# Catering the Cognitive Requirements of Diversified Learners with Technology-Enhanced Collaborative Learning Approach: A Case Study on Learners' Progression for Design Based Courses in Electrical Engineering Program

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***Abstract*- A scientifically designed Design based courses namely, Electrical Machine Design has remained challenging to the learners. Additionally, limited critical thinking, inappropriate strategies to identifying the technical attributes of a problem make the task difficult. Students face limitations in understanding the inter-relationships of design variables and their influence on design parameters using theoretical approach of teaching. For teachers, imparting such higher order learning attributes are difficult using conventional pedagogy. Use of one of the modern pedagogies namely "Collaborative Learning Approach" (CLA) may be one of the solutions. CLA is well accepted method for catering the learners' diversified cognitive requirements. However, for the design-based courses it is seldom practiced and requires detailed study and customization. This paper represents the outcomes of a case study. The learners of electrical engineering undergraduate program were taught with the design solutions in Design of DC Machine and Transformers in semester 6 and Design of AC Machine course in semester 7 using modified CLA model. The CLA model was modified by scaffolding the values of design parameters, use of spreadsheet as a teaching aid, and unique data set for each group. The objective was to demonstrate that using CLA as a pedagogical tool, the learners can develop skills to modify the design under the real time conditions. The study showed excellent cognitive improvement in leaners ensuring the success of modified CLA model. The results revealed that CLA may customized to cater diversified learners namely premier, average and challenged students. The study revealed that with a few innovative changes, CLA can effectively provide a better learning experience for students for design-based courses.**

***Keywords*- Collaborative Learning Approach, Pedagogy, Electrical Engineering, Electrical Machine Design, Modern teaching aids, Cognitive Learning**

***ICTIEE Track*- Technology Enhanced Learning**

***ICTIEE Sub-Track*- Technology assisted Collaborative Learning**

## I. Introduction

ELECTRICAL machines consume 70% of power generated globally (A. T. De Almeida, 2011). Conventionally since its inception till few years back, DC machines, induction machines and synchronous machines are widely adopted in industrial and commercial applications (I. Husain, 2021). However, due to rapidly growing advancements in technology, these machines are being replaced by more efficient machines. Applications in electric vehicles and wind turbines require induction machine but with altogether of different characteristic requirement of speed range, torque requirement and efficiency etc. (C. H. T. Lee, 2021). Recently many combinations of

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machines have emerged in a category of hybrid machines (Luiz Fernando, 2014). The characteristics of conventional machine is also required to modify to meet with the demand of recent application. This development drift has amplified the demand for skilled electrical engineers to design, and operation and maintenance of different classes of machines. Unfortunately, the electrical machine design course offered to engineering students still focus on traditional design methodology of conventional electrical machines. Moreover, this single perception teaching methodology is ineffective to produce electrical engineers suitable for the rapidly evolving industrial demand. This raises the requirement of novel teaching practices to be introduced in institute for teaching electrical machine design courses.

The majority of programs in engineering employ traditional face-to-face lectures in which the instructor serves as the principal source of information and students passively listen without any active participation. Adaptation of active learning techniques such as problem-based learning (Aryan, 2023; Andersen, 2021), collaborative learning (Sathyendra Bhat, 2020), technology-enhanced learning (Vrushali Waghmare, 2024; Ying Liu, 2024)), think-pair-share (Mahendra Deore, 2022; Lukas Mundelsee, 2021), and flipped classrooms (Yan Ma, 2023; Samala, 2024) in conventional pedagogy are proven to enhance motivation, engagement, and student performance. Problem-based learning (PBL) (Andersen, 2021; Samala 2024; C.E. Hmelo 2004) collaborative learning (Sathyendra Bhat, 2020; Samala, 2024) method fosters students problem-solving skills and critical thinking as they work on real time industrial problems, enabling experience-based education and self-directed learning etc. In (Wolfgang Riedl, 2024) to bridge the gap between theoretical education and industry requirement, a PBL project course is introduced employing "Agile" teaching mindset in technical institute. Students work on unresolved real-time problems, taking appropriate decisions based on information provided, and defend the end results which replicate a real industrial process.

Courses such as AC-DC machine design, and transformer design demand high level of subject understanding for selecting unknown machine design parameters by performing complex tedious computations. Habitually this calculation is performed on paper using calculators by referring text book. During this theoretical approach students lack to recognize the technical attribute of the design problem as well as interrelation of design variables and influence on design parameters. Moreover, the course coordinators grapple with the task of maintaining student engagement and interest throughout the teaching

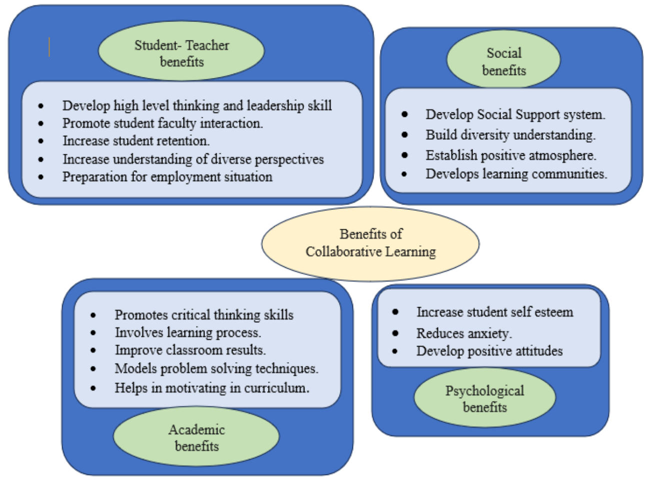



Fig. 1. Benefits of collaborative learning approach.

process. Consequently, majority of students loose interest or abandon these courses, deterred by its monotonous process and complexity.

