Effective Engineering Education Through Active Learning Techniques

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***Abstract*—Active learning transforms the lengthy monologue sessions to more participative discussions. This inherently increases student engagement not only with the class, but also with the subject. Each active learning technique, when used appropriately, vastly simplifies the complexities of technical education, encourages discussions and helps students effectively visualize and assimilate the knowledge.**

The techniques that could be most effective in engineering education with specific use cases are introduced in this paper. The paper also defines the concept of active learning and its key elements; examines specific models and strategies that professors can use to implement active learning across the curriculum. The primary objective of the study was to determine whether active learning teaching could improve the academic achievement motivation in engineering education when compared with the traditional teaching method.

Keywords—Active learning, Engineering eduction reforms, Active learning techniques for engineering eduction

I. INTRODUCTION

It is difficult for students to stay focused throughout a lecture. But, a student can only comprehend advanced engineering topics when the attention is glued to the lecture. As per a research [1], students recalled 70% of the information immediately after the lecture and only 20% of that from the last ten minutes.

The Traditional teaching method begins with the instructor passively delivering a lecture with full attention on the quality and quantity of the content being delivered. The students are supposed to focus their attention on listening to the session and pulling their diverging mind to stay focused. The understanding of the student is first limited by the attention, next by visualization or by mere memorization. This would also need students to spend considerable amount of time after the session in revising and memorizing. In this method, the instructor on a podium is in such a dominant position, that he/she remains incognizant of the students' attention. Sometimes it makes one wonder if the session is for the instructor or the instructed.

The effectiveness of the teaching can be measured by the degree to which the student has acquired the knowledge that the teacher has intended to impart. This literature presents a practical perspective of techniques which ensure active engagement of students throughout the length of the classroom session.

II. ACTIVE LEARNING

Active learning is a term that refers to several models of instruction, which make learners own responsibility of learning. As per a research [4], active learning is defined as an instructional method that engages students in meaningful activities during the process of learning. The activities stimulate them to ponder on and react on the presented information. The direct involvement techniques of Active learning can include short writes, brainstorming, quick surveys, think-pair-share, formative quizzes, debate, role playing, cooperative learning, collaborative learning, and student presentations. The classroom environment is turned around with students contributing the most. This can be applied to any learning environment; be it online or standard lectures or even a blend of these. Active learning provides opportunities for learners to think critically about the classroom content through a wide range of relevant activities. These activities help challenge learners and prepare them for professional situations they could encounter through evaluative, problem solving or critical reasoning skills.

In Active learning, students engage in reading, writing, discussing and problem solving. These encourage analysis, synthesis and thorough evaluation of delivered content. Some of the approaches that promote active learning are cooperative learning, problem-based learning, use of cases and simulations based methods.

A. Active Learning Techniques

These techniques involve in engaging discussions, workshops, small group activities in pairs, trios and groups. These strategies ensure individual participation in small groups. Some of the key techniques which are highly applicable to engineering education are elaborated in subsequent sections.

III. THINK SHARE PAIR

This technique highly engages students with the training content at an individual level, in pairs, and finally as the group at large. The activity helps organize prior knowledge, apply, or integrate new information.

A. Procedure

- Individuals reflect on for a minute or two in response to a question
- Participants pair up with someone sitting near them and share responses/thoughts verbally for a short while.
- The discussion leader randomly chooses a few pairs to give thirty-second synopses of ideas they discussed.

B. Case study

This technique can be used to involve the students in understanding practical applications of engineering topics. For example, the professor explains about KVL earlier and asks the students to do think/share/pair on applying KVL for distribution network near their homes. It involves calculating the voltage drop at the end of a line and how they would compensate the voltage drop.

This technique can also useful as an extension of a previously explained topic. For example, the professor explained the functionality of a DC motor earlier and now asks the students to understand the DC generator functionality based on the working principle of DC motor.

IV. Ten Two Strategy

Presenter provides information for ten minutes and then stops for a couple of minutes to encourage listeners to pair and share their ideas. They use this time to fill in any gaps or misunderstandings, and allow each other to gain clear understanding.

A. Case study

This could be effective when teaching complex topics that require a lot of visualization. The complex topic can be divided into a series of smaller topics. After the small topic is introduced, the students could be encouraged to have short discussions to share their understanding.

For example, professor explains about transformer and asks the students to start experimenting by changing the number of windings on either side. They can also calculate how much flux is induced and how voltage is changed on either side.

V. Question And Answer Pairs

In this technique, students are engaged with readings and then paired to answer particular questions.

A. Procedure

- Participants respond to presentation with one or two questions.
- The participants pair up. An example is A asks a prepared question and B responds; then B asks a prepared and A responds.
- The leader could ask for a sampling of questions and answers.

