Enhancing Engineering Students Attention and Concept Retention: Insights from Synesthetic Learning and Microteaching

B M Bharath[1], R Bavatharani[2], Naresh Kumar Sharma[3], V Lakshmi Narasimhan[4]
[1] Computer Science and Engineering, Kalasalingam Academy of Research and Education, Tamil Nadu, India
[2] Biomedical Engineering, Kalasalingam Academy of Research and Education, Tamil Nadu, India
[3] Director, Teaching Learning Centre, Kalasalingam Academy of Research and Education, Tamil Nadu, India
[4] Patterson Distinguished Professor, Elizabeth City State University, NC, USA
[1] bharathbm83@gmail.com [2] bavatharanitrs24772@gmail.com [3] naresh@klu.ac.in
[4] srikar1008@gmail.com

***Abstract*—In the present education scenario, there is a growing trend towards continued student interaction and support of the retention of complicated engineering concepts. Conventional education renders classes passive. Numerous students lose concentration and reason less. Multisensory techniques assist the student to connect new concepts to familiar ones. They also demonstrate the fitment of ideas. Compared in this paper are Synesthetic Learning Pedagogy (SLP) and Microteaching (MT). The two supplement sound and brief activities to improve attention and memory. MT involves teachers to provide brief lessons in order to develop understanding and articulated speech. SLP involves the utilization of sight, sound, and movement to make the lessons more interesting. Pilot classroom tests involving a population of about 130 B. Tech students showed considerable improvement of up to 47 percent in concept retention in the long term as compared to the control. Although SLP can be employed to boost retention, its complete effects on creativity and learning require further investigation. This was carried out among engineering students of varying year levels. The findings demonstrate the influence of every approach on the concentration of students and their ability to remember what they have learned. The paper recommends that application of various teaching ways depending on learning objectives, has the propensity of preferring the attentiveness and assimilation of instructional material.**

***Keywords*—Engineering Education; Microteaching (MT); Synesthetic Learning Pedagogy (SLP); Attention Span; Concept Retention; Active Learning; Pedagogical Strategies.**

***ICTIEE* Track*:* Innovative Pedagogies and Active Learning**

ICTIEE Sub-Track: Gamification and Student Engagement Strategies

I. INTRODUCTION

THERE is a pertinent issue with engineering education now. Schools find it difficult to keep students interested as well as aid them in remembering difficult concepts. Employers desire graduates who can do more than just theory and practical skills as well as be creative and flexible. The conventional technical instruction is insufficient. They fail to impart all the skills required by engineers to work in the contemporary context, as Mashwama and Madubela (2025) observed. Earlier on, engineering majors were theory-based. The individuals recruited by companies today are unable to apply knowledge to address actual problems (Brunhaver et al., 2017). In order to address this, teachers employ interactive, innovative instructions. Such approaches are not limited to passive lectures. They make students grasp concepts. They allow students to practice engineering in the real-life scenarios (Nirmalakhandan et al., 2007).

A. *Need for Differentiated Pedagogy in Engineering Education*

Students of engineering programs have various backgrounds. They possess different classes, abilities and learning styles. Such combination enriches the classroom but poses teachers with huge challenges. Teachers are forced to alter what they teach, the manner in which they teach and also how they mark. Such modifications are beneficial to address the needs of students and provide all people with equal opportunities to perform well. There are recent findings which demonstrates that learning can be enhanced through student-centered approaches (Mashwama and Madubela (2025). They do more than lectures. They assist students in studying the content. They also develop teamwork, critical thinking, creativity and communication. This is important to the engineering learners (Sadikin et al., 2024). The differentiated instruction method increases both motivation and comprehension. It involves working, regular reviews, and prompt feedback. It also equips learners with tough engineering careers in dynamic work environments (Remesh, 2013).

Naresh Kumar Sharma
Director, Teaching Learning Centre, Kalasalingam Academy of Research and Education, Tamil Nadu, India
naresh@klu.ac.in

B. Overview of Synesthetic Learning Pedagogy (SLP)

Synesthetic Learning Pedagogy (SLP) is an innovative method of teaching. It involves a great number of senses, such as hearing, sight, touch, and motion. It is one of the methods that assist students in learning and retaining more, as well as remaining active. Cognitive neuroscience attests SLP as it draws on the experience of the brain to process multiple senses of information.

As we activate one of the senses, it may alter the way we perceive and acquire knowledge in a different sense. This enables us to store information using various senses. That enhances long term memory and thinking. SLP employs the multisensory techniques in learning. They engage in music, visual images in colors, movement, and process. They enhance concentration, give rise to creativity and problem solving. They are also effective in vast disciplines as engineering, medicine and science (Lakshminarasimhan et al., 2021) (B M Bharath et al., 2025). SLP also supports inclusion as it fits itself to various learning styles. This allows students having different thinking/sensory needs to engage in the study material. SLP transforms passive lessons to active ones. The transformation is appropriate to student-centered, practical, and diversified teaching.