In response to these above challenges, this paper proposes a modern pedagogies namely collaborative leaning approach (CLA) with the help of specially design spreadsheet. The proposed pedagogy was adopted in Batchelor of Technology program, Electrical Engineering Department, for teaching design of DC machine and transformer (DDMT) in $6^{th}$ semester and design of AC machine (DACM) in $7^{th}$ semester. The spreadsheets are tailored to the unique demands of electric machine design subjects based on industrial demand, offering a platform where students collaboratively tackle complex design problems, perform computations, visualize solutions and understand the interrelation of design parameters. The use of technology in this manner aims to engage students actively in the learning process as well as students are trained skillfully to face the real time design work challenges maintaining industrial standards. Further, academic performance of the students with the proposed modified CLA was analyzed thoroughly and presented.

## II. Collaborative Learning Approach

In 1920's the practice of working in groups emerged giving rise to an effective work culture in the organizations (Mehdi Elahi, 2016). Thereafter, in no time this culture founded its roots into non-technical educational institute. In 1999, the European Higher Education Area proposed collaborative learning as a useful tool for the development of skills and abilities among university students (J.P. Muñoz Miguel, 2016). Since then, the use of this methodology within the framework of educational has become widespread due to the integration of new informative technologies (J.P. Muñoz Miguel, 2016; Jesús Armando, 2022; Yang, X, 2023). Recently, digital learning environments, have played a pivotal role in advancing collaborative learning (Seng Chee Tan, 2022). In particular, the implementation of computer-supported collaborative learning (CSCL) has exerted a substantial influence on group activities within educational institutes succeeding COVID-19

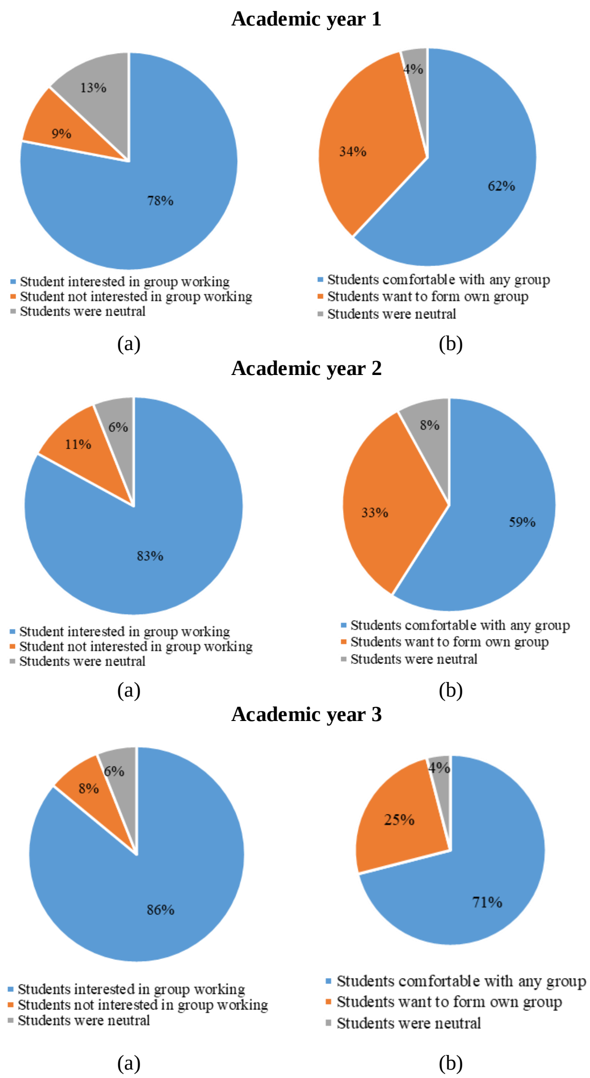



Fig. 2. Survey conducted before applying the strategy (a) Survey on group working, (b) Survey on group formation.

(Mohammed Saqr, 2022). Numerous studies highlight CSCL effectiveness in technical education (Mariano Velamazán, 2023). This is achieved through increased student participation and cooperation, enabling adaptable versatile teaching learning activities, incorporating the skill of higher- level content mastery, critical thinking skills, interpersonal skills, problem solving, and metacognitive skills within the students that are crucial in job recruitment process (Guangming Li , 2024). Fig. 1 shows the social, academics and psychological benefits of collaborative learning.

In CLA effective planning, scheduled task and team activities enhance learner's efficacy through shared knowledge exchange. However, knowledge exchange doesn't always align with the expected outcome, as a result, integrating design approach as part of the research and testing is absent in most engineering programs teaching (Chan, S. C. H, 2019). This discrepancy is resulted from adopting ineffective teaching methodology, incorporating group learning irrelevant to industrial demand, insufficient skills within the group, lack of group cohesion and commitment due to the preference for individual learning endeavors. There are instances where individuals remain unaware of the groupmates abilities and skills leading to heightened emotional exposure, a phenomenon frequently observed in the context of business education (Curs¸eu, P, 2020). Hence, the effectiveness of collaborative learning hinges on adopting appropriate and effective teaching learning methodology, proper group formation and group task, group activities, and group and personal evaluation as per industrial demand and individual awareness of their fellow group members.

