Coupling of Active Learning Tools to Enhance Understanding of Fundamental Principles of Taylor's Series and Generate Dynamic Class Room Environment with Healthy Social Interaction

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***Abstract*—Teaching in engineering education encompasses numerous curriculum factors and has become increasingly complex and challenging, particularly due to students' short attention spans and difficulty in sustaining focus. This challenge is further intensified by the constant exposure to vast volumes of information in the digital era, making it harder to identify and retain meaningful learning content. This work proposes a systematic methodology that integrates and couples active learning tools through a coherent, symbiotic teaching–learning–evaluation process designed to foster a student-centred environment and nurture the joy of learning. The approach combines three complementary strategies—Think-Pair-Share (TPS), Concept Mapping, and Student Team Achievement Division (STAD)—and is implemented in a first-year engineering mathematics course. The lecture plan, learning activities, feedback mechanisms, and evaluation processes are developed at a micro-level to accommodate diverse learning styles and the psychological needs of contemporary learners. Quantitative and qualitative comparisons with the traditional teaching approach indicate notable improvements in self-confidence, critical thinking, innovation, and social interaction. Notably, end-semester examination scores increased by 28.49% compared to the traditional method, affirming the effectiveness of the integrated approach. Based on observations from a class of sixty students, statistical analysis performed using ANOVA software, results show that there is a positive improvement in the proposed methodology, but however reliability and consistency needs to be tested for heterogeneous range of students.**

***Keywords*— Coupled active learning tools, Think pair share, Concept mapping, Students team achievement division, Coherent-symbiotic-integration.**

I. INTRODUCTION

HUMAN being is continuously striving hard to understand the complex process of teaching and learning phenomena. Knowing the science behind teaching and learning is a epic point of research from the ancient period to till date (Álvarez A. J., 2024). In the earlier stage of civilization, guru has been regarded as the source of knowledge and educated his disciples under the perfect, undisturbed and dedicated academic environment. But in the current scenario, availability of several sophisticated gadgets like mobile technology, data technology, information technology, digital technology, etc. have added on to the educational institutions as learning resources and facilitating the teacher and students. But, learning of students and enhancement in their capabilities or attributes acquired through existing engineering education (Patil, Y. M., & Kumbhar, P. D., 2021) eco-system is questioned and daunted throughout the world (Russo, D., 2023). Every academic institute is struggling to adopt novel practices which could inculcate deep engineering knowledge, accountability, commitment and best ethical practices. The pertinent feature of higher education is to equip the students with problem solving ability, cooperative learning, (Tiwow D. *et.al*. 2020) experiential learning and remain sensitive to the contemporary issues emerging in the society. Recently, usage of active learning tools (Lima R., 2016) have emerged as widely popular tools in higher learning engineering institute. Curriculum components include several courses which belongs to the category like theoretical, numerical, problem based, experimental investigations and combination of these types. Using active learning tools which acts like a driver to reinforce fundamental principles of the courses and ensure enjoyable learning during lecture and practical session is widely accepted and it is best practiced activity. The conventional pedagogies, such as covering the pertinent issues in lectures and tutorials, may make it too difficult for the field in Science, Technology, Engineering, and Mathematics (STEM) students to comprehend certain ideas/facts/logic, etc. In past two decades, several active learning (AL) approaches are adopted to improve student attractiveness and retention. Effectiveness of teaching has been demonstrated by implementing STAD (Syahidi A. A., & Asyikin A.N, 2018) approach to high school students and co-

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operative behaviour during the activity is the main essence of the success of this activity. Tink pair share (Tanujaya. B. & Mumu J., 2019) event has been employed to deliver the fundamental concepts of metrology (Hernandez *et.al.* 2009) and mathematics (Tanujaya. B. & Mumu J., 2019) course respectively. Introducing games (Wang G. G, 2004) and concept map assessment (Baroody, A. J., & Bartels, B. H.2000) within the classroom environment promoted students to explore new concepts with joy and enthusiasm.