B. Case study

This helps to deepen the level of analysis of presentations/readings, and helps engage participants in explaining new concepts, as well as considering how/where to apply the concepts to their own thinking.

Consider a scenario where a professor is trying to explain a theory and would to get interpretations from students. The focus is not on evaluating the validity, but on wishfully analyzing the theory. The success measure is to identify as many interpretations and refining the theory.

VI. Numbered Heads Together

This technique works for students in groups. A group member asks a question, and then others discuss and ensure everyone knows the answer. Next, the question asker picks one from the group to answer the question. This can also be implemented with multiple teams.

A. Procedure

- Team A asks Team B a question.
- Team B collaboratively discusses and makes sure each team member knows the answer.
- Then Team A selects a Team B member to answer the question.

B. Case study

Imagine the enthusiasm and competitive spirit that this technique generates in solving mathematical problems.

Split the class literally into multiple teams. One team discusses what they know and they challenge other team to answer it. Another team takes up the challenge which is generates a competitive spirit and improves focus on the subject. This technique works in scenarios which has lot of practical applications and need more mathematical and practical analysis.

For example, if students understand the functions of logic gates, they can write programs for simulating simple circuits using logic gates.

VII. Round Table

A. Procedure

- A question is posed by a group leader, professor or another participant.
- Each person writes one answer on paper that is passed around in the group.
- The answers are shared or presented in groups to the entire class.

B. Case study

This could be an excellent technique to summarize or recap the understanding of students on a difficult topic.

An example is the steps involved in drawing Bode Plot in control systems. Most students get confused in drawing it. By using this technique, the students can write short phrases on their understanding. Passing these around ensures common and comprehensive understanding.

VIII. Problem-Based Learning

Professor presents a problem to the class/group. The problem needs to be based on an authentic or real life situation that the participants could connect to. Small groups must apply the presented information to resolve the problem.

A. Case study

Real world problems are excellent means to captivate students to their seats and gain profound understanding of actual applications of Engineering. A disaster that happened at a power plant could be taken as an example to understand how minor changes to frequency have devastating effects and how a seemingly trivial equation governs the integrity of power generation.

IX. Note Check

In this technique, students pair with a partner or a small group to briefly share notes for two to five minutes. They clarify among themselves the key points covered, generate and resolve questions. They could also generate a problem to solve or even solve a problem posed by the instructor.

A. Case study

Consider a session when the instructor has to cover a large number of small topics in a limited time. The instructor can recommend this technique to the students to use periodically. This ensures that the students are engaged throughout and they do get short breathers intermittently as well.

This technique is also very useful when revising all the topics of a subject that are taught earlier.

X. Jigsaw Team Work

A jigsaw is an active learning exercise derived in the spirit of jigsaw puzzles. Functioning as a successful team requires the integration of many different activities.

A. Procedure

- A general/technical puzzle is divided into smaller and interrelated pieces
- Each member of team or each team is assigned a different topic, which is analogous to a piece of puzzle, and expected to become an expert
- Each person shares his/her learning on the piece of puzzle to the others
- After each person has briefed others, the puzzle has been reassembled and everyone in the team knows key things about every piece of the puzzle.

B. Case study

A student is limited to the electives that he/she takes up. Using jigsaw teamwork, in a class which has taken multiple electives, the whole class can familiarize all subjects/topics.

Consider a class which is divided into multiple teams working on a Humanoid Robot. This project has multiple systems like mechanical design, electrical system, electronic control system etc., in which every team focuses to develop their own system. At last they have to connect all the pieces together. Benefit of this technique is, though every team specializes in their own system, they share their learning with other teams.

XI. Instructional Strategies

As per the reference [2], active learning instructional strategies include a wide range of activities that share the common element of "involving students in doing things and thinking about the things they are doing". Active learning instructional strategies can be created and used to engage students in:

- Thinking critically or creatively
- Speaking with a partner, in a small group, or with the entire class
- Expressing ideas through writing
- Exploring personal attitudes and values
- Giving and receiving feedback and
- Reflecting upon the learning process

XII. Benefits

A. For Students:

- The engaged student is no longer bored. The classroom atmosphere becomes more vibrant and jubilant.
- The students not only learn, but discuss, think through and live with the subject.
- The approach promotes critical thinking and analytical capabilities

B. For Professors:

- Teachers get an opportunity to explore the subject better. They actually get a chance to learn from students.
- With diverse thoughts and ideas on topics, the mastery of teachers is also enhanced multi fold.

XIII. Conclusion

Living in the time when infants are taught in digital classrooms, traditional methods are simply inadequate to explain ever evolving technical education. Students have to be taught the basic engineering concepts, the advancements as they happen, with the proficiency as demanded by current market standards, and in the very same four years. Active

learning techniques multiply the time that the professor has in the class, as the students are highly engaged and excited.

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