## III. Students Background Information

Prior to implementing the proposed CLA, a concise survey was administered to students using questionnaires to assess their willingness to engage in group work and as well as to identify any challenges they encounter while studying electrical machines design courses. Fig. 2 displays the survey outcome for 3 consecutive academic years. In academic year 1 majority of students accepted facing difficulty in understanding electrical machine design courses and also show discomfort in performing learning activities in group. Moreover, it was also observed during electrical machine design laboratory students were unable to complete the laboratory experiment in assigned time limit when conventional theoretical approach is adopted. Hence while writing the laboratory report most of the students copy the procedure and calculation without gaining any machine design understanding and knowledge. In academic year 2 and 3 the proposed CLA was implemented and we found that the students were hesitating to work in groups assigned in academic year 2 and were interested in forming their own group. However, in academic year 3 after discussion and deliberation and interaction with seniors the students have shown more inclination to work in group as well as they were ready to work in the assigned groups.

Fig. 3 displays the academic performance of academic year 1 students before adopting the proposed CLA. Though passing percentage is above 80%, the majority of students fall in average category. Based on the survey, the teaching reform of the electrical machine design courses is carried out from the aspects of teaching objectives, teaching mode, assessment procedure, and laboratory activities, which provides a basis for the continuous improvement of the curriculum. Based on the experience the modified CLA with spreadsheet was implemented in academic year 2 and 3, and fallouts are discussed in result section.

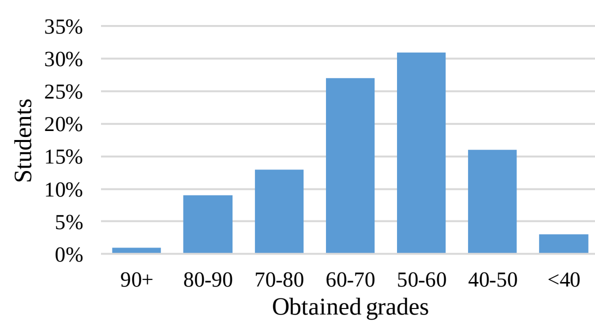



Fig. 3. Student academic performance of academic year 1.

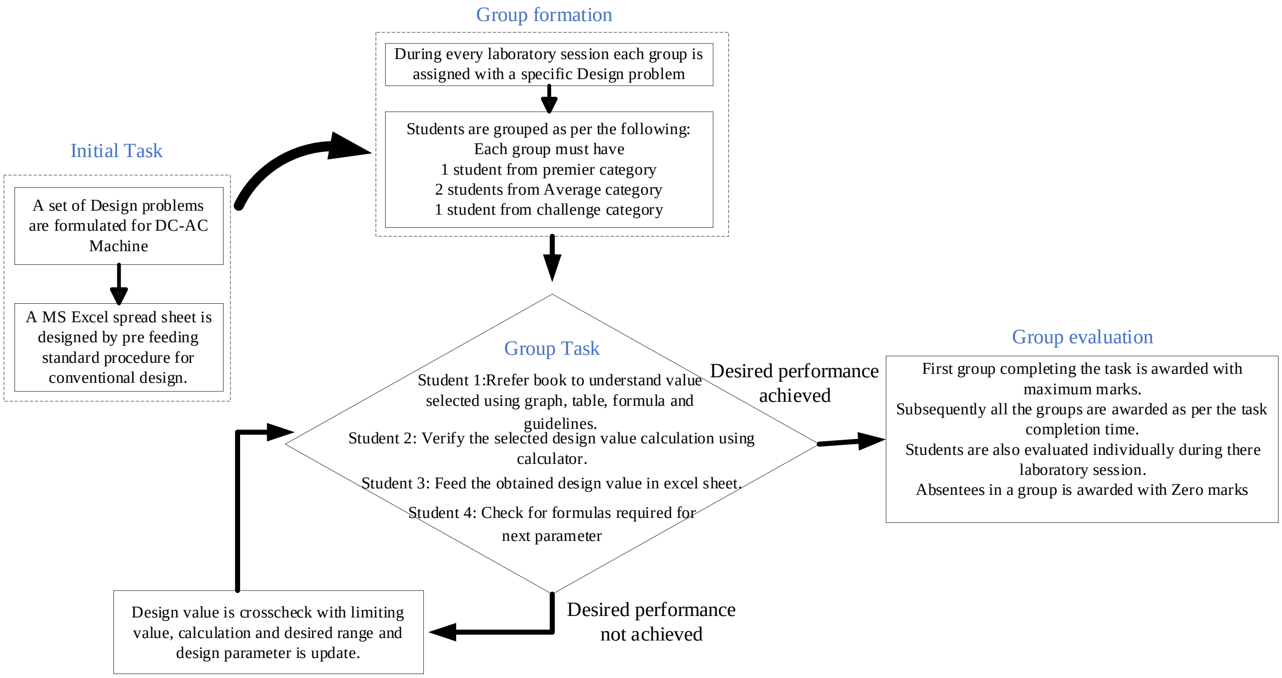


Fig. 4. Flowchart for the proposed modified CLA for electrical machine design courses.