Looking into the information available in the literature and exploring existing knowledge, in connection with usage of active learning tools and its integration, few research questions seems to be investigated so as to gain in depth knowledge. The research questions (RQ) can be framed as:

1. RQ1: Does the coupled TPS–Concept Mapping–STAD intervention improve student learning (unit test and ESE scores) relative to the traditional approach? If yes, then in what sequence the active learning tools has to be used.

2. RQ2: Does the intervention improve self-reported knowledge, confidence, and socialization?

3. RQ3: Which measurement mechanisms is appropriate to quantify the learning in the academic environment?

Though the active learning tools discussed in the literature are used to teach a particular class level students and to convey specific basic concepts are often confined to single active learning tools. There is a requirement to design a systematic methodology to interlink think-pair-share, concept map and STAD activity especially while teaching complex mathematical concepts and initiate symbiotic relationship between teacher and students for effective teaching-learning process. In the GenAI era, where attention spans are short and information is abundant, structured, interactive pedagogies like TPS, STAD, and Concept Mapping play a crucial role in helping students develop analytical thinking and adaptability—skills essential for working with intelligent systems. These collaborative and constructivist strategies align well with the pedagogical needs of the GenAI era, where human-AI interaction, self-directed learning, and adaptive thinking are becoming central to engineering education. Next part of the section discusses on segmental sequential methodology adopted in the implementation of coupled active learning tools.

II. DESIGN METHODOLOGY TO INTEGRATE AND COUPLE ACTIVE LEARNING TOOLS FOR THE MATHEMATICS COURSE

Engineering mathematics course demands skill sets namely application, analysis and evaluation. The first-year engineering students entering in to the institute are having the background of mugging the formulas without real sense of mathematics (Mealasari E., 2017) principles and often lags in applying the concept. In order to nurture and enhance analytical and applying skill sets. a systematic, coherent and symbiotic methodology is designed and proposed as follows. The syllabus of mathematics comprises of six major units' matrices-I, matrices II, solution of simultaneous algebraic equation, ordinary differential equation of first order and first degree, numerical solution of ordinary differential equation, finite difference and interpolation.

TABLE I
SEQUENTIAL FLOW OF DETAILS OF THE ACTIVITY PLANNED FOR THE UNIT-5 AND SUBTOPIC TAYLOR SERIES

Unit Name	Subtopic	Description of the event	Skill desired/Active learning tools	Symbiotic/ Coherence observed
Unit-5: Numerical solution of ordinary differential equation	Taylor series	Origin and significance of Taylor series	Knowledge/ TPS-1	One-to-one feedback between teacher and student and Vise-versa. Socialization
		Dependent and independent terms in the series	Knowledge/ TPS-2	Existence of coherence with TPS-1
		Logic of Taylor series and its construction	Constructing skill/CM	Coherence with TPS-1 and 2
		Applying boundary conditions.	Application/TPS-3	Coherence with TPS-2
		Solving Taylor series to obtain dependent parameter	Problem solving/TPS-4	Mutual feedback, Socialization
		Effect of higher order terms on the solution.	Analysing skill/STAD-1	Mutual feedback, Socialization
		Verification of solutions with analytical approach	Evaluation skill/TPS	Confidence level
		Application of concept to beam, fluid flow, heat transfer	Application/STAD-2	Socialization and demonstration of ability

Every content of each unit is divided in to subtopic and details of each subtopic and required skill sets along with type of active learning tools is clearly drafted in minute wise lecture plan. Input and output of each active learning tool is successively modified and re-modified as per the coupling desired. Observations and suggestions sought in the previous activity are explored while hosting next activity. Sufficient care is taken to communicate to the students regarding tangible and intangible benefits of the coupled activity aligned along the expected symbiotic, coherent behavior of the students. Due to limitation of size and length of present paper, instead of complete course plan only segmental part of the course plan for particular topic is presented. The content of activity planned within the lecture session for the unit-5, numerical solution of ordinary differential equation and subtopic Taylor series is reported in the Table 1.