C. Overview of the Microteaching Approach

A prominent example of an applicable method of enhancing teaching is microteaching (MT) (Edwin G. Ralph, 2014). It focuses on practice after 10-15 mins of learning. Small groups are taught short lessons by their teachers. They receive feedback and thereafter test their skills. Every lesson has some most important ideas taught by student teachers or instructors. The teacher asks questions at the end of the lesson to assess comprehension. The teacher examines the responses and re-teaches areas that the students had problems with. This aids students to achieve improvisation with each cycle of MT. Studies indicate that microteaching increases the memory, comprehension, and learner confidence. It is particularly applicable in STEM where concepts may prove to be tricky (Tutiariani Nasution et al., 2023). Microteaching provides a secure space in which pre-service and in-service training of teachers occur. Microteaching assists the teachers with classroom management. It is also a way of making them develop skills and receive feedback with peers and mentors (Yogesh Popat, 2020). Microteaching is better in good condition and research indicates that peer comments, introspection, and second-opportunity to teach are beneficial (Edwin G. Ralph, 2014). Microteaching subdivides lessons into small units and allows the learners get to work on challenging concepts within brief classes. It seals learning gaps and increases student scores.

D. Rationale for Year-Specific Pedagogical Mapping

The students of engineering evolve by learning. Their minds, emotions and abilities develop with each year of learning. Lessons are planned by teachers on a year-by-year basis in order to accommodate these changes. This improves the teaching process and assists the students to learn. The first-year students are most effective with microteaching by teachers when they restate major ideas. Knowledge is developed by repetition of basics. It increases self-assurance, and students have power over their learning. Hand-on lessons involve the use of numerous senses in teaching old students. One of them is Synesthetic Learning Pedagogy (SLP). It relies on a number of senses to enhance memory, enhance creativity and connect subjects especially for students with lower cognitive skills.

Empirical evidence within the recent past makes this differentiated approach. One of the studies on SLP was done in a controlled experiment where students of engineering listened to particular sounds predominantly 40 Hz. Students in a quiet environment had a poorer recall and comprehension over time compared to those who attended classes with a background sound (B M Bharath et al., 2025). Multisensory integration assists neurocognitive research. The combination of sounds, sights and touch enhances working memory. This additionally enhances purposeful retention in various situations of learning (Esplendori GF et al, 2022).

Microteaching is an effective teaching approach. The microteaching model, which is teach, review and reflect re-teach, was introduced in the 1960s at Stanford University and has continued to be used extensively in teacher development due to its emphasis on precise feedback and circles of improvement. The meta-analytical sources, such as the Visible Learning project by John Hattie, place microteaching among the most efficient techniques to improve the performance of students. Microteaching has demonstrated effectiveness in enhancing self-learning and oral presentation, as well as self-regulatory skills of engineering students (Herrera et al, 2018), (Campos-Sánchez, 2013). Combining these pieces of advice, annual pedagogical mapping makes learning experiences aligned with the developmental level of students and academic requirements, i.e., offering personalization, supporting skill mastery, and encouraging cohort-wide advancement.

E. Objectives and Hypothesis of the Research.

The aim of the study is to compare the effect of Synesthetic Learning Pedagogy and Microteaching on attention, and concept retention among the engineering students of various years in a systematic manner. The hypothesis entails application of feedback-based methods in the initial years like Microteaching, and multisensory, creative methods like SLP to examine the difference between more significant changes in the attention span, memory and creative involvement among engineering students than the conventional undifferentiated method of teaching.

II. Methodology

The research involved a comparison of two instructional procedures Synesthetic Learning Pedagogy (SLP) and

Microteaching (MT). It evaluated whether these approaches enhance important skills among engineering students in college. Mixed combinatorial approaches were used to demonstrate the effectiveness of both methods. The team employed the qualitative interviews and written answers along with quantitative data for analysing the methods to provide a complete picture of the outcomes (Creswell and Plano Clark, 2017).

A. Study Design

The research was based on a quasi-experimental, multi-cohort design in order to compare two teaching methods. The SLP was assigned to some groups of students and MT to the other; only one method was employed by each group in the research. Each intervention was assigned by the students depending on the year and the curriculum. This was appropriate to the level of cognition of students (Sadikin et al., 2024).

The two interventions did not only test people on one FTT occasion but were assessed results at baseline. The group revisited immediately after the end of every instructional unit or session. A final check was carried out later to determine whether effects were persistent. The lessons were conducted to both groups at the same classes. The rooms were lit, seated and sounded the same. The slot timings were also measured during the sessions and used the same materials in order to eliminate environmental bias.

B. Participants and Year Level Grouping.

The respondents were undergraduate engineering students at Kalasalingam Academy of Research and Education, TN 626126, India, in which undergraduate students registered in the university on a full-time basis and were recruited for this study using the informed consent. It involved 130 students (70 first year students in the MT group and 60 students (II and III year levels) in the SLP group.

1. MT Group (n=70) - These cohorts were chosen because since these are first-year students, it is in the foundational years where practice-based and formative pedagogies do best (Remesh, 2013).

2. SLP Group (n=60) - It included students of all 2-3 years old, as advanced, creative, and integrative learning strategies are most effective with them (Lakshminarasimhan et al., 2021).

C. Pedagogical Implementation

1) Synesthetic Learning Pedagogy (SLP).

It involved 60 undergraduate engineering students in the SLP intervention with all of them passing through three experimental stages:

1. No Music (Baseline) – Students learned and were in classes with no auditory stimulus in the background.
2. Soft 20 Hz Music -Students listened to and studied in classes with the background of soft music at a frequency of 20 Hz.
3. Hard background Music 40 Hz Hard 40 Hz Music - students have listened and attended classes with background music at 40 Hz.

We did not allow carry-over effects, by separating phases by time. In order to reduce the bias in sequencing, we randomized the order of phase among the participants.