## IV. FRAMEWORK FOR PROPOSED MODIFIED COLLABORATIVE LEARNING APPROACH

The proposed modified CLA was implemented initially by upgrading the conventional machine design course and laboratory as per the required industrial requirement and standards. Machine design problem to be solved in laboratory session as group task are formulated, inspired from real time industrial challenges. The use of specially designed spreadsheets and simulation software is adopted as a part of information communication technology tool to implement blended learning. A dedicated spread sheet is designed for each electrical machine design. The proposed modified CLA in electrical machine design course is structured in view to achieve higher bloom taxonomy level for the subject, to review effect of design variable variation on machine performance parameters, and improved academic grade. The designed spreadsheet is available to students and is made easily accessible through mobile and computer. Fig 4. represent a flowchart of the proposed modifies CLA methodology. The step-by-step process practiced for learning teaching sessions is detailed as following.

*Group formation*: During laboratory sessions the class is divided into sections of strength 20-25 students. The students are further divided into groups each having 4 students. The group is formed by arranging students in descending order of their previous semester academic result. Top 25% students were assigned a role of leader for each group, next 75% were allocated to each group till all groups has around 4 students. Students were not allowed to change groups in ideal condition, if they needed to change their allocated group due to internal conflicts then group members were exchanged for the same academic category, i.e., member 3 of average category in 1st group is allowed to interchange only with member 3 of average category of another group. This was to ensure the that each group must have student from every academic level. For the reference a survey was conducted to know the student's satisfaction on the adopted strategy for group formation at the end of academic year 1 which is shown in Fig. 5.

TABLE I
ELECTRICAL MACHINE DESIGN PROBLEMS.

| SYNCHRONOUS MACHINE DATA | INDUCTION MACHINE DATA | 3 PHASE TRANSFORMER DESIGN DATA | GROUP |
|---|---|---|---|
| 25000 KVA, 13.8 KV, 1500 rpm, Star Connection, pf = 0.85 lagging | 50 KW, 300 V, 1500 rpm, Efficiency: 87%, p.f. =0.86, 3 phase Squirral cage induction motor | 200 KVA, 6600/440 V, star / delta connected, Distribution | 1 |
| 500 KVA, 415V, 1500 rpm, Star Connection, pf = 0.82 lagging | 175 KW, 500 V, 3000 rpm, Efficiency: 84%, p.f. =0.87, three phase slip-ring induction motor | 100 KVA, 2200/480 V, Star/ Delta, Distribution Transformer | 2 |
| 25000 KVA, 13.8 KV, 62.5 rpm, Star Connection, pf = 0.85 lagging | 25 KW, 350 V, 1750 rpm, Efficiency: 90%, p.f. =0.85, 3 phase Squirral cage induction motor | 250 KVA, 11 KV/440 V, Star/Delta, Power Transformer | 3 |
| 400 KVA, 415V, 1500 rpm, star connection, Pf = 0.85 lagging | 48 KW, 400 V, 300 rpm, Efficiency: 90%, p.f. =0.92, three phase slip-ring induction motor | 50 KVA, 11 KV /440 V, Delta/Star, Distribution Transformer | 4 |
| 5000 KVA, 6.6 KV, 187.5 rpm, Star Connection, pf = 0.85 lagging | 5 KW, 430 V, 900 rpm, Efficiency: 82%, p.f. =0.9, 3 Phase Squirral cage Induction Motor | 15MVA, 33/11 KV, 50 Hz, 3-phase delta / star core type power transformer | 5 |
| 1000 KVA, 415KV, 1500 rpm, Star Connection, pf = 0.85 lagging | 10 KW, 415 V, 1440 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 350 KVA, 6.6 KV/440 V, 50 Hz, 3-phase star / star core type distribution transformer | 6 |
| 2500 KVA, 6.6 KV, 3000 rpm, Star Connection, pf = 0.8 lagging | 7.5 KW, 415 V, 2880 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 1250 KVA, 11KV/3.3kV, 50 Hz, 3-phase delta / star core type power transformer | 7 |
| 2500 KVA, 6.6 KV, 187.5 rpm, Star Connection, pf = 0.85 lagging | 12.5 KW, 300 V, 2750 rpm, Efficiency: 80%, p.f. =0.80, slipring motor | 2.5 MVA, 33/11 KV, delta - star power transformer | 8 |
| 750 KVA, 415V 1500 rpm, Star Connection, pf = 0.85 lagging | 5 KW, 415 V, 1440 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 250 KVA, 11/430 V, delta- star, distribution transformer | 9 |
| 15000 KVA, 11 KV, 3000 rpm, star connection, pf = 0.85 lagging | 25 KW, 300 V, 1500 rpm, Efficiency: 84%, p.f. =0.85, slipring motor | 25 MVA, 66/11 KV, delta-star power transformer | 10 |
| 1000 KVA, 3.3 KV, 250 rpm, Star Connection, pf = 0.8 lagging | 10 KW, 415 V, 1440 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 75 KVA, 11KV /3.3 KV, delta-star, distribution transfomer | 11 |
| 75000 KVA, 13.8 KV, 187.5 rpm, Star Connection, pf = 0.85 lagging | 7.5 KW, 415 V, 2880 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 750 KVA, 11/6.6 KV, Delta- Star, 3 phase power transformer | 12 |
| 1250 KVA ,6.6 KV, 300 rpm, Star Connection, pf = 0.8 lagging | 12.5 KW, 300 V, 2750 rpm, Efficiency: 80%, p.f. =0.80, slipring motor | 25 MVA,11KV /33 KV, Power Transformer, Delta-Delta | 13 |
| 75000 KVA, 13.8 KV, 3000 rpm, Star Connection, pf = 0.86 lagging | 5 KW, 415 V, 1440 rpm, Efficiency: 85%, p.f. =0.85, Squirral cage motor | 37.5 MVA, 132/66 KV, Delta-Delta connection, Power transformer | 14 |
| 20000 KVA, 11 KV, 3000 rpm, star connection, pf = 0.85 lagging | 25 KW, 300 V, 1500 rpm, Efficiency: 84%, p.f. =0.85, slipring motor | 63 KVA, 11 KV/440 V, star-Star connection | 15 |

