

Non-conventional Teaching Methodologies for Emerging Technologies and Innovative Thinking

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Abstract

This research paper discusses the implementation of newer and non-conventional methodologies that are implemented by the author for tutoring emerging technologies such as Smart Materials, Composites and Smart Composites for beginner-level engineering students from different educational backgrounds, and learning technical and newer subjects seems to be a challenging task for them. The research involves implementing a “Do-and-Learn-in the Class” method that involves the students making and developing new and simpler materials that resemble the real ones, thus helping them understand the concept behind the materials and processes. Smart and composite materials can be taught using these techniques to facilitate better understanding among students.

Keywords: *Smart Materials, Composite Materials, Smart Composite.*

1. Introduction

The modern, fast-evolving technological landscape has witnessed rapid advancements in the research, testing, and development of materials that are lighter, stronger, and more efficient in performance. These advancements have created an increasing demand for engineers who are not only familiar with conventional materials but also capable of understanding and applying emerging technologies in material science. In this context, continuous learning and effective pedagogical approaches are essential to enable students to grasp complex and interdisciplinary concepts at an early stage of their education (Callister & Rethwisch, 2020; Gibson, 2016).

One such emerging area is smart composites, which integrates the principles of smart materials and composite materials. Smart materials represent a rapidly evolving branch of modern engineering characterized by their ability to respond to external stimuli, while composite materials form a foundational area within mechanical and aerospace engineering, focusing on the design and development of high-performance structural components (Gandhi & Thompson, 1992; Hull & Clyne, 2019). Understanding smart composites therefore requires learners to synthesize knowledge from both domains, making it inherently complex for beginners.

However, first-year engineering students, particularly those from diverse educational and non-core backgrounds, often lack prior exposure to these concepts. As a result, they face significant difficulty in

comprehending such interdisciplinary subjects when taught using conventional lecture-based methods, which tend to emphasize passive learning and theoretical delivery (Prince, 2004; Freeman et al., 2014). This gap highlights the need for more engaging and student-centered instructional strategies that can bridge the divide between theory and application.

Therefore, this study explores the implementation of a non-conventional, activity-based teaching methodology, referred to as “Do-and-Learn in the Class,” aimed at enhancing conceptual understanding through hands-on experience. Such approaches are aligned with active and experiential learning paradigms, which have been shown to improve student engagement, retention, and overall academic performance (Kolb, 1984; Felder & Brent, 2016). By enabling students to directly interact with materials and construct simplified models, the proposed method seeks to foster deeper learning and promote innovative thinking among beginner-level engineering students.

2. Problem Encountered

As discussed above in the introductory section the subject Smart Composites as an emerging field that deals with two major parts in it, one being the composite materials technology that involves the development of newer and non-conventional materials made by the combination of two or more materials which can be lighter, stronger and better; and the other being smart materials that deals with new and emerging materials that are developed with specifically engineered properties. To understand the subject, students need to have the basic know-how of engineering materials, alloys, metals, non-metals, and composite materials, which was not possible in this case as the students were beginners in the field of Robotics and Artificial Intelligence and came from diverse educational backgrounds.

The challenge was to teach the students a completely new subject from a perspective that they would be able to understand and comprehend the finer aspects of technological advancements in developments over a period of time. The second aspect of the challenge was to make the students remember the key concepts and represent the same in the examination, which could not be possible unless they understood the subject matter and the underlying principles of operation and working.

3. Need of a different method for tutoring the subject

The students were not able to grasp the subject and concept of smart composites and their uses and applications; therefore, there was a need to devise and implement a new method to help the students understand the concepts. Based on the educational background of the students and their method of learning, it was planned and decided to implement a method called “Do-and-learn in the Class.” In this method, students will be given simple components in the class itself, and they will be asked to prepare simple components that resemble the actual materials and can be used for basic household applications where the loads acting on them will be minimal.

This method is based on the kinesthetic method of learning, which is considered one of the best methods for imparting quality knowledge. The knowledge gained by this method is assured to stay longer and is deep-rooted. There are three types of learning styles:

- a. Auditory Learning Style: Auditory types of learners are those who can learn and understand well by listening to lectures, podcasts, or pre-recorded audios.
- b. Visual Learning Style: Visual learners learn and understand by seeing videos and actual things/objects.
- c. Kinesthetic Learning Style: Kinesthetic learners are those who learn and understand by actually doing things and performing tasks.