The table 1 is the sample copy for the subtopic Taylor series of the unit-5. Micro-level planning of subtopic involves sequential content to be delivered, essential skill set to be nurtured, selection of active learning tool and testing symbiotic-coherence attitude of students. Author is of the opinion that if the admitted students in the institute are from rural background, then there is a need to exert extra efforts to build the openness, reduce shy nature, inferiority complex, etc. Socialization and coherence parameter is also dealt in the class and measured via designed google form and also through visual observation.

The questionaries framed in the google form basically tests the student's perception regarding knowledge acquired, confidence level to solve complex concepts, individual attitude and social behaviour.

Testing of knowledge and skill sets acquired after the usage of active learning is examined through quiz, assignment and presentation. Prepared content of subtopic as shown in table-1 is extended for all the units and it is reflected in the course plan and made available to students in the beginning of the semester on Moodle platform. Fig.2.1 shows the process implementation of active learning tools and its architecture with interventions. In the next part of the section, methodology along with results and discussions is reported.

Its execution begins with the teacher presenting an issue, after which the students independently come up with a solution (think), discuss in pairs (talk), and finally, have a class discussion (share).

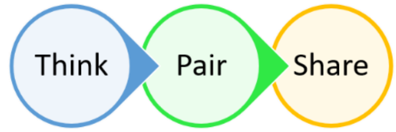

Fig.3.1. Architecture of Think Pair Share (TPS) Model

TPS has been endorsed due to its benefit of allowing students to reflect on their thinking, communicate their rationale, and receive immediate feedback on their comprehension. After delivering the lecture for five minutes on each of the topic mentioned in table 1, namely, significance of Taylor's series

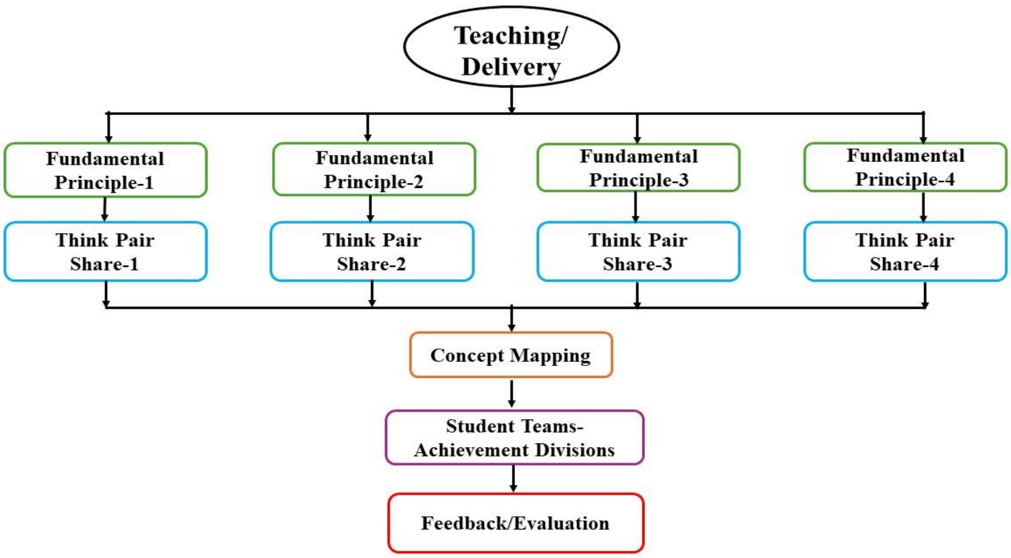

Fig. 2.1. shows the process implementation of active learning tools and its architecture with interventions.

(TPS-1), segregation of dependent and independent variables (TPS-2), TPS activity is conducted in the theory class. Success of the activity is measured via designed google form which includes the question related to gained knowledge, developed skill set, socialization, self-esteem and communication. Each of these success parameters are calculated on five-point scale and converted to bar chart for pictorial representation.