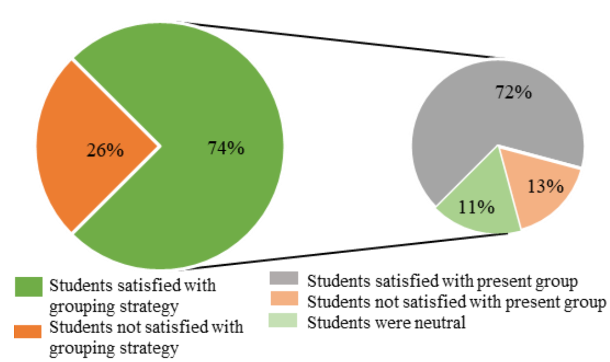


Fig. 5. Survey on group formation after end of academic year 1

TABLE II
IMPROVED PROPOSED CLA FOR TEACHING ELECTRICAL DESIGN COURSE.

| **Conventional practice followed in electrical design courses** (Main concentration is on design.) | **Practice followed in Industry** (Main concentration is on performance) | **Proposed Improvement CLA for teaching electrical design course** (Students are able to learn design process as well as achievement of performance) |
|---|---|---|
| • Single design problem solved through tedious hand calculation to achieve desired design performance parameters.<br>• From above parameters design sheet is prepared to show front view elevation and side view.<br>• An excel sheet is prepared using input and calculated design Parameters.<br>• Effect of variation in temperature mechanical forces etc. are not performed.<br>• Results are not analysed. | • Every design is treated as new design problem<br>• Dedicated software is available where input parameters are adjusted and by trial-and-error performance parameters are achieved<br>• 3D drawing is drawn using above obtained parameters.<br>• FEA analysis is performed<br>• Results are analysed through number of graphs | • A spread sheet is used with pre-feeded conventional parameters.<br>• Designed parameters are verified through calculations.<br>• Input parameters are changed in excel sheet to achieve new design parameter.<br>• Motor CAD is used to perform FEA through 3D Model<br>• Results are analysed through number of graphs<br>• Students are able to learn design process as well as achievement of performance |

*Lab activities:* Each group during laboratory session was assigned with a different electrical machine design problem/ experiment and students are allowed to used laptops and desktop according to the needs. Detailed theory and problem-solving methodology were provided beforehand to the students as an individual/ group in classroom. Students are informed to come with a minimum 1 textbook and a calculator to perform laboratory session. The design problem assigned has sub-parts and Table 1 show the transformer, synchronous and induction machine design problems allotted to students in a group. In each laboratory session formed groups had to solve the minimum sub-part of design problem with desired performance parameters. During the laboratory session it is identified that one studemt in the group noramlly enters the value in the computer. one student reffer book to understant values to be selected from the range using graph, table or machine parameters guidelines. One student verify calcultion using calulater and the last one check for the next formula and parameter value. Students work in grop exchanging knoweledge and discussing about the machine parameter section to achieve desired machine performnce.

*Lab assessment and grading:* Grading assessment is performed based on group tasks and individual performance. The groups completing given task of machine design problem at the earliest without error is assigned the highest marks, and the group completing task at the last is assisted with minimum marks. The teacher assessment and peer review were used for individual performance for individual grading. In case one or more members is absent in the group during theory/ laboratory session the group is incapable in achieving the target and ultimately not achieving higher ranking. The student who remained absent is awarded with zero marks for the corresponding laboratory session. The obtained marks by the group are entered in canvas LMS and is made visible to the students for motivation. This strategy has led in improve attendance and belongingness in the students.

The grading was done on internal assessment for 50 marks and external assessment for 50 marks. Internal assessment further divided into 30 marks consisting of class test for 10 marks, quiz for 10 marks, and theory exam for 10 marks, and remaining 20 marks were allotted based on continuous evaluation which is average marks of each laboratory session. External assessment is done based on laboratory report and the student involvement in group for 25 marks, Practical examination for 15 marks and group presentation for 10 marks marking total of 50 marks.

