practices and harness technology as an enabler to learning.

3. Details of Changed Pedagogy In Machine Drawing And Heat Transfer Lab Courses

Education is an important segment of society that influences many other domains essential to global sustenance, like agriculture, defense, medicine, commerce and governance. The role of education cannot be undermined because it plays a vital role in development of human resource and technology that catalyses growth and development. The strong foundation laid by sustainability principles are designed to make equitable coexistence of competing ideologies. The COVID pandemic made its mark on global education, necessitating counter strategies to deal unforeseen situation. Engineering education has applied innumerable learning models to cater new-age learners with more liberal ways to gain knowledge. The challenge lies in creating an ambience that puts learners into task execution framework; thereby contributing positive 'out of box' thought process. Our university operating on the frame work of 'Creating value-Leveraging knowledge' has adopted outcome based education in all engineering and allied Programmes. It has an established process oriented strategy operating on Plan-Do-Check-Act (PDCA) cycle in its academic practices to provide necessary support to take-up new initiatives that catalyzes learning. This is implemented to evolve refined pedagogical practices evidenced through student performances.

The reported pedagogical ordeal targeted attainment of four Graduate Attributes (GAs),

- Engineering Knowledge (PO1)
- Design/ Development of Solutions (PO3)
- Conduct investigations of complex problems (PO4)
- Modern Tool Usage (PO5)

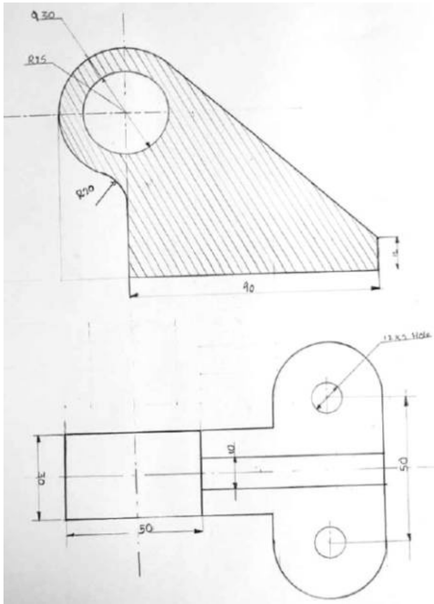
The one-to-one mapping of course outcomes to Programme Outcomes by detailing out sub-components in each GA to the level of Course outcomes (CO) and Performance indicators (PI) was meticulous planned and executed. The detailed rubrics were developed for assessment of student performance with respect to each of GA.

A. New practices: machine drawing and heat transfer

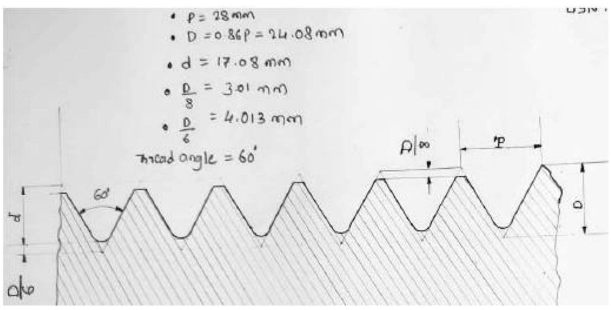
The new initiatives were practiced at individual level in two courses are presented as course content and COs detailed in table 1 and table 2 respectively. The relevant inputs obtained from the industry personnel are incorporated in refining the content to make it more relevant to current situations. The novelty of pedagogy lies in its implementation, providing scope for continuous improvement and ensuring experiential learning. The machine drawing course provides a strong foundation to read drawings required by practicing engineers. The changing industry practices at shop-floor level or client interactions are accounted in curriculum design and delivery. The fundamentals and computer competence to build industry relevant drawings are delivered in dual mode that includes hand sketching and computer mode.

The sample student submission of sectional view generation from given isometric drawing of the machine is presented in fig.1 (a) as part of study on BIS conventions. The feedback provided to the student is violation of BIS norm- ribs, keys not to be hatched in sectional view. The assessment involves marks deduction against the stated hatch convention not followed by student. The task illustrated by fig.1 (b) shows thread profile activity taught as part of BIS conventions to metric threads. The feedback provided to student response- hatching lines to be not drawn parallel to outer edges. The fig 1(c) depicts assembled orthographic view of strap joint from individual component part drawings. The students are instructed on matching component dimensions to logically correlate their relative positions in assembly. The assembly drawing has no major mistake except for conflict of hatch patterns of part 1 and part 2 in the front view. The sample examples are representative of the activity performed in machine drawing lab. The changes brought in better involvement of faculty and students proving the worthiness of new practices.