Usually, the kinesthetic method of learning is considered to be the method with the highest learning rate, where the student gets involved and uses his motor skills, thus helping him grasp the subject and concept in depth.

3.1. Theoretical Framework

The proposed “Do-and-Learn in the Class” methodology is grounded in established learning theories, particularly active learning, experiential learning, and kinesthetic learning. Active learning approaches have been shown to significantly improve student performance and engagement (Prince, 2004; Freeman et al., 2014). The present methodology aligns with this paradigm by involving students directly in the learning process rather than passive listening. The framework also draws upon Kolb’s Experiential Learning Theory (1984), which emphasizes learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation. The hands-on material fabrication activity corresponds to the “concrete experience” stage, while subsequent discussions enable reflection and conceptual understanding. Additionally, the approach is consistent with kinesthetic learning principles, where physical engagement enhances retention and comprehension. By integrating material construction with conceptual explanation, the methodology bridges theory and practice effectively.

4. Methodology

This study adopts a quasi-experimental pre-test–post-test design within an action research framework to evaluate the effectiveness of the “Do-and-Learn in the Class” methodology. The intervention was implemented during regular classroom sessions, where the instructor facilitated structured hands-on activities aimed at improving conceptual understanding of smart composites.

A non-traditional teaching approach called "Do-and-Learn in the Class" was used in this study's classroom intervention-based quasi-experimental research design, and its effects on students' learning were noted. Since the teacher actively delivered the intervention and assessed its efficacy in the classroom setting, the study used an action research methodology. Student comprehension was evaluated both before and after the methodology was put into practice as part of the design's pre-intervention and post-intervention comparison.

First-year undergraduate students enrolled in robotics and artificial intelligence studies made up the sample. The following criteria were used to choose the participants: enrollment in the course that presented smart composites and materials, exposure to engineering ideas at the beginner level and a variety of educational backgrounds, including students from non-core and vernacular engineering programs. Ten students, representing a cross-section of the class with strength of 25, were chosen at random for a thorough investigation of their knowledge acquisition. The total class consisted of $N = 25$ students. From this cohort, 10 students were randomly selected to provide a representative analytical subset capturing diverse academic backgrounds. This subset was used for detailed statistical analysis, while overall classroom observations supported qualitative findings.

The methodology involved performing an initial level of search on materials and developing a similar type of component that resembles the actual product and learning about its concepts in the classroom itself. Here, the concept that was required to be taught was “Smart Composites” for which the students first needed to know what composite materials and smart materials are. Therefore, the learning method implemented in the class was to develop a simple type of composite material that resembles the actual product and study it.

The next step was to convert that composite material into a smart composite that resembles the actual real-time product at least in certain aspects (20 to 30 percent). Some components that were developed in the class as a part of implementation of the “Do-and-learn in the Class” concept are shown in Figure 1.



Fig 1. Composite Material developed using American Beech Wood and Epoxy Resin.

As shown in Figure 1, a composite material was developed using American Beech wood and epoxy resin, enabling students to understand the interaction between the reinforcing material and the binding matrix. However, Figure 2 shows cotton fiber soaked in epoxy resin. It can be used as a reinforcement fiber layer between glass panels to strengthen and prevent the breaking and splitting of glass into fine pieces during impact.



Fig 2. Cotton fiber soaked in Epoxy Resin with a considerable increase in strength.

Figure 3 presents a fiber-glass epoxy composite panel developed collaboratively by the author and students, serving as a hands-on demonstration of composite fabrication and reinforcing the experiential learning approach adopted in this study.



Fig 3. Fiber-Glass Epoxy Composite Panel developed by the author and students as a part of the “Teaching and Learning Process”.

Similar types of thicker composite panels are used to make the front panels of vehicles, such as TVS Scooty and fender panel/front panel of Tata Marco Polo Buses. Figures 4(a) and 4(b) illustrate the development of a component analogous to a smart composite, created by integrating a piezoelectric sensor with a glass-fiber composite panel; Figure 3(b) shows the backside view of the assembled structure.