*Expected outcome:* The outcome-based education is concentrating on achieving higher level of bloom's taxonomy. Student are expected to reach up to the level of analyses and preferably to evaluate level from apply level. Following goals were set for the proposed modified CLA,

1. To achieve higher bloom's taxonomy level and to achieve course outcomes in the laboratory. It is desired in courses that students must work on a unique and separate design problem, achieve desired performance goals within stipulated time. In one semester students have to complete minimum 2 designs problem and submit 2 sheets. However, in a conventional system, 1 design problem is assigned during laboratory session making it a common problem to everyone. Very few interested students would solve the design problem and remaining students copy it to complete the task within timeframe.
2. To increase the student's interest towards the iterative designing process for machines design.
3. To improve individual grades and the overall university result in the design courses (i.e., Design of DC Machines & Transformer in 6th semester and Design of AC Machines in 7$^{th}$ semester).
4. To comprehend the constraints in machine design and the impact of these constraints on the desired machine efficiency, aiming to achieve the specified performance parameters.
5. To avoid rework by the students or even if it is required, it is to be done with minimum efforts.
6. To evaluate the effect of variation in parameter selection for design courses with stringent goal of performance parameter which is a case in industry.
7. To map program outcome of ethics, Modern tools, Teamwork and communication with a technical subject.

TABLE III
DESIGNED SPREADSHEET FOR INDUCTION MACHINE DESIGN.

| induction motor design group 1 ( squirrel cage ) | | | | | |
|---|---|---|---|---|---|
| | QUANTITY | RATING | UNIT | | |
| main dimension | | | | | |
| data | power | 50 | kw | | |
| | voltage | 300 | v | | |
| | speed | 1440 | rpm | <-n | ns-> 1500 rpm |
| | efficiency | 0.87 | | 87% | |
| | pf | 0.86 | | | |
| | phase | 3 | | | |
| | frequency | 50 | hz | | |
| | slip | 4 | % | | |
| | pole | 4 | | assumed | |
| main dimension | syn speed | 1500 | rpm | Ns=120f/p | |
| | syn speed (in sec) | 25 | rps | ns=2f/p | |
| | no. of pole | 4 | | | |
| | KVA input | 66.8270516 | KVA | | |
| | Bav | 0.45 | wb/m2 | | 0.3 to 0.6 |
| | ac | 10000 | A/m | | 5000 to 45000 |
| | Kw | 0.955 | | | winding factor |
| | C0 | 47.2725 | | | C0=11*Bav*ac*Kw*10^-3 |
| | D2L | 0.05654624 | m3 | | |
| | ratio L/tau | 1 | | | can be taken 0.6-2 |
| | L | 0.7853 | D | L/tau= l/(piD/p) | tau=sqrt(0.18L)=piD/p |
| | D3 | 0.07200591 | m3 | | |
| | D | 0.41602814 | m | 416.0281408 | mm |
| | L | 0.3267069 | m | 326.7068989 | mm |
| | Va(peripheral speed) | 32.658209 | m/s | va=pi*d*ns | |
| | ventilating duct | 0 | | for L>125mm | duct required |
| | kd | 1 | | | |
| | nd | 0 | | L<125m | |
| | tau(pole pitch) | 0.32658209 | | tau = piD/p | |
| | net iron length (Li) | 0.29403621 | m | | |
| | | 294.036209 | mm | | |
| winding | | | | | |
| stator winding & design | | | | | |
| | stator voltage/phase | 300 | v | single layer mush winding as power rating <50 | |
| | flux per pole (fi) | 0.04801348 | Wb | fi=L*tau*Bav | |
| | turns per phase Tph | 29.471465 | turns | Tph=Es/4.44*f*fi*kw | |
| | turns per phase Tph= | 30 | turns | round-up | |
| | q (slot per pole per ph | 4 | | | |
| | Yss if 25mm | 49.9233769 | | stator slot pitch | yss=piD/s, no of slots s=25 |
| | Yss if 35mm | 29.3102761 | | stator slot pitch | yss=piD/s, no of slots s=35 |
| | Yss 25 | 50 | m | | |
| | Yss 35 | 30 | m | | |
| | Ss(total number of st | 48 | | ss=q*p*no of phase | |

TABLE IV
DESIGNED SPREADSHEET FOR SYNCHRONOUS MACHINE DESIGN.