1. Class and Study Sessions: There was a 45-minute lesson in each of the phases. The classroom was used and materials were in line with the curriculum.
2. Tests were administered immediately after every session, and 3 days and 7 days later. The comprehension and retention checks were done using multiple-choice and problem-solving on them.
3. Data Collection: The scores were tabulated at every stage and after every assessment each time. The mean and SD were then determined for the deviations.
4. General environmental factors were verified like ambient noise and sitting arrangement. This maintained uniform conditions in all phases of SLP.

It is a multisensory learning protocol based on Lakshminarasimhan et al. (2021) and modified as per the needs of the present study. Research also associates auditory rhythm and sound frequency with thinking and memory (Jäncke, 2008; Perham and Currie, 2014).

2) Microteaching (MT)

The MT intervention was administered to 70 first-year engineering undergraduate students on WhatsApp, making it fast and easy to reach, with the help of polls and replies. The modified micro teaching cycle was as follows:

1. Topic Delivery Concise one topic lesson.
2. Immediate Assessment A test question that was administered immediately after topics were delivered using WhatsApp.
3. Progressive Learning - Cycle Repeated four or five times on the other topics with a new question each time.
4. Re-teaching & Reinforcement- When the performance of certain topics is weak, they were re-teached during the next day.
5. Final Recording- After every day, the records of queries given, correct/incorrect answers as well as attendance was recorded in the Excel work sheets.

This fast-feedback methodology is in line with microteaching practices (Remesh, 2013) and current studies on mobile-based formative assessment (Naveed et al., 2023).

D. Data Collection Analytics and Measures.

The both populations were evaluated with the help of validated instruments:

1. Assessment quizzes, Multiple-answer and short answer questions regarding declarative and applied knowledge.
2. Retention tests – Post test immediately after the session, and 3-day and 7-day later (Lakshminarasimhan et al., 2021) (B M Bharath et al., 2025).
3. Attendance records - To analyse the engagement and absenteeism.
4. Checklists of observation - In the case of MT, the response rate and involvement were monitored; and in the case of SLP, the creative involvement and multisensory interaction could be observed.
5. Student feedback- Utilize structured survey to obtain perceptions, satisfaction and self-reported engagement.

In the case of SLP and MT, the data will contain the assessment dates of the four months long course. It takes note of correct, wrong and absent responses. Only verified tools with regard to reliability were used. Data before analysis were anonymized. Any ambiguous questions in the quiz were corrected to ensure that the evaluations were in line with the learning outcomes.

E. Evaluation Parameters

The effectiveness was measured through:

1. Attention span -Time on task and immediate recall.
2. Memory retention -measured as changes in scores.
3. Accuracy- numbers of correct and incorrect responses recorded on the MT/SLP cycles.
4. Creative engagement Distribution Rated on SLP qualitative outputs.
5. Student feedback- Scanned to identify frequent themes.

Statistical tests involved ANOVA, post-hoc Tukey HSD and descriptive statistics. A examination of the qualitative feedback on themes were also performed based on student perception and group discussions.

III. Results

We put a comparison between SLP and MT amongst college engineering students. Both numerical findings with statistical tests and qualitative results are presented. A comparison of the approaches on attention, memory and learning has been demonstrated.

A. Descriptive Statistics of SLP

Three categories of music were tested (control, 40Hz and 20 Hz) at respective stages of the semester with same sets of students. The average scores of each group at various assessment times are as shown below (Table I):

TABLE I
ASSESSMENT RESULT

Condition	Same Day Assessment	3rd Day Assessment	7th Day Assessment
No Music (Control)	30.14	27	28.63
Soft 20 Hz Music	42.5	40.5	42.07
Hard 40 Hz Music	26.42	33.7	36.39

TABLE II
ANOVA RESULT SLP

F-Statistic	13.67
P-Value	0.0058

ANOVA discovered that there was a real group difference ($p < 0.05$) ruling out randomness and attributing the learning outcomes with listened categories of sounds. The F and P values implies that sounds had an influence on learning outcomes.

As observed in Fig. 1, a bar plot demonstrating the mean count of individuals that responded correctly to the answer given to the sound conditions. Data are presented in three instances: same day, day 3 and day 7.

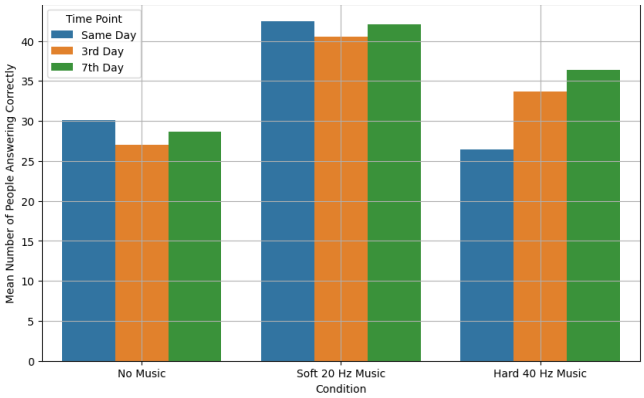

Fig. 1. Mean value of current answer during SLP

A display of the mean number of students who answered questions correctly under different music scenario is shown in Fig. 1. It makes a comparison of three auditory states; No Music, Soft 20 Hz Music and Hard 40 Hz Music. Students that listened to Soft 20 Hz Music on the same day were the most correct and demonstrated immediate learning. Soft 20 Hz Music remained strong in the succeeding days. Hard 40 Hz Music was enhanced, and this implies enhanced long-term retention. The lowest score was on students who had no music and this indicates that background sound aids learning. Low volume music may help to enhance concentration and interest. This is

similar to Savan (2009) and our result that Soft 20 Hz Music stimulates immediate learning.