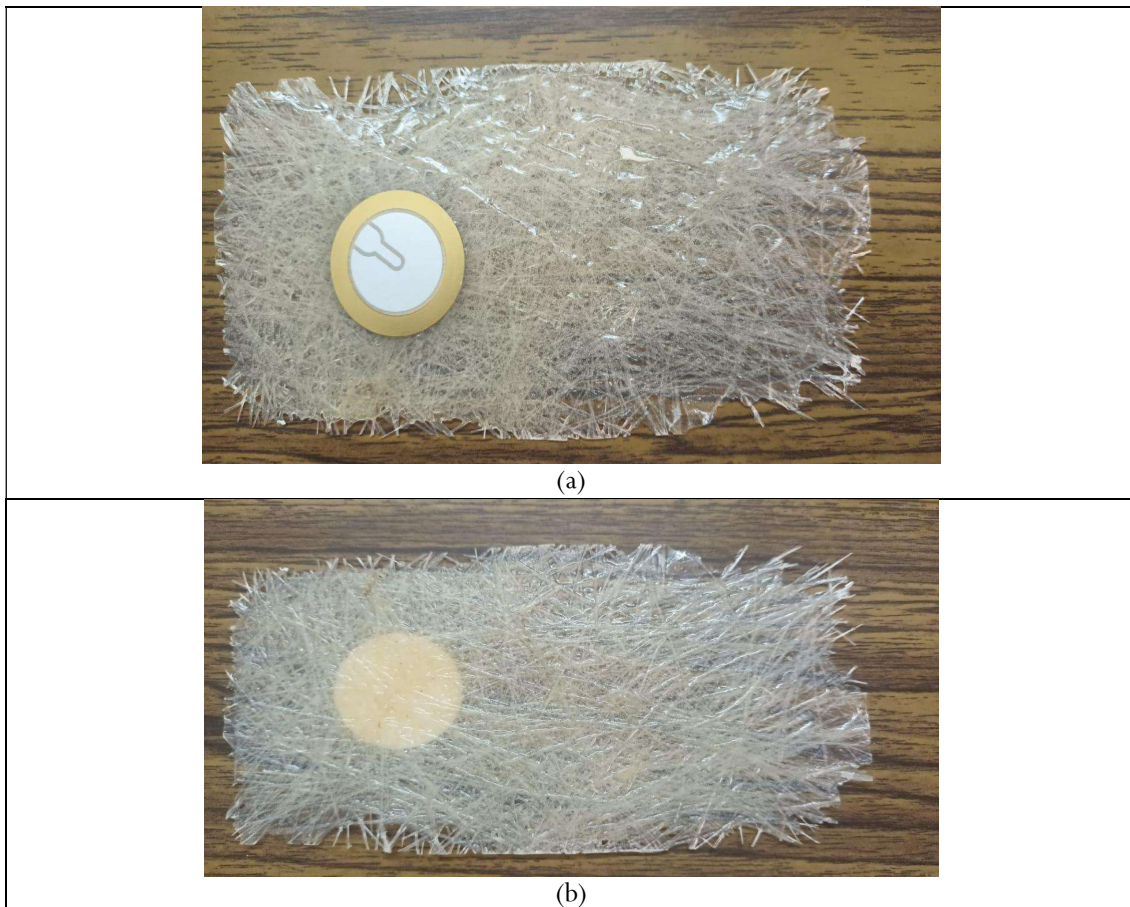


Fig 4. (a) A component similar to a “Smart Composite” is developed using the glass-fiber composite panel with the addition of a Smart Material called “Piezo-electric sensor” (b) Backside view of the “Smart Composite” shown above.

Components developed for the purpose of teaching new emerging and enforcing design and innovative thinking: Figures 5, 6(a), and 6(b) illustrate a drone frame developed using American Beech wood and epoxy resin as an economical lightweight composite material, along with close-up views highlighting the composite sections.