| SYNCHRONOUS MACHINE DESIGN | | | | | |
|---|---|---|---|---|---|
| DESIGN OF SYNCHRONOUS MACHINE | | | | | |
| DATA | 25000 KVA , 13.8 KV, 1500 rpm , Star Connection, pf = 0.85 lagging | | | | |
| | SR. NO | DIMENSION | SYMBOL | VALUE | UNIT |
| MAIN DIMENSION | 1 | Power rating in KVA | Q | 25000 | KVA |
| | 2 | Line Voltage | VL | 13800 | V |
| | 3 | Phase voltage | Vph | 7967.433715 | V |
| | 4 | Frequency | f | 50 | Hz |
| | 5 | Power factor | cosϕ | 0.85 | |
| | 6 | Specific magnetic loading | Bav | 0.6 | $Wb/m^2$ |
| | 7 | windings factor | Kw | 0.955 | |
| | 8 | Spectific electrical loading | ac | 60000 | A/m |
| | 9 | rpm | Ns | 1500 | rpm |
| | 10 | Synchronous speed | ns | 25 | rps |
| | 11 | Number of pole | p | 4 | |
| | 12 | Output Coefficient | Co | 378.18 | |
| | 13 | assumed peripheral velocity | Va | 175 | m/s |
| | 14 | Product D2L | $D^2L$ | 2.644243482 | $m^3$ |
| | 15 | Stator bore | D | 2.229299363 | m |
| | 16 | Gross copper length | L | 0.53206496 | m |
| | 17 | Pole pitch | τ | 1.75 | m |
| LENGTH OF AIR-GAP | 18 | Armature mmf per pole | ATa | 52500 | A/m |
| | 19 | Assuming Short circuit ratio | SCR | 0.6 | |
| | 20 | No load field mmf | $AT_{fo}$ | 31500 | A/m |
| | 21 | MMF for air gap | Atg | 25200 | A/m |
| | 22 | Maximum Flux Density | Bg | 0.9 | Wb/m2 |
| | 23 | Gap contraction Factor | Kg | 1.1 | |
| | 24 | Length of Air-gap | lg | 0.031818182 | m |
| | 25 | Assumed Length of Air gap | lg | 30 | mm |
| | 26 | Diameter of Rotor | Dr | 2.169299363 | m |
| | 27 | Peripheral Speed | Va | 170.29 | m/s |
| STATOR WINDING | 28 | Flux per pole | ϕ | 0.56 | Wb |
| | 29 | Voltage per phase | Eph | 7967.43 | V |
| | 30 | Turns per phase | Tph | 67.27 | |
| | 31 | Updated turns per phase | Tph | 113 | |
| | 32 | Conductors per phase | Zph | 226 | |
| | 33 | Total armature conductors | Z | 678 | |

TABLE V
DESIGNED SPREADSHEET OF TRANSFORMER DESIGN.

| 3Ø Transformer Design | | | | |
|---|---|---|---|---|
| 200 KVA , 6600/440 V ,star/delta connected, Distribution | | | | |
| | Nomenclature | Value | Unit | Remarks |
| DATA | Q | 200.0000 | kVA | |
| | | 200000.0000 | VA | |
| | $V_p$ | 6600.0000 | V | |
| | $V_s$ | 440.0000 | V | |
| | Primary connecton type | Delta | | |
| | Secondary connection type | Star | | |
| | f (Frequency) | 50.0000 | Hz | |
| | Transformer Type | Distribution | | |
| | Max. temperature rise | 45.0000 | °C | |
| CORE DESIGN | K | 0.4500 | | [Page 377 - Table 7.2] |
| | $E_t$ (Voltage per turn) | 6.3640 | V | $E_t = K\sqrt{Q}$ |
| | $Ø_m$ (Flux per turn) | 0.0287 | Wb | Øm = Et/4.44f |
| | $B_m$ (Flux density) | 1.0000 | $Wb/m^2$ | 1.1 to 1.35 $Wb/m^2$ [Page 383 - 7.37] |
| | $A_i$ (Area of iron core) | 0.0287 | $m^2$ | $A_i = Ø_m / B_m$ |
| | | 28666.4911 | $mm^2$ | |
| | d (Diameter of circumscribing circle) | 218.5806 | mm | 3-step core $A_i = 0.6d^2$ [Page 382 - Table 7.3] |
| | a | 196.7226 | mm | a = 0.9d |
| | | 197.0000 | | Round up figure of a |
| | b | 153.0064 | mm | b = 0.7d |
| | | 154.0000 | | Round up figure of b |
| | c | 91.8039 | mm | c = 0.42d |
| | | 92.0000 | | Round up figure of c |
| WINDOW DESIGN | $K_w$ | 0.2732 | | Kw = 10 / (30 + (HV = $V_p$)) [Page 396 - 7.67 |
| | δ (Current density) | 1.7000 | $A/mm^2$ | 1.1 to 2.3 $A/mm^2$ [Page 384] |
| | | 1700000.0000 | $A/m^2$ | |
| | $A_w$ (Area of window) = $H_w$ × $W_w$ | 0.0902 | $m^2$ | $Q = 3.33 f B_m K_w δ A_w A_i 10^{-3}$ |
| | | 90213.8848 | $mm^2$ | |
| | $H_w / W_w$ (Hight to width ratio | 2.0000 | | 2 to 4 |
| | $W_w$ (Width of window) | 212.3840 | mm | $W_w = A_w / (H_w/W_w$ ratio) |
| | | 213.0000 | | Round up figure of $W_w$ |
| | $H_w$ (Hight of window) | 424.7679 | mm | $H_w = W_w × (H_w/W_w$ ratio) |
| | | 425.0000 | | Round up figure of $H_w$ |
| | D (Distance between adjace | 430.9646 | mm | $D = W_w + d$ |

Table 2 represent the proposed improved CLA approach and the difference form the conventional teaching learning practice. The electrical machine design parameters obtained from tedious calculation is calculated from specifically designed spread sheet in the proposed approach. Hence the student aims on obtaining the desired machine performance rather than only calculating machine design values. Moreover, the results are analysed using Motor-CAD software using number of graphs.