1) ANOVA Results Bar Plot

Bar plot showing the ANOVA F-statistic for various auditory conditions is shown in Fig 2.

Fig. 2. ANOVA F-Statistic for different auditory conditions

The figure of the F-statistic of ANOVA test is presented and this test is used to test the differences in the learning results under varying auditory conditions. The F-statistic of 13.67 is high and indicates the strong effects of the auditory stimuli on the learning performance, which proves the effects of the various frequencies of music on student learning. Another study initiated by Thompson, Schellenberg and Husain (2001) indicated that some auditory stimuli could make a great influence on mood and cognitive arousal, which is associated with better learning performance, and this once again proves the efficacy of auditory stimuli in learning activities.

2) Summary of SLP Trends:

1. The comparison of the immediate learning and retention between Soft 20 Hz Music, No Music, and Hard 40 Hz Music shows that the former improves the learning and memory compared to the others. This study demonstrated that soft music is more effective in increasing attention span and short-term memory and the immediate outcome of learning Savan, A. (2009).
2. Hard 40 Hz Music demonstrates gradual improvement with time, which implies that it is beneficial to long-term retention. The study conducted by Llinas and Ribary (1993), and B M Bharath (2025) showed that rocky 40 Hz music might result in long-term cognitive functions and memory improvement that were significant and supported the improvement in days.
3. No Music is less efficient than conditions of 20Hz and 40 Hz hearing. It indicates that background sound can be used to enhance learning.

These tendencies make us observe the influence of various sounds on learning. They can also provide the concepts on how to apply sound to enhance learning and memory.

B. Microteaching (MT) – Descriptive Statistics and ANOVA

The dataset of microteaching (MT) consists of multiple evaluation dates in four months. It follows up on four questions (Q1 -Q4), where Correct, Wrong, and Absent are observed.

1) Overall Performance

The average number of correct answers (39.52 SD = 7.71), incorrect responses (4.34 SD = 4.85), and absences (26.14 SD = 8.62) of the students on all dates and questions (Table III) were 39.52, 4.34, and 26.14, respectively. The maximum score was 53 and the minimum was 26. There were 0 -21 wrong answers, 8-38 absences. This exhibits moderate performance and attendance variation.

TABLE III
OVERALL DESCRIPTIVE STATISTICS FOR MT PERFORMANCE

Measure	Correct	Wrong	Absent
Mean	39.52	4.34	26.14
Std. Dev	7.71	4.85	8.62
Min	26.00	0.00	8.00
Max	53.00	21.00	38.00

2) Performance by Question

As indicated in Table IV there was a variation in the performance of students during the Microteaching (MT) sessions across the months with the obvious improvements at the end of the semester. Students recorded the least mean of correct score (37.00 ± 6.40) and highest mean of wrong score (7.60 ± 8.42) and the highest rate of absenteeism (30.80 ± 7.04) in March 2025 attributed to cultural events across the campus and at other colleges. Whereas in April 2025 performance started to improve with the mean correct responses increasing to 41.00 (6.38) and mean wrong responses decreasing to 3.77 (3.95). The mean correct score was 42.25 (± 1.00) by May and mean wrong score had reduced drastically to 1.75 (1.26). The level of absenteeism reduced a little to 30.80 in March to 26.25 in May 2025.

In general, Table IV demonstrates the gradual increase in performance of the students and their participation. The reduction of the erroneous answers and the minimal decrease in absenteeism, coupled with the increase in the number of the correct ones, indicate that the students were more involved into the MT activities. This tendency points to higher learning retention and more accuracy when the study went on.

TABLE IV
DESCRIPTIVE STATISTICS BY MONTH

Month	Correct (M±SD)	Min–Max	Wrong (M±SD)	Min–Max	Absent (M±SD)	Min–Max
February	50.00 ± 0.00	50–50	4.00 ± 0.00	4–4	16.00 ± 0.00	16–16
March	37.00 ± 6.40	30–45	7.60 ± 8.42	0–21	30.80 ± 7.04	19–38
April	41.00 ± 6.38	27–53	3.77 ± 3.95	0–12	27.15 ± 6.40	8–37

May	42.25 ± 1.00	40–44	1.75 ± 1.26	0–3	26.25 ± 0.50	26–27

3) *ANOVA Results of MT*

A one-way ANOVA was conducted to test the differences in mean correct responses in four months of the Academic year 2025-26 i.e., February, March, April and May. The outcomes indicated that there was a strong influence of month on performance of students (Table V). This implies that the amount of correct responses did not remain constant during the semester but varied with time (Fig. 3). Subsequent analysis showed that performance was very poor in March, and it has been gradually increasing in April and May.