III. IMPLEMENTATION OF COUPLED ACTIVE LEARNING TOOLS FOLLOWED WITH DISCUSSION OF RESULTS

Coupled active learning tools refers to the series of activity conducted in a uni-directional manner so that output of one activity acts like a input to the other activity. At the end, cumulative effect leads to learning of Taylors series concept in a effective manner with enjoyment.

A. Think pair-Share

Think-Pair-Share (TPS) (Lee C. *et.al.*, 2018) is a popular technique which is designed on the principle of mutual benefits of two students.

Think Pair Share model was introduced for the first time by Frank Lyman in 1985. The activity "Think Pair Exchange" can help students to consider the issue and then share ideas with others, where others' ideas can be used to advance their abilities.

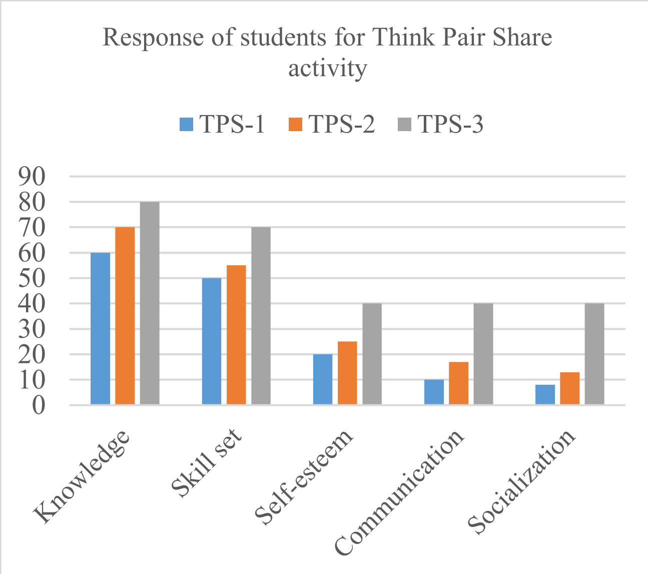

Fig. 3.2. Think Pair Share activity responses conducted in the classroom for TPS-1, TPS-2 and TPS-3

The response shown by the students in all TPS-1, 2, 3 is depicted in the Fig. 3.2. It is clearly evident from the graph that all the success parameters are steadily increasing in the successive TPS activity. It is to be noted that concern raised by students during TPS-1 regarding the time allotment of the activity, guidelines and topic content, seating arrangement in the class room were addressed in the subsequent TPS activity 2 and 3. Even the visual observations during the activity confirms that, both students and faculty are proceeding towards healthy interaction essential for TPS activity. There is almost rise of 20% in the knowledge, skill set and self-esteem, whereas communication and socialization enhance by 30%. It has been noticed that class-ecosystem is transformed towards positive ebbs which is the result of student's openness, active participation, willingness to support their colleagues and many students were successful in breaking their safer-zone shell and marching towards joy of learning.

B. Concept Mapping

As discussed in the previous section, where in Think-Pair-Share activity (TPS-1,2,3) is employed to ensure that every small bit of fundamental concepts required for Taylor series are digested by the students. It is often experienced by mathematical course instructor that, due to lack of previous knowledge, teachers frequently discover a large number of pupils who are unable to solve mathematical issues in the field. It has a variety of causes. One of them is that pupils' ability to relate mathematical concepts to one another is so poor that they are unable to comprehend the notion. In contrast, the previously taught notion will be associated with and used once more to acquire new concepts when teaching math. As a result, acquiring new arithmetic information, experiences and prior learning from someone will influence the learning process. A concept mapping strategy is a plan for how to learn and accomplish learning goals using the concept map tool. Additionally, it is described as a two-dimensional map made up of nodes for concepts and labelled lines for connections between pairs of nodes. Students can benefit from the concept mapping learning technique. The student's ability to solve issues in mathematics learning will be substantially aided by a sufficient understanding of identifying the relationships and linkages between a concept with other concepts that are connected through the concept mapping learning approach.

