Using JIGSAW in Engineering Courses to Practice collaboration in Class room

[1] G Lakshmi Bhavani, [2] Tuti Sandhya
[1], [2]KG Reddy College of Engineering & Technology, Hyderabad
[1]lakshmisrinivas.2010@kgr.ac.in [2]sandhyatutiece@kgr.ac.in

***Abstract*— In contemporary engineering education, collaborative techniques have been shown to create more substantial and enduring knowledge among students. The shift from solitary learning to group-based learning has posed a significant challenge, especially when individuals need to effectively communicate and collaborate with their peers in both industrial and social contexts. This paper delves into a practical, collaborative activity implemented within the undergraduate Power Systems course in the Electrical Engineering curriculum, employing the Jigsaw method. It provides a comprehensive overview of the activity, detailing the challenges encountered and the solutions and recommendations devised to address these issues in both small and large classroom settings. The case study conducted demonstrates how the Jigsaw technique enhances students' understanding and retention of the course material, thereby improving overall learning outcomes.**

***Keywords*- Collaborative learning, Jigsaw, Group activity, Engineering Education**

I. INTRODUCTION

According to educational studies, more profound comprehension results from interactive, contextual, and captivating learning experiences. These experiences aid in the development of sophisticated leadership, communication, and thinking abilities—all of which are highly prized in professional contexts. To accomplish shared objectives, industries place a high value on cooperation and teamwork. However, a lack of collaboration abilities causes many students to fail in professional settings, even with stellar academic records. For students' personal and professional development, collaborative learning must be incorporated into engineering education. In engineering, collaborative learning takes a holistic approach in which students teach and learn from one another as well as their teachers. This approach encourages students to share accountability for their education. For group activities to be successful, selecting an efficient collaborative learning strategy is essential.

Rather than passively receiving it from teachers. This approach turns teaching into a shared effort where all participants collaboratively build knowledge. It encourages students to become self-directed learners and researchers. For instructors to successfully implement a collaborative project, they need to understand their students' learning styles and their own teaching beliefs. The benefits of collaborative learning include fostering student-faculty interaction, enhancing student relationships, increasing self-esteem, promoting responsibility, and preparing students for real-world social and professional situations. Various collaborative strategies can be employed in the classroom, such as Stump Your Partner, Think-Pair-Share, Catch-Up, Fishbowl Debate, Think-Aloud Pair Problem Solving (TAPPS), STAD, and Jigsaw. The effectiveness of these methods depends on their alignment with the learning context. Among these, the Jigsaw method stands out as it focuses on cooperative learning by encouraging students to assist each other, thereby developing critical thinking and social skills necessary for completing tasks together.

This paper explores the implementation of the Jigsaw method in a case study focused on the subject of Electronics Devices and Circuits. It discusses the advantages of this approach, the challenges faced during its application, and provides recommendations to improve its effectiveness in diverse classroom settings.

II. BACKGROUND

- Kumar et al. (2017) investigated the impact of the jigsaw cooperative learning method on medical students' cognitive skills. This method organizes students into small groups, with each member responsible for mastering and teaching a specific segment of the course material to their peers. The study assessed the effectiveness of this approach by measuring improvements in students' cognitive abilities, specifically their comprehension and retention of complex medical topics. The results indicated that the jigsaw method significantly enhances critical thinking and problem-solving skills, in line with active learning principles that emphasize student participation and interaction. The study highlights the potential of cooperative learning techniques in medical education, fostering a deeper understanding and application of knowledge.
- Kritpracha et al. (2018) explored the development and implementation of cooperative learning through jigsaw activities to improve learning outcomes and self-directed learning behaviors among nursing students. This method involves dividing students into small groups, each of which is in charge of teaching and learning various aspects of the subject. The study assessed how this method affected students' academic performance and capacity to control their own learning. The results showed that jigsaw exercises encouraged students to learn more independently while also improving their comprehension and memory of the subject matter. This is in line with the ideas of active learning, which place an emphasis on student participation and teamwork. The study highlights the advantages of cooperative learning techniques in nursing education, which help students succeed

academically and develop their capacity for self-directed learning, thereby preparing them for the needs of the healthcare industry.

- A study comparing the effects of jigsaw learning and conventional lecture-based teaching techniques on student performance and learning experiences was carried out by Costouros (2020). The jigsaw method creates an engaging and cooperative learning environment by giving students separate portions of a subject to study on their own before teaching to their group members. The study assessed how these approaches affected students' academic performance and opinions of the educational process. According to the results, students who engaged in jigsaw learning outperformed those who attended regular lectures in terms of marks and reported a more enjoyable and interesting educational experience. This study emphasizes the benefits of active learning strategies like the jigsaw technique, which support improved academic performance, higher levels of