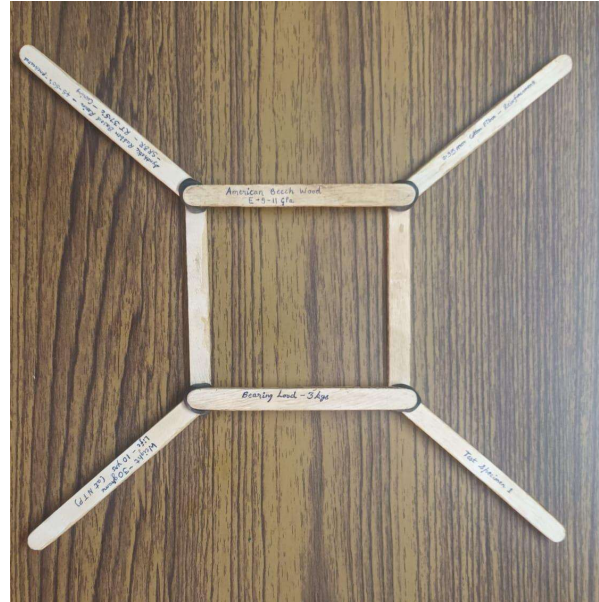


Fig 5. Drone Frame developed using American Beech Wood and Epoxy Resin – an economical lightweight composite material.

Figure 7 demonstrates the application of glass–epoxy-soaked cotton fiber and polypropylene composites in panel glass, highlighting their ability to improve impact resistance and prevent the glass from shattering into sharp fragments. As shown in Figure 8, wood–epoxy sample specimens were prepared to demonstrate the basic properties and behavior of composite materials.

The methodology applied to implement the learning process is as follows:

- Study and Selection of materials
- Selection of resins
- Method of deploying the resin on the fibers
- Lay-up technique study
- Curing time and temperature study
- Application of a measurement device

4.1 Method of Assessment

Students were requested to write important terms, definitions, and applications pertaining to smart composites in order to assess their learning utilizing a structured descriptive evaluation method.

The following criteria were used to analyze the responses: the quantity of accurate conceptual points, explanation clarity, and relevance to the subject. A predetermined score was given to each legitimate piece of information, which served as the foundation for calculating knowledge gain. The intervention was conducted over a 30-minute structured session, followed by guided discussion. The procedure involved:

1. Introduction to composite and smart materials (5 minutes)
2. Hands-on fabrication of a simple composite material (15 minutes)
3. Demonstration of smart composite integration (5 minutes)
4. Reflection and concept linking discussion (5 minutes)

A 20-item multiple-choice questionnaire (MCQ) was used as the assessment instrument. Each correct response was awarded one mark, and total scores were converted into percentages (0–100%). This standardized scoring approach ensures consistency and aligns with common educational assessment practices. To measure learning improvement more rigorously, normalized gain (g) was computed using (Equation 1):

$$g = \frac{\text{post-pre}}{100-\text{pre}} \quad (1)$$

This metric is widely used in educational research to evaluate instructional effectiveness.