TABLE V
ANOVA RESULT MT

F-Statistic	4.79
P-Value	0.007

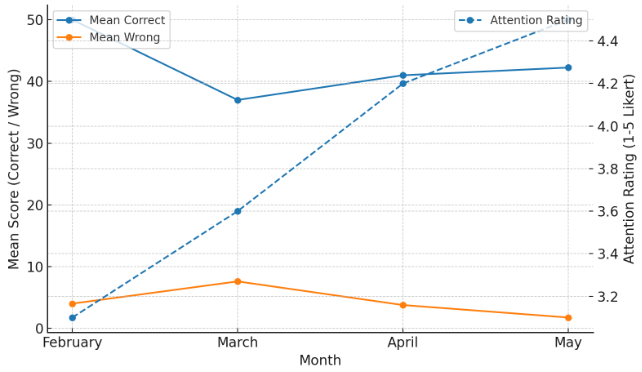

Fig. 3. Correct Responses Over Time

From the Fig. 3, changes in mean correct and mean wrong responses are shown with respect to study months (X – axis). The student attention rating is also displayed in the right Y-axis. February has a high performance and medium attention. While in Marc, there is a marked decrease in Correct responses and an increase in Wrong responses. After April, there is an increase in Correct responses and a decrease in Wrong responses. The Rating of attention as based on Likert scales rises consistently between 3.1 in February to 4.5 in May (Fig. 4). This trend indicates that the increased attention level would result in an increase in the student performance in the long run.

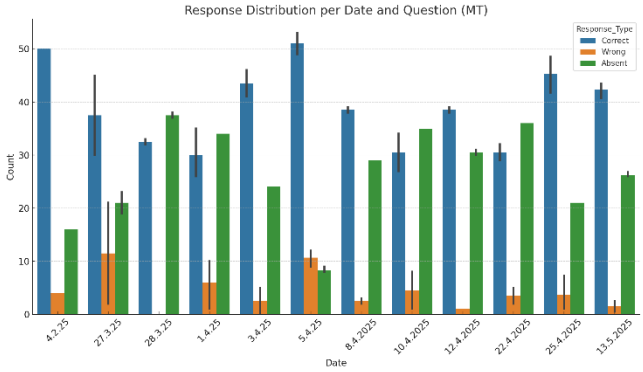

Fig. 4. Distribution of Correct, Wrong, and Absent Responses

The breakdown of date and student responses against question is depicted in Fig 4. Correct responses are the most prevalent. With the next are Absences and the last group is Wrong responses. In certain dates such as 28.3.25 of Q1 and Q2 absences are high, whereas wrong counts are low. This implies less involvement and not misinterpretation. Conversely, wrong responses are more on 27.3.25, in case of Q2. This is an indication of the difficulty of the content or the unpreparedness.

4) *Summary Trend – Microteaching (MT)*

On the whole, there was no change in the performance in terms of question and day. The performance had slight variations as time went by. Nevertheless, statistical analysis (ANOVA) showed that there were no significant differences in questions. This shows that the knowledge of the content was very homogenous. There was a fluctuation in attendance with some of the dates recording very high levels of absence; this did not influence much the overall trend of achievement. The results indicate that there are consistent retention of knowledge and uniformity in the response on every item. There were times of performance increase and decreases based on attendance.

IV. DISCUSSION

An attempt is made herein to compare the Synesthetic Learning Pedagogy (SLP) and Microteaching (MT). It relates such results to the recent developments in engineering education and cognitive neuroscience.

A. *Comparative Analysis of Both Approaches*

1) *Cognitive and Neural Mechanisms*

The Synesthetic Learning Pedagogy (SLP) intervention significantly enhanced the attention and memory of the engineering students. It employed certain auditory stimuli. It conforms to the current study by Lucchesi et al. (2025), which reveals that the process of multisensory integration assists the brain to merge data of various senses, which enhances perception due to neuroplasticity. The efficacy of auditory stimulation at 40 Hz is the same as the results by Paltoglou, A. E., Sumner, C. J., and Hall, D. A. (2009). Their article mentions

frequency-specific neural improvement. Empirical studies by Lee, M., and Lee, J. H. (2024) demonstrate that frequency-composition algorithms may be quite effective in enhancing the cognitive processing in the process of learning.

The 20 Hz situation was cognitively beneficial in the short term. This can be supported by the recent research presented by Lucchesi and Maya-Vetencourt (2025) that demonstrates rapid neural reorganization with the help of auditory-visual stimulation. Prolonged gains of 40 Hz stimulation are comparable with the results of Motlagh Zadeh et al. (2019), who demonstrated that prolonged high-frequency hearing improves cognitive functions by improving neural synchronization.

These are corroborating to the objective of the study to investigate the impact of multisensory stimulation on cognitive outcomes.

2) Microteaching: Iterative Mastery Development

Microteaching resulted in gradual learning gains by repeated teach back assess feedback. The approach increased learners confidence and understanding on different engineering subjects. Recent research articles present that formative assessment in higher education has enormous effects on student learning with continuous feedback (Parmigiani et al., 2024). Meta-analyses by Foster (2024) support the claim; formative assessment plans, such as microteaching, enhance the student performances and promote self-regulated learning in various educational institutions.

The availability of its consistent advantages in the content areas demonstrates the comprehensive pedagogical scope of microteaching. This is in line with the results of Yadav, J et al. (2025) on active learning in engineering education, according to which, the cycles of feedback are structured to improve the cognitive and metacognitive abilities. The study of Dominguez et al. (2025) on faculty development is another study that confirms that microteaching promotes expertise due to deliberate practice and reflection.

This fact supports the objective of the study to determine the role of microteaching in apprehending basic engineering subjects.

3) Complementary Learning Mechanisms

SLP employs multisensory activation in a high speed. The multisensory integration model by Lucchesi et al. (2025) demonstrates the fact that concurrent application of multiple sensory pathways enhances neural activity and leads to better information processing. Recent neuroimaging reports by Raduner et al. (2025) observe that multisensory learning elicits wider cortical networks, which comprise areas of association, prefrontal areas, and sensory specific cortices. A study by Paraskevopoulos et al. (2024) notes that automatic top-down transfer of training is advantageous when it comes to multisensory training. This promotes the creative interaction and attention acquisition that occurs in our SLP intervention immediately.