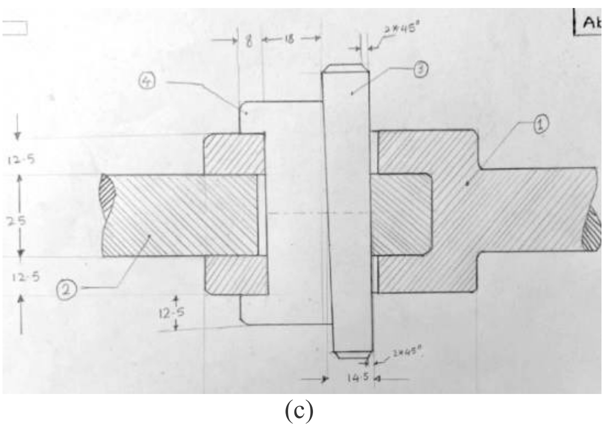
The heat transfer lab gave engineering perspective to heat transfer process from practical stand point. The detailed methodology included three phases namely exercises, demonstration and statistical analysis that function to move from concept level (L2) to application level (L4). The fig. 2 shows sample representation of activities in heat transfer lab. The batch-wise students groups work on significantly problem statements, which are uniquely defined to bring in diversity of instructions to explain the fundamental concepts. The Fourier law illustrated in fig 2(a) was demonstrated for different geometries that included slab, hollow cylinder and hollow sphere. This created a major shift from conventional approach that was based on set of standard instructional pattern that gets repeated with less scope for inquisitive thought in learning. The exercise based experiment shown in fig 2(b) demonstrates higher learning levels through in-depth study on parameters: capacity ratio (Cmin/Cmax), overall heat transfer coefficient (U), logarithmic mean temperature difference (LMTD), effectiveness, number of heat transfer unit (NTU) and heat transfer rate(Q). A comparison between parallel



(a)



(b)



(c)

Fig. 1: Sample Activities in Machine Drawing Lab Courses.

and counter flow mode of heat exchange was taken up in this cycle of lab.

The fig 2(c) shows the next level of learning by bringing home a series on real time problem statements that create an ambience to reach L4 learning level.

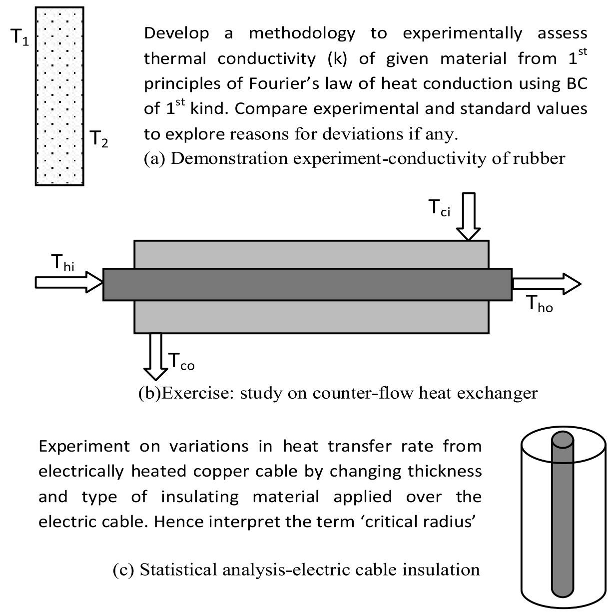


Fig. 2: Sample Activities In Heat Transfer Lab.

The detailed investigative study through 'what if questions' lead to optimized selection of parameters essential in design of suitable insulation to enhance cooling rate in electric cables. Several interesting applications of heat transfer were made part of this lab course.

B. Reflections - New practices in mechanical engineering

The approach used in two courses together form basis for discussion of pedagogical initiatives in laboratory courses. These courses had in-semester assessment (ISA) of 80% marks against 20% assigned to end-semester assessment (ESA) highlighting importance of consistency in student performance throughout course duration. The assessment in these courses needed separate passing grade in both ISA and ESA components for student to be declared successful. The heat transfer lab course targeted attainment of selected segments of three GAs indicated above by defining specific PI indicators. Fig. 3 indicates percentage distribution of marks in the student evaluation in the two lab courses.