Concept mapping, learning approach involves the following steps:
(a) identifying all the concepts that will be represented on it;
(b) identifying potential connections between concepts by drawing connecting lines and describing the connection; and
(c) ensuring that the layout and completeness of connections between concepts make the concept maps simple to read and analyze.

Identified nodes in the concept of Taylors series, subtopic of unit-5 (numerical solution of ordinary differential equation) are node1: Origin of Taylor series, node2: motivation, node3: dependent and independent variable, node4: construction of Taylor's series of first order, node5: construction of Taylor's series of second order, dot6: fixed boundary conditions, node7: cantilever boundary conditions, node8: temperature boundary conditions, node9: heat flux boundary conditions, node10: velocity boundary conditions, node11: solving to obtain dependent parameters, node12: error estimation, node13: analytical solutions, node14: verification and validation, node15: beam problem, node16: fluid mechanics, node17 heat transfer, node18: solid mechanics, node19: one dimensional.

Fundamental concepts involved with these dots are discussed through TPS activity. Mapping of concepts and sequential connection of these nodes to solve a problem is thoroughly dealt in the concept mapping activity. Let us consider a case of one-dimensional cantilever beam analysis problem and students are expected to obtain displacement field using Taylor's series up to the error tolerance of 10%. During the concept mapping activity, students are compelled to critically think to logically connect the nodes in the sequential manner and generate the path way which leads to the solution of the beam problem. For beam analysis correct pathway is node1-node2-node18-node14-node3-node5-node7-node10-node11-node12-node13 shown as path A in the Fig. 3.3.

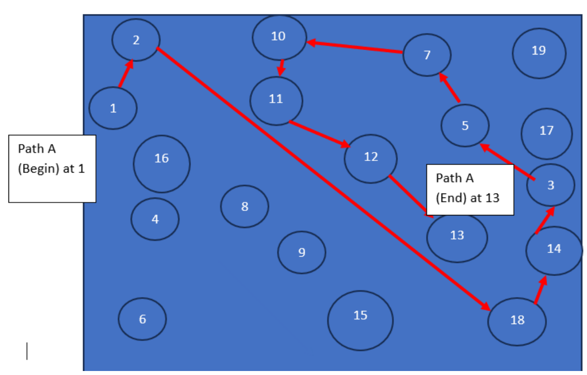

Fig. 3.3. Schematic distribution of node 1-19 representing the concepts within the domain of Taylor's series and Path A is the correct solution for beam analysis problem.

New approach of teaching via concept mapping activity is really enjoyed by students and vibrant dynamic academic condition in the classroom is observed. The exact path way generation to solve the problems elevated logical thinking and improved the confidence of solving complex problem. With reference to the feedback taken to ascertain the effective implementation of concept mapping as shown in Fig.3.3.1, around 80% of the students have strongly agreed that this method is useful in clearing the doubts and provide multiple ways to tackle the problem.

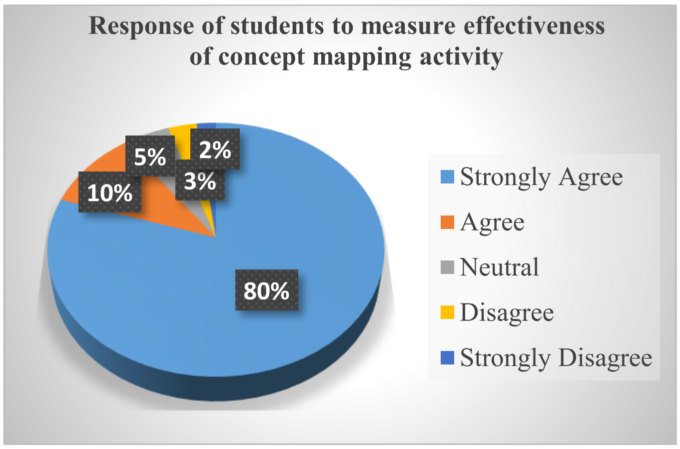

Fig. 3.3.1. Pie chart showing satisfaction level of students in concept mapping activity.