MT is centered on the iteration of skills in reflection. Microteaching strategy is based on a conscious practice and feedback. This helps build expertise as demonstrated by Parmigiani et al. (2024) and Yadav et al. (2025). Using the structured feedback cycles in education, Foster (2024) discovered that cognitive and metacognitive skills increase and students gain a higher level of self-regulation and learning techniques.

4) Temporal Learning Dynamics

SLP facilitates rapid mental interaction by the so-called fast multisensory processing pathways that Lucchesi et al. (2025) discuss. A study by Motlagh Zadeh et al. (2019) and Raduner et al. (2025) demonstrates that the neural activity may be synchronized through multisensory stimulation and the attentional drive can be enhanced within a few minutes. This is the reason why our immediate effects were strong in the 20 Hz condition and the long-term benefits recorded in recent frequency specific studies.

Conversely, the skill acquisition of MT occurs slowly with the help of spaced practice and strengthening of registration as supported by Parmigiani et al (2024) and Foster (2024). A study by Skedsmo and Huber (2024) on educational psychology reveals that instant feedback spaced practice leads to more permanent learning in comparison to massed practice. This is the reason why there is an upward trend of improvement in MT as was witnessed in our research.

The contrasting influences of SLP and MT point out the objective of the study to compare the two methods regarding their aid to learning in different stages.

5) Integration Potential

The way these methods are complementary is very promising in terms of teaching methods. This has been emphasized in the active learning case study of Yadav, J. et al. (2025) in engineering education. The use of new teaching tools is investigated by Mashwama, N. X., and Madubela, B. (2025), and the research of Dominguez et al. (2025) on faculty training proves that multisensory engagement and regular feedback are more effective than the one-method approaches. However, as the recent research conducted by Hsu, Y. et al. (2025) showed in favor of the engineering students for both immediate cognitive activation (with the help of SLP) and the systematic development of skills (with the help of MT) with effective implementation of these approaches during the course of their studies.

B. Implications for Engineering Curriculum Design

The findings are in favor of year-specific instruction. The main emphasis of the foundational-year modules is to address repetitive cycles of MT which are feedback-driven. These techniques increase the retention, as they involve retrieval practice and formative assessment. This is consistent with the principles of the curriculum design that support the use of structured, scaffolded instruction in novices. In upper-level educations, the multisensory approach of SLP can be implemented in designing and capstone courses. It fosters innovation, generalization, and problem-solving (Xing et al., 2016). The curriculum can utilize the neuroscience discoveries in frequency-specific learning benefits by applying auditory stimuli associated with cognitive objectives 20 Hz in short-term attention. It also fulfills the needs of student-centred learning which caters to various preferences and advantages (Thaut et al., 2014).

Virtual Reality (VR) and Augmented Reality (AR) are some of the ways that can be used to improve SLP. They give equivalent multisensory clues and actual life situations (Carvalho, 2019). This combination aids students to advance beyond the basic skill acquisition and learning to the level of an expert with the skill-building offered by MT (Gaser and Schlaug, 2003).

Overall, these results are in line with the objectives of the study as they demonstrate when, how and to which students' groups appropriate teaching method are to be the most effective.

CONCLUSION AND RECOMMENDATIONS

As demonstrated in this paper, Synesthetic Learning Pedagogy (SLP) and Microteaching (MT) can have very useful advantages to engineering learning. SLP includes certain multisensory stimuli in order to enhance attention and memory. It uses 20 Hz to gain instant attention and 40 Hz to gain long term memory. The approach can improve the use of neural mechanisms to achieve creativity and engagement. It operates by entraining gamma-oscillations and multisensory integration. MT consists of teaching, evaluating and feedback procedures. These cycles accumulate the necessary knowledge, promote self-confidence, promote thought, and raise the level of attention. The approach is useful in making students understand different subjects in engineering, irrespective of the subject.

By matching these strategies with developmental stages of the students, curricula facilitate fast thinking and long-term acquisition of skills.

C. Recommendations

1. Year-Level Pedagogical Mapping- In first and second semester classes, concentrate on the development of core skills with a focus on MT. Then, implement SLP in upper-level and capstone courses to become more creative and problem-solving.
2. Faculty Education- Train the faculty on the use of MT techniques and multisensory instructional design. This assists the educators in adding and combining these strategies with ease.
3. Technology Integration to have VR/AR and adaptive learning. These products provide dynamic multi sensory experiences and real-time feedback. They successfully increase SLP and MT targets.
4. Continuous Formative Assessment-Carry out low stakes frequent tests in each course. Provide instant feedback and modify content according to the SLP engagement metrics and the data of the MT performance.
5. Continuous Assessment and Investigation- Start up long-term research and pilot projects in blended-pedagogy. These will track retention, creativity and graduate outcomes.

These suggestions are meant to establish a learner-based engineering education. This strategy will create profound knowledge and creativity and dynamic abilities to meet the needs of our contemporary technology based learning.