The major assessment was contributed by student capabilities to perform experiments and interpret results. The other two components stressed on concept-application and use of modern computational tools. The proportion of marks distribution was justified owing to the focus of course on

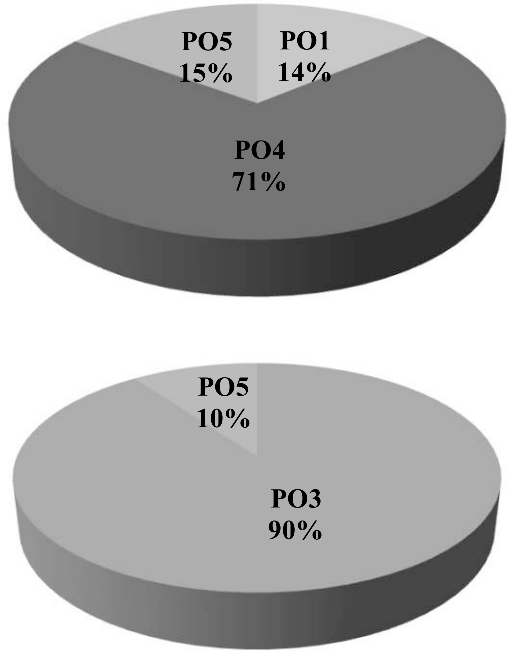


Fig. 3: Po-wise Marks Distribution in Heat Transfer (above) And Machine Drawing (below) Lab Courses.

experimentation. Table I gives details of laboratory courses considered for pedagogical intervention. The machine drawing course had CO1, CO2, CO3 and CO4 with weights of 35%, 15%, 40% and 10% respectively. Heat transfer experiments on demonstration, exercises and statistical analysis had marks with 20%, 50% and 30% respectively with objectives of basic understanding, detailed experimental and micro-level analysis. Fig.5 indicates % marks distribution in evaluation with respect to COs defined for machine drawing and heat transfer lab. The COs are linked to PO in machine drawing (PO3 and PO5) and heat transfer (PO1, PO4 and PO5). The three groups based on increasing level of difficulty and student involvement were in order as sections A, B and C. The verification of thermal conductivity, emissivity and heat transfer coefficients and dimensionless numbers contribute major part of assessment. The basic concepts were covered through minor weightage.

The Table II provides details of COs defined for laboratory courses in machine drawing (4 COs) and heat transfer (6 COs) covering application of fundamentals till analysis. The heat transfer lab course emphasizes on design of simple heat transfer systems using computational tool. These marks distributed were 50% collectively for CO1 to CO4 with remaining 35% and 15% respectively assigned for

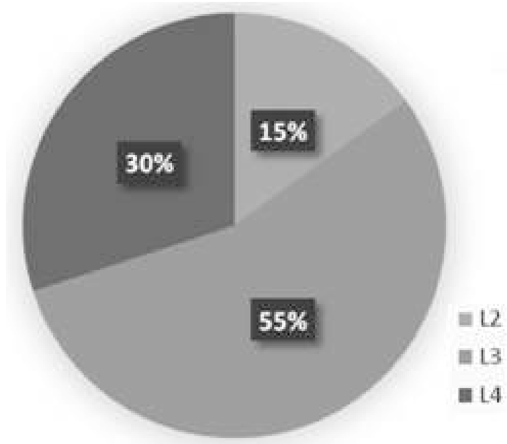


Fig. 4: Learning Level-wise Assigned Marks In Ht Lab Course.

CO5 and CO6. The proposed method was adopted to promote enhanced student learning levels through attainment of higher learning levels as compared to earlier practice that was restricted to Level-3 of Blooms taxonomy.

The fig.4 indicates % of assigned marks for three levels of learning - L2, L3 and L4 to be 15%, 55% and 30% respectively. The L2 tasks were provide reconnect between theory studied in earlier semester with experiments conducted and were hence restricted to 15% on account of students already familiar with heat transfer. The L3 level constituted a major segment due to provision for familiarizing experimental protocols involved in conduct of the heat transfer lab and interpreting the results obtained. The higher learning at L4 was envisaged through experiments specifically designed to encourage students to make detailed probing into parameterization of experimental results. The better insight provided through the use of computational tools facilitated students to explore greater depths of course content. The use of computational tools would also align student capabilities towards mastering CFD tools that are advanced means for research in heat transfer and fluid flow.

The machine drawing laboratory course demands the student to hone the technical drawing reading skill. Due to pandemic situation, online delivery was inevitable. The drawings courses were delivered taking one drawing at a time and proceeding with step wise approach. For example, a drawing activity started from first step with positioning of XY line to the last step of annotating front and top views. The way of drawing course delivery was simplified in

Table 1: Details of Course Content in Laboratory courses.