C. *Student Team Achievement Division (STAD)*

Basic intension of this section is to integrate TPS and concept mapping with STAD activity so as to expand the horizon of students understanding in the concept of Taylor's series. Underlying principles of STAD activity stands on the behaviour of cooperative or collaborative learning. Every student in the class is triggered to grasp the fundamental concepts and contribute to their team to achieve the assigned target. Heterogeneous nature of students belonging to different caste, religion, region, gender, learning speed are clubbed in a team and compelled to work on a problem through discussions, focussed thinking, critical inquires and generate new knowledge by retuning the existing knowledge delivered in the class. The students are divided into teams or small groups comprising of 5-7 members. Due care is taken while forming the groups so that all high or low performer will not fall in the same group. Resource material, guidelines for activity, roles and responsibility, date and timing of activity, evaluation process along with rubrics are shared with students prior to the commencement of STAD activity. Each team has to provide the solution to the problem. While designing the team problem, all the content mentioned in table 1 are succinctly embedded in the problem statement. These problems are selected from the domain of structural mechanics, fluid mechanics, heat transfer, etc. For example, apply the Taylor's series to compute displacement field in a cantilever beam and acceptable error tolerance must be in the range of ∓ 0.002. Students are expected to use the knowledge gained during the activity TPS-1, TPS-2, TPS-3 and concept mapping to solve the problems assigned during STAD activity. Performance in the STAD activity is assessed based on individual and team scores with the aid of designed rubrics. Team is allowed to deliver their presentation and defend their path way of generated solution.

Impact of newly proposed integrated approach of using active learning tools on students' performance is further examined. Average based continuous evaluation sheet for the consecutive years of batch 2022-23 (traditional approach) and 2023-24 (newly proposed approach) are used to investigate the overall impact on students' technical advancement. Table -2 provides the relevant data computed on average-based marks of in-semester-evaluation (ISE), unit test-I (UT-1), unit test-II (UT-2) and end-semester-exam (ESE) for the batch of 2023-24 and 2024-25 respectively. It is evident from the data presented those average marks of students' performance is progressively increasing for the batch 2024-25 in respect of various components of ISE, UT and ESE.

TABLE II
AVERAGE MARKS IN ISE, UT AND ESE FOR THE YEAR 2023-24 AND 2024-25

		Average marks scored in the ISE, UT and ESE			
Batch	Type	ISE (20)	UT-1 (25)	UT-2 (25)	ESE (100)
2023-24	Traditional	11.16	10.22	10.45	44.01
2024-25	Newly proposed approach	12.23	12.01	13.25	56.55
Percentage of increase in average marks		9.58	17.5	26.79	28.49

Significant change in average marks of 2024-25 batch as compared to batch 2023-24 is the reflection of smooth integration of TPS, STAD and concept mapping. It is to be noted that overall performance of students in end-semester-examination is steeply enhanced by 28.49 % in comparison with previous batch (Table 2).

Further, statistical investigation is carried out to reveal various connections and reliability of computed parameters. Using the scores obtained by students in ISE, UT-1, UT-2, ESE, statistical analysis using ANOVA software is performed. The pertinent statistical parameters like control mean, intervention mean, standard deviation, mean difference, t and p-tests value and Cohen's d value is evaluated and presented in table-3. Similarly, statistical parameters are also computed for the data collected from google survey form where the student is exercising his/her response in the view of knowledge, ability to solve complex problems, confidence and learning through socialization. The results of survey form is presented in table-4.