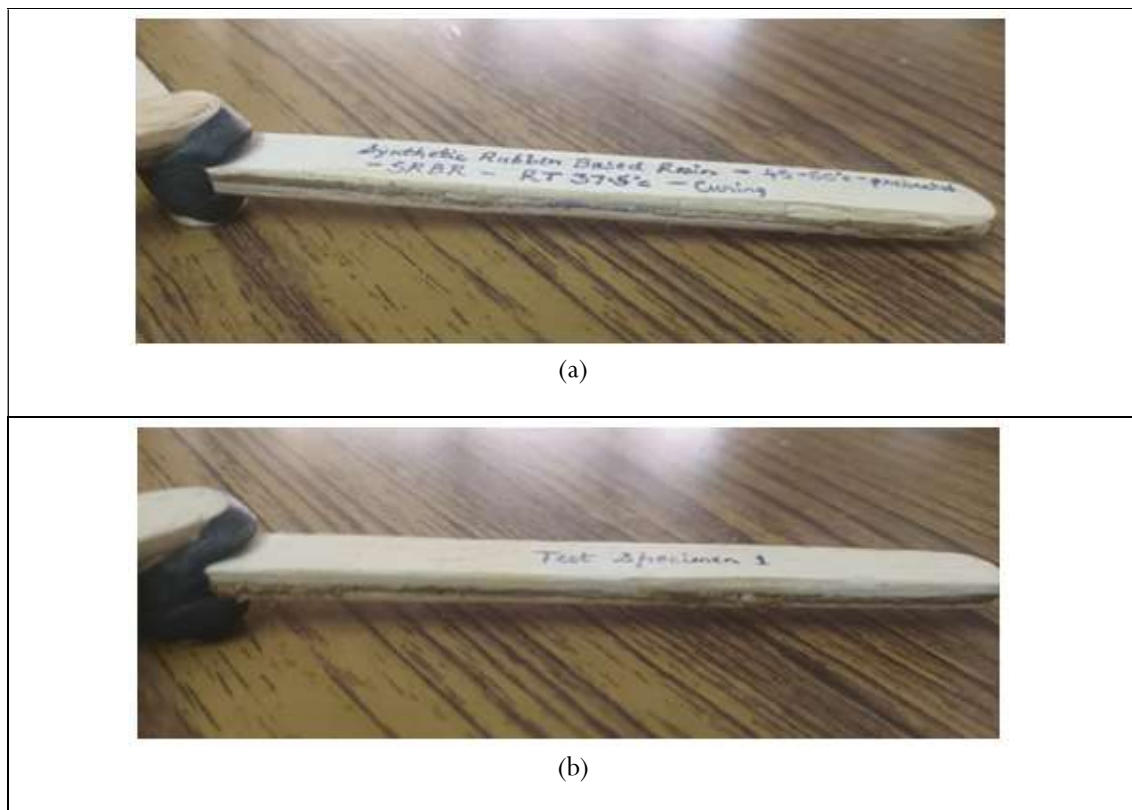


Fig 6. (a) Close-up view of the composite section of the Drone Frame, (b) close-up view of the composite section of the Drone Frame.



Fig 7. The glass-epoxy-soaked cotton fiber and glass-epoxy-soaked polypropylene composite for Panel Glass can provide resistance to glass getting split into a number of sharp parts when hit by an impact force.



Fig 8. Wood-Epoxy Sample Specimens.

4.2. Impact on the Students/Learners

After the implementation of the method, there was good reciprocation from the students as related to learning different and newer concepts from the subject. The students were able to grasp the concepts better and reproduce the concepts taught to them with considerable ease. Even students from vernacular backgrounds were able to understand the concepts, the theory behind the technology, practical applications, and industrial uses, and reproduce around percent of what was taught to them with an appreciable amount of grip on the topics.

5. Results and Conclusion

The findings show that the "Do-and-Learn in the Class" approach significantly improved students' comprehension and replication of concepts (See Figure 9). Students' active participation in hands-on learning, which allowed them to make connections between theoretical ideas and real-world applications, is responsible for this development. The results also support the ideas of kinesthetic learning, which holds that physical engagement improves intellectual clarity and recall. Students' academic performance

improved as a result of their increased ability to visualize material behavior and connect it to practical applications.

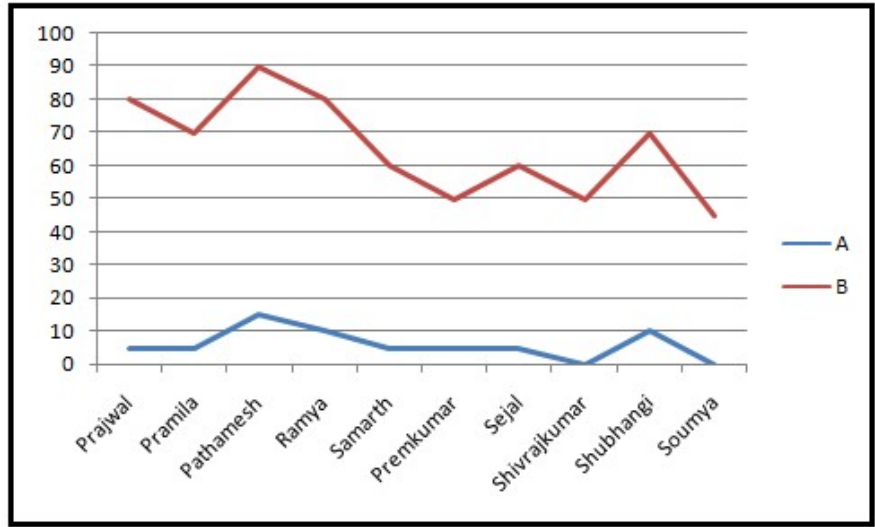


Fig.9. The above graph shows the performance of students before the methodology being applied (A) and after the methodology being applied (B).