Machine Drawing Laboratory course

Sectional views: Machine parts involving half section, full section, offset section, revolved section and local section. (use 1st and 3rd angle of projection) – (4 sessions)

Threaded Fasteners: Drawing of bolts, nuts, screws and their conventional representation. (3 sessions)

Part and Assembly Drawing using manual and CAD tool:
(1) Screw Jack (2) Protected type flanged coupling
(3) Pipe vice (4) Clapper box (5) Non-return valve
(6)Universal coupling (7) Pin and cotter joints (2 and 4 sessions)

Assessment :(**ISA /ESA**)

Class work and Assignment	50	ISA 80% weight
In-sem Assessment –I	15	
In-sem Assessment- II	15	
End semester Assessment	20	ESA 20% weight

Heat Transfer Laboratory course

A. **Demonstration** (3 sessions)
1. Thermocouple junctions- construction and calibration
2. Flow measurement - air and water media
3. Thermal property : conductivity- metals, insulation and liquids
4. Convection heat transfer-free and forced mode
5. Surface emissivity to thermal radiations

B. **Exercises** (4 sessions)
6. Thermal conductivity changes with temperature
7. Extended surface effectiveness - free /forced mode
8. Characterization of flow - convective heat transfer coefficient
9. Characterization of Heat Exchangers.

C. **Statistical Analysis** (6 sessions)
10. Design "cylindrical container insulation" to minimize heat loss
11. Investigation of combined modes of heat transfer
12. Experimental investigation of 2D temperature distribution in a heated plate and comparison with analytical solution

Assessment: Evaluation	**ISA**	**ESA**
Demonstration	16(20%)	--
Exercise	40(50%)	10(50%)
Statistical Analysis	24(30%)	10(50%)
Total	80 (100%)	20(100%)

order to facilitate better student learning. As stated above for heat transfer laboratory, PO5, is also addressed in machine drawing laboratory course for online delivery. The reported work on implementation of outcome based education in undergraduate heat transfer course has emphasized on adopting an integrated approach to teach heat transfer through practice oriented experiments [11]. There are reported work on the heat transfer concepts taken up to research oriented studies using CFD tools as reported by Ajit Madival et al., through case studies involving post graduate students working on thermal engineering project [12]. The reported literature and present work make it quite evident that activity based learning methodologies, connecting real world problems aided by analytical approaches and experimentation can improve learning of intricate concepts better.

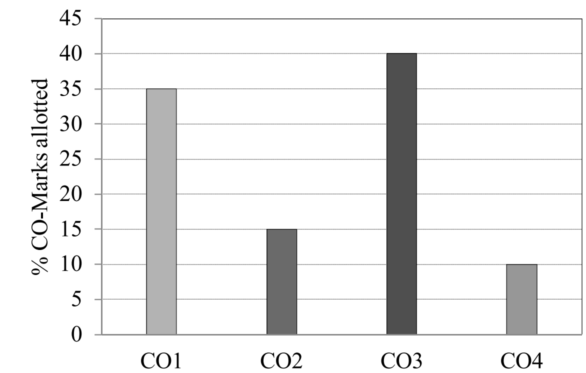
The treatment adopted for machine drawing aimed to address lower learning level (L2) as it was taught as

Table 2: Course Outcomes of Laboratory courses.

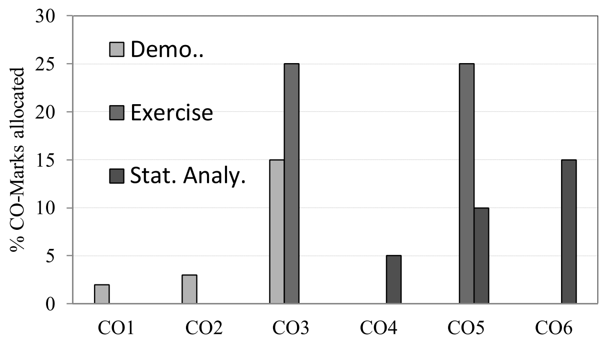
Machine Drawing Laboratory course
1. Draw orthographic projections of machine parts with section in firs angle of projection.
2. Draw and represent thread forms and threaded fasteners on drawings a per BIS conventions.
3. Draw part and assembly drawings with sectional view.
4. Create assembly drawings using CAD software

Heat Transfer Laboratory course
1. Apply basic governing laws to fluid flow and heat transfer problems
2. Apply principles of fluid flow and heat transfer to measure flow velocity and temperature
3. Experiment to verify thermal conductivity, emissivity and heat transfe coefficients
4. Perform error analysis in experimental determination of heat transfer coefficients
5. Evaluate dimensionless numbers (Re, Gr and Nu) to investigate heat transfer in water and air
6. Design simple fluid or thermal components/systems for a specified application through use of computational tools like MATLAB

foundation course at sophomore level with students having limited knowledge in engineering at this stage. Thus the presented case throws light on methodology to be adopted to courses at basic as well as advanced levels in engineering. It is evident that proper planning and meticulous execution of new practices becomes essential to ensure a fair acceptance by student community. PDCA cycle works to be an effective tool



(a) marks distribution for machine drawing lab course



(b) marks distribution for heat transfer lab course

Fig. 5 : Co- Wise Marks- (a) Machine Drawing and (b) Heat Transfer Lab Courses.

to dynamically seek interventions in order to improve overall efficiency of defined process.