## V. DESIGNED EXCEL SPREADSHEET

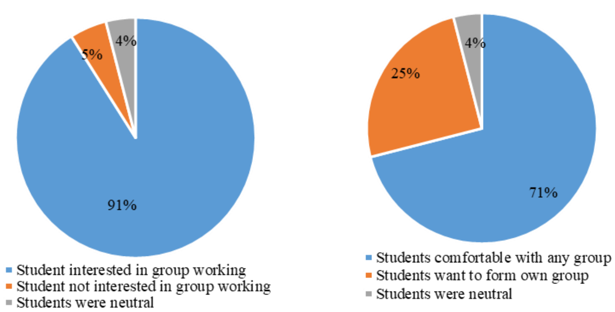
For the adopted CLA an excel sheet is designed for the course like AC machine design, Design of DC machine and transformer in view to help students understand the core concept of designing in par with industrial standards. In addition, students must also have the knowledge of the design parameter change and its effects on overall machine designed and efficiency. Designed spreadsheet present all the required design paraments such as stator design, conductor size, rotor design, slot width, airgap design, stator slot, stator teeth, stator core, rotor slot, rotor core, rotor teeth, loss components, efficiency, temperature rise and all related performance parameters. Based on the respective formulas the students are able to identify the most dominating design parameter during machine design.

In the adopted CLA, the students in a formed groups solve the allotted design problem effectively. Each group is allotted a different question in during each laboratory session. Table 3, Table 4, and Table 5 give the information on the designed excel sheet for engineering design course on induction machine design, synchronous machine design and transformer design respectively.

## VI. RESULTS AND DISCUSSION ON IMPLEMENTED COLLABORATIVE LEARNING APPROACH

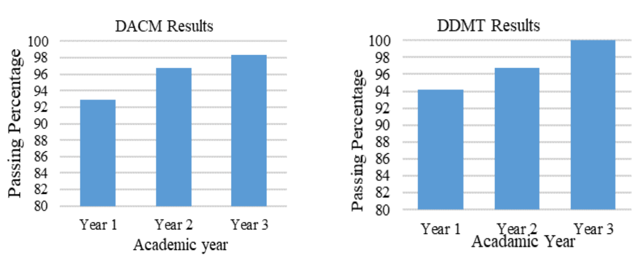
The proposed CLA was implemented in Bachelor of Technology program for students of pre-final year in DDMT (Design of DC machine and transformer) and final year in

DACM (design of AC Machine). The collaborative learning deals with forming groups by using various methods and then they are expected to do the tasks, normally the task would be common. In Modified CLA the groups are formed randomly but keeping the group strength equal, the competition is offered to work on different datasets and the evaluation is carried out on group based as well as individual based. This brings many advantages. The student attendance was improved year on year, as there was commitment and force from peers. To achieve fast and better results the group started sharing work. one student was doing a data entry in a spreadsheet, the other one student was supporting with a calculator, next student used to take care of the sequence and last one student was taking a call to select the value of a given parameter, these roles were interchangeable as per group's convenience. This allowed for discussion, learning among groups members exchanging knowledge. The group had combination of Premier, average and challenged students. Very few time the same student group got highest marks. At the end of the semester a feedback survey was conducted to analysis the students mindset during collaborative learning and the survey results are shown in Fig. 6. More students were interested in group working with respect to survey conducted before activities. Also, students were more prepared to work with people they were not comfortable before, which will help them to work in team in professional environment. Improvement in the passing percentage of students in DDMT and DACM course in university examinations after implementation of posed CLA during three consecutive years is shown in Fig. 7. It is visible that the pass percentage is improved in both subjects over the year. Fig. 8 shows the overall academic performance of the students in the




(a) (b)

Fig. 6. Survey on students after implementing improved collaborative learning approach, (a) Survey on group working, (b) Survey on formation of group.




(a) (b)

Fig. 7. Academic performance after adopting CLA (a) Academic performance in DACM (b) Academic performance in DDMT.

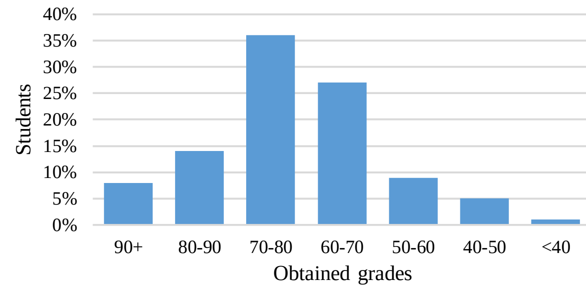



Fig. 8. Students academic performance after implementing modified CLA.

academic year 3 after implementation of proposed CLA. Which clearly depicts that with respect to Fig. 3 which talks about obtained grade with normal teaching-learning method, there is shift in grades towards higher grades. In Fig. 9 there are more students who received 90+, 80-90 and 70-80 and there are less students in 50-60, 40-50 and <40%. The CLA had been instrumental to improve the results of all premier, average and challenged.

## VII. Conclusion

The proposed modified CLA with the help of designed spreadsheets, showed excellent cognitive improvement in students with improvement in academic performance. Students were now able to complete electrical machine design problems given as group task required well before the planned date and with desired level of performance parameters. Further, the strategy allowed to achieve higher level of bloom's taxonomy. The university result of DDMT was raised from 94.2% (without collaborative learning) to 96.8% and 100 % in consecutive years with the implemented strategy. The same way for DACM subject respective figures was 92.9%, 96.7%, and 98.3%. Hence, the study revealed that with a few innovative changes, CLA can effectively provide a better learning experience for students for design-based courses.

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