LIMITATIONS OF THE STUDY

Although the study highlights strategic interventions in engineering students learning, a few important limitations which needs to be considered according to the recent educational research standards:

1. The experiment was conducted in a single school under one field of engineering. This restricts the generalizability of the results to other situations and students.
2. The 2-3 months intervention time might fail to cause permanent retention, learning transfer, or learning behavior changes after the test period.
3. A discrepancy in the execution and internal validity could have arisen because of the differences in lesson delivery and classroom circumstances, as well as the absence of independent monitoring.
4. Short-term assessments and quizzes were primarily in terms of recall and retention. They did not take into consideration deeper competencies such as creative design, cooperation, or problem-solving. These skills require improved performance-based tools.

FUTURE WORK

The future research may concentrate on some basic aspects that have been put forward by the recent findings:

1. Multi-institutional, long-term research within entire academic programmes. This will assist in determining the long term impacts of SLP and MT on knowledge retention, graduation rates and performance at the workplace.

2. Experiment and develop hybrid versions of the curricula incorporating SLP and MT courses. Assess the optimum sequencing, dosage and interaction effects on the cognitive, creative, and professional abilities.
3. Take advantage of immersive technologies (VR/AR) and AI-based learning analytics. These devices have the potential to offer individual multisensory experiences. Determine how effective they are in enhancing engagement and establishing adaptive learning pathways.
4. Enhance STEM areas, culture, and learners, such as neurodiverse students. This will assist in studying the background, cognitive style and motivation influence on teaching responsiveness.
5. Use both descriptive techniques of in-depth interviews, focus groups and ethnographic observations. This will indicate the way SLP sensory engagement and MT feedback loops operate, informing the development of the improvement of instruction design and fidelity.

REFERENCES

Mashwama, N. X., & Madubela, B. (2025). Innovations in pedagogy and technology for engineering education: A systematic review. Interdisciplinary Journal of Education Research, 7(s1), a10. https://doi.org/10.38140/ijer-2025.vol7.s1.10

S. R. Brunhaver, R. F. Korte, S. Barley, and S. D. Sheppard (2017), "Bridging the Gaps between Engineering Education and Practice," in US Engineering in the Global Economy, NBER: University of Chicago Press, ch. 4. [Online]. Available: https://doi.org/10.7208/chicago/9780226468471.003.0005

Nirmalakhandan, N., Ricketts, C., McShannon, J., & Barrett, S. (2007). Teaching tools to promote active learning: Case study of a First-year engineering course. *Journal of Professional Issues in Engineering Education and Practice*, 133(1), 31-37.

Sadikin, A., Rusdi, M., Hasibuan, M. H. E., & Siburian, J. (2024). Theoretical construction of the microteaching model-based PjBL and blended learning for prospective biology teachers. BIO-INOVED Jurnal Biologi-Inovasi Pendidikan, 6(2), 244. https://doi.org/10.20527/bino.v6i2.19337

Remesh A. (2013). Microteaching, an efficient technique for learning effective teaching. Journal of research in medical sciences : the official journal of Isfahan University of Medical Sciences, 18(2), 158–163.

Lakshmi Narasimhan, V., Vasistha Bhargavi, G., Lakshmi, C., Lee, L. (2021). Synesthetic LearningPedagogy (SLP)—An Exploratory Investigation. In: Agrawal, S., Kumar Gupta, K., H. Chan, J., Agrawal, J., Gupta, M. (eds) Machine Intelligence and Smart Systems . Algorithms for Intelligent Systems. Springer, Singapore. https://doi.org/10.1007/978-981-33-4893-6_1

Bharath, B. M., Sharma, N. K., & Narasimhan, V. L. (2025). An Evaluation of Synesthetic Learning Pedagogy for Engineering Education. Journal of Engineering Education Transformations, 38(2), 495–504. https://doi.org/10.16920/jeet/2025/v38is2/25061

Nasution, T., Meliani, F., Purba, R., Saputra, N., & Herman, H. (2023). Participation performance of students' basic teaching skills in microteaching. AL-ISHLAH Jurnal Pendidikan, 15(2), 2441–2448. https://doi.org/10.35445/alishlah.v14i4.2307

Popat, Y. (2020). MICROTEACHING: AN EFFECTIVE TOOL TO ENHANCE THE TEACHING SKILLS. International Journal of Engineering Applied Sciences and Technology, 5(8). https://doi.org/10.33564/ijeast.2020.v05i08.030

Ralph, E. G. & College of Education, University of Saskatchewan. (2014). The Effectiveness of Microteaching: Five years' findings. International Journal of Humanities Social Sciences and Education (IJHSSE), 1(7), 17–28. https://www.arcjournals.org/pdfs/ijhsse/v1-i7/3.pdf

Esplendori, G. F., Kobayashi, R. M., & De Araújo Püschel, V. A. (2022). Multisensory integration approach, cognitive domains, meaningful learning: reflections for undergraduate nursing education. Revista Da Escola De Enfermagem Da USP, 56. https://doi.org/10.1590/1980-220x-reeusp-2021-0381

Herrera, Rodrigo F. & Vielma, Juan & Muñoz La Rivera, Felipe. (2018). Impact of Microteaching on Engineering Students' Communication Skills*. International Journal of Engineering Education. 34. 1768-1775.

Campos-Sánchez, A., Del Carmen Sánchez-Quevedo, M., Crespo-Ferrer, P. V., García-López, J. M., & Alaminos, M. (2013). Microteaching as a self-learning tool. Students' perceptions in the preparation and exposition of a microlesson in a tissue engineering course. Journal of Technology and Science Education, 3(2). https://doi.org/10.3926/jotse.71

Creswell, J. W., Plano Clark, V. L. (2017). Designing and Conducting Mixed Methods Research. United States: SAGE Publications.