The reported work on heat transfer lab has evolved on account of series of modifications undertaken over the years with each cycle contributing positive element in the practice. The approach will undergo further changes in subsequent cycles to account for new challenges and technology requirements to suit sustainability principle emerging in a strong way. The proposed hypothesis “lab courses in engineering are enriching to learn new concepts” appears obvious at first stage, but need strong circumstantial evidence as attempted in the ensuing section of results and discussions. However reported work can be treated as a 'work in progress' practice that requires more trials to establish as new method.

4. Results And Discussions

The data for reported investigations is based on sample size of 35 students, opting heat transfer lab as part of 7th semester. The interpretations drawn are helpful to do necessary changes in methodology for further improvements and its scaling-up. The indicated better overall learning was owing to fundamental concepts covered by demonstration set (L2) that recorded higher scores than to L3 and L4 activities. This initial process aided students in higher level learning given with adequate time and space to strengthen fundamental. The ISA of referred sample in demonstration, exercises and statistical analysis were respectively 90.59%, 75.30% and 75.75% as indicated in fig. 6.

The high score in demonstration category was on account of their familiarity to fundamentals. The relatively lower performance that was comparable in both exercises and statistical analysis task was due to need of additional efforts to effectively apply concepts on higher level problem solving and competence in use of computational tool. The student performance in ISA with respect to individual experiments as depicted in fig. 7 showed their comfort levels in E1 to E5 to be good compared to exercises and statistical analysis. The standard deviations values were lower for demo-class showed strong basics with lower application orientation.

The standard deviations for E1-E5 (0.0214 to 1.026) were relatively lower compared other groups E6-E9 and E10-E12 that had 1.2161-1.34 and 0.635-0.83 respectively.

The data strongly indicated diversity in learning capabilities with respect to assigned tasks that challenge their competency. The performance variation within group was attributed to variations in focus levels in execution within student group. The modifications in machine drawing laboratory course included the online mode of course delivery through a virtual platform to meet the exigencies arising due to pandemic. The process was able to keep the students engaged owing to proactive participation in completely new way of learning till that point of time. The student responses of machine drawing laboratory course exercises gave the course instructor a feel of satisfaction and contentment. However, the online delivery for drawing course is not suggested for the first-time learners.

5. Conclusions

The following conclusions were drawn from the presented case studies on two lab courses in Mechanical Engineering,

- The course design and assessment in machine drawing and heat transfer lab courses entrusted more student-instructor interaction to resolve rudimentary and complex intricate issues related to courses. Students need more opportunities to express themselves and engage into better learning with more faculty and peer discussions.

- The proposed methodology was designed for L4 level attainment to an extent of 30%, not evident in early mode of course delivery practiced in Programme. The inclusion of higher degree of L4 activity facilitated more complex task definition; to enhance depth of knowledge acquired.

- The machine drawing and heat transfer lab courses resulted in better student performance with average grade between 7-8 (B-C grades) on a scale of 0-10 (S-10; A-9; B-8; C-7; D-6; E-5 F-0) based on combined ISA and ESA..

- The student performance in lower learning segments (L2) of heat transfer lab was higher by 16.67% than higher level segments (L3 and L4). There was further improvisation possible in teaching learning methodology to motivate students acquire higher level competencies in heat transfer.

- The Section B provided the necessary

reinforcements and lead to attainment of higher level of learning (L3). The section C posed challenges to students in terms of thinking beyond the confines of basic theory and application transiting them to basic research level.

- The student perception of heat transfer concepts have improved through the implementation of statistical analysis of the experimental results that can motivate students to take up studies in advanced heat transfer research

- The challenges posed by pandemic situation and the need of online delivery makes the technical drawing courses look difficult to learn for first time learners. Hence, the machine drawing laboratory course is preferred to be delivered in the offline mode for first time learners and the same is preferred in the online mode for advanced learners.

- The weightage given to CO1 and CO3 in machine drawing course accounted to 75% marks in assessment, due to emphasis laid on manual drawing to build competence in reading industry drawings. The CO2 covers conventions of thread-form representation which are essential to build assembly drawings. The integration of knowledge acquired through manual drawings culminates into CO4 that aims to generate assembly drawings using CAD tools.

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