TABLE III
DESCRIPTIVE & INFERENTIAL - UNIT/EXAM SCORES

Measure	Control (N=62) Mean ± SD	Intervention (N=60) Mean ± SD	Mean diff (95% CI)	t (df)	p	Cohen's d
ISE	11.16 ± 16.2	12.23 ± 15.1	3.2	1.4	0.003	0.31
UT-1 (%)	10.22 ± 13.2	12.01 ± 11.2	3.6	1.6	0.048	0.33
UT-2 (%)	10.45 ± 11.5	13.25 ± 12.0	3.8	1.7	0.049	0.35

ESE (%)	44.01 ± 10.5	56.55 ± 9.5	12.5	4.7	0.001	0.86

TABLE IV
CRITERIA FOR FEEDBACK SURVEY RANGING FROM 1 – 5 SCALES

Scale	Control Mean ± SD (N=62)	Intervention Mean ± SD (N=60)	mean diff (95% CI)	t	p	Cohen's d
Knowledge (1–5)	2.8 ± 0.6	3.4 ± 0.7	0.6	4.4	0.001	0.88
Ability to solve complex problems	2.7 ± 0.8	3.3± 0.5	0.6	3.7	0.001	0.89
Confidence (1–5)	2.6 ± 0.7	3.2 ± 0.8	0.7	3.8	0.001	0.75
Learning through socialization (1–5)	2.9 ± 0.5	3.5 ± 0.6	0.6	5.2	0.001	0.95

With reference to table-3, control mean for N=62 and intervention mean for N=60 indicates that there is a gradual positive progress from ISE to ESE component. The t values which are positive and non-zero signifies that the effect of TPS, CM, and STAD activity have influence better learning as opposed to traditional approach. All p-values of ISE, UT-1, UT-2, ESE are lesser than 0.05 which means that there is no chance of misleading of results may be due to accidental errors or incorrect collection of data. The t (>0) and p (<0.001) values depicted in table-4 indicates that gain in knowledge and learning through socialization has impacted for improvement in the academic learning. This means that coupled-integrated active-learning tool approach proposed in this paper is highly reliable and yields satisfactory results.

Concurrency and coherency maintained in the active learning tools (TPS, STAD, concept mapping) have resulted in to building required competency to apply concepts of Taylor's series and solve wide variety of mechanical engineering problems. Newly proposed integrated approach of employing TPS-STAD-concept mapping has nourished students to develop technical skill sets along with self-confidence, self-esteem, improved communication and experiencing joy of learning. The proposed model can be scaled-up or down and sustainable output will appear. Provided, there is a systematic plan for implementation, well designed rubrics, guidelines and outcome of each of the active learning tools is priorly known to the students before actual execution in the class.

Author is of the opinion that traditional approach of teaching mathematics course can be substituted by newly proposed methodology.

CONCLUSION

Newly proposed methodology to integrate TPS, STAD and concept mapping activity within the premises of coherent and symbiotic connections are demonstrated on the topic content of Taylor's series of the mathematics course, taught at first year level of engineering. Student's reflections and responses obtained during TPS-1 to TPS-3 and concept mapping are molded for fine tuning within the STAD activity. Implications of replacing traditional approach with proposed approach can be summarized as follows. Though, first exercise of TPS-1 revealed that involvement, commitment and accountability of students were not satisfactory. By fine adjustments done in methodology of implementation, continuous counselling resulted in smooth conduction of coupled active learning tools with sufficient gain by teacher and student both. Concept mapping activity tool proved to be indispensable and noticeable changes are observed in the respect of skill sets namely application, analysis, problem solving ability. Output of TPS and concept mapping are used as input to STAD activity.

Overall impact of concurrent, coherent approach of aligning TPS, concept mapping and STAD activity has yielded progressive improvement in average marks of testing batch (2024-25). ANOVA software-based analysis clearly shows that the computed optimum value of statistical parameter like p-tests and t-tests values indicate that there is a significant enhancement in academic performance of students and worthiness of proposed methodology. Other intangible benefits of this approach are increase in self-confidence, self-esteem, commitment, accountability, socialization and elevation of dynamic class room environment. The consistency and reliability of proposed model applied to all diversity and class size and effect of quality of students on the model has to be further examined and this can be considered as extension of this proposed work.

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