The results were collected in the form of the percentage of information/knowledge that the students were able to reproduce after performing the experiment in the class. The amount of work the students had done while performing the experiment in the class for a duration of half an hour was converted in the form of a quiz type of test. A set of 20 questions (MCQ) was prepared and shared with the students. Answering 1 question meant 5%, 2 questions meant 10%, 3 questions meant 15% and so on till answering 20 questions which is a complete 100 percent. A test was conducted before conducting the experiment and one after conducting the experiment. The students who were not able to understand and answer certain questions by the basic method of teaching were able to understand and answer most of the subject questions after performing the experiment. Table 1 presents data from a randomly selected subset of 10 students, used for detailed statistical analysis. This subset represents varying levels of prior knowledge and learning ability.

Table 1. Data of 10 randomly selected students who reproduced the knowledge gained before doing the experiment and after the experiment.

Sl.No	Name	Gain before the experiment(A)	Gain after the experiment(B)
1	Prajwal	5	80
2	Pramila	5	70
3	Pathamesh	15	90
4	Ramya	10	80
5	Samarth	5	60

6	Premkumar	5	50
7	Sejal	5	60
8	Shivraj Kumar	0	50
9	Shubhangi	10	70
10	Soumya	0	45

(Note: Here a set of 20 questions (MCQ Type) was given for validation of the experiment being conducted where answering 1 question was considered 5%, 2 questions was 10%, 3 questions was 15% and so on till answering 20 questions was considered 100%. With the above consideration the above result data was obtained based on how many questions the students answered before and after the test.)

This study compares the same students before and after the experimentation, so the most appropriate statistical method that can be applied is Paired Sample t-Test.

A paired sample t-test was conducted to determine whether the observed improvement in student performance was statistically significant. This test is appropriate as it compares two related measurements (pre-test and post-test scores) from the same participants.

The 3 main reasons for choosing this method is:

- 1) Here the information of the same students is measured twice, before and after test.
- 2) The data is a quantitative type of data that uses the percentage gain as a measure of improvement.
- 3) We want to check if improvement is statistically significant or not.

Steps:

- 1) Define Hypotheses

Null Hypothesis (H_0): Null Hypotheses is a fundamental statistical assumption that there is no effect, no relationship, or no difference between two variables or groups. There is no significant difference in learning before and after the methodology.

Alternative Hypothesis (H_1): Alternative Hypothesis a statement in statistical testing that proposes a significant relationship, effect, or difference between variables, acting as the opposite of the null hypothesis. There is a significant improvement after applying the methodology.

- 2) Calculate Standard Deviation (Equation 2)

$$\text{Standard Deviation (SD)} = \sqrt{Z/n} = \sqrt{36575/10} = 60.48 \quad (2)$$

Where Z = Sum of square of the differences and D = Mean of the differences.

The t value was found in Equation 3:

$$t = \frac{D}{SD/\sqrt{n}} = \frac{59.5}{60.48/\sqrt{10}} = 3.11 \quad (3)$$

As seen in Equation 3, the value of $t=3.11$ is significantly higher to reject null hypothesis. This means that the teaching method has a considerable impact on the student's learning.

Obtaining Effect Size: in our case, the effect size (Cohen's $d \approx 0.98$) is greater than 0.8, indicating a large effect size and a substantial impact of the teaching methodology (See Equation 4). The calculated t -value ($t = 3.11$) indicates a statistically significant improvement in post-test scores compared to pre-test scores. This confirms that the observed improvement is unlikely to be due to chance. If $d > 0.8$, it is considered a large effect size.

$$\text{Cohen's } d = \frac{D}{SD} = \frac{59.5}{60.48} = 0.98 \quad (4)$$

The normalized gain values further confirm that the intervention resulted in substantial conceptual improvement, consistent with findings reported in active learning literature. This reinforces the effectiveness of the "Do-and-Learn in the Class" methodology. The calculated t -value ($t = 3.11$) indicates a statistically significant improvement in post-test scores compared to pre-test scores. Additionally, the effect size (Cohen's $d \approx 0.98$) suggests a large practical impact of the intervention, indicating that the observed improvement is not only statistically significant but also educationally meaningful.

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