Jäncke, L. (2008). Music, memory and emotion. Journal of Biology, 7(6), 21. https://doi.org/10.1186/jbiol82

Perham, N., & Currie, H. (2014). Does listening to preferred music improve reading comprehension performance? Applied Cognitive Psychology, 28(2), 279–284. https://doi.org/10.1002/acp.2994

Naveed, Q. N., Choudhary, H., Ahmad, N., Alqahtani, J., & Qahmash, A. I. (2023). Mobile Learning in Higher Education: A Systematic Literature Review. Sustainability, 15(18), 13566. https://doi.org/10.3390/su151813566

Savan, A. (2009). The Effect of Background Music on Learning. In: de Souza, M., Francis, L.J., O'Higgins-Norman, J., Scott, D. (eds) International Handbook of Education for Spirituality, Care and Wellbeing. International Handbooks of Religion and Education, vol 3. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9018-9_56

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. Psychological

Science, 12(3), 248–251. https://doi.org/10.1111/1467-9280.00345

Llinás, R., & Ribary, U. (1993). Coherent 40-Hz oscillation characterizes dream state in humans. Proceedings of the National Academy of Sciences, 90(5), 2078–2081. https://doi.org/10.1073/pnas.90.5.2078

Lucchesi, M., Maya-Vetencourt, J. F., & Rusciano, D. (2025). Multisensory integration, brain plasticity and optogenetics in visual rehabilitation. Frontiers in neurology, 16, 1590305. https://doi.org/10.3389/fneur.2025.1590305

Paltoglou, A. E., Sumner, C. J., & Hall, D. A. (2009). Examining the role of frequency specificity in the enhancement and suppression of human cortical activity by auditory selective attention. Hearing research, 257(1-2), 106–118. https://doi.org/10.1016/j.heares.2009.08.007

Lee, M., & Lee, J. H. (2024). Effects of Frequency-Composition Algorithm and Phoneme-Based Auditory Training in Older Hearing Aid Users. Journal of audiology & otology, 28(4), 300–308. https://doi.org/10.7874/jao.2024.00122

Motlagh Zadeh, L., Silbert, N. H., Sternasty, K., Swanepoel, W., Hunter, L. L., & Moore, D. R. (2019). Extended high-frequency hearing enhances speech perception in noise. Proceedings of the National Academy of Sciences of the United States of America, 116(47), 23753–23759. https://doi.org/10.1073/pnas.1903315116

Parmigiani, D., et al. (2024) - Formative assessment in higher education: exploratory study within programs for education professionals, Frontiers in Education

Foster, H. (2024) - The impact of formative assessment on student learning outcomes: A meta-analytical review, Academy of Educational Leadership Journal

Yadav, J. ., Desai, S. ., Patil, S. ., Jagtap, P. ., & Mulla, S. . (2025). Implementing NEP 2020: Active Learning and Student Engagement in Engineering Education. Journal of Neonatal Surgery, 14(18S), 1018–1024. Retrieved from https://www.jneonatalsurg.com/index.php/jns/article/view/5516

Dominguez, A., Truyol, M. E., Quezada-Espinoza, M., Calderon, J. F., & Zavala, G. (2025). Active learning in engineering education: Insights from a faculty development program in higher education. Eurasia Journal of Mathematics Science and Technology Education, 21(2), em2585. https://doi.org/10.29333/ejmste/15955

Raduner, N., Providoli, C., Di Pietro, S., Schneebeli, M., Karipidis, I. I., Casimiro, E., Bedi, S., Von Rhein, M., Raschle, N. M., Ruff, C. C., & Brem, S. (2025). Growing Minds, Integrating Senses: Neural and Computational Insights into Age-related Changes in Audio-Visual and Tactile-Visual Learning in Children. bioRxiv (Cold Spring Harbor Laboratory). https://doi.org/10.1101/2025.03.04.639748

Paraskevopoulos, E., Anagnostopoulou, A., Chalas, N., Karagianni, M., & Bamidis, P. (2024). Unravelling the multisensory learning advantage: Different patterns of within and across frequency-specific interactions drive uni- and multisensory neuroplasticity. NeuroImage, 291, 120582. https://doi.org/10.1016/j.neuroimage.2024.120582

Skedsmo, G., & Huber, S. G. (2024). Enhancing feedback practices and formative assessment in education: insights and challenges from diverse contexts. Educational Assessment Evaluation and Accountability, 36(2), 141–144. https://doi.org/10.1007/s11092-024-09436-7

Hsu, Y., Chiang, D. F., & Kehinde, I. (2025). Transforming engineering education in the digital era: findings from a systematic review. Frontiers in Education, 10. https://doi.org/10.3389/feduc.2025.1568917

Xing, Y., Xia, Y., Kendrick, K. et al. Mozart (2016), Mozart Rhythm and Retrograde Mozart Effects: Evidences from Behaviours and Neurobiology Bases. Sci Rep 6, 18744. https://doi.org/10.1038/srep18744

Thaut MH, McIntosh GC, Hoemberg V (2015). Neurobiological foundations of neurologic music therapy: rhythmic entrainment and the motor system. Front Psychol. doi: 10.3389/fpsyg.2014.01185. PMID: 25774137; PMCID: PMC4344110.

Gaser, C., & Schlaug, G. (2003). Brain Structures Differ between Musicians and Non-Musicians. Journal of Neuroscience, 23(27), 9240–9245. https://doi.org/10.1523/jneurosci.23-27-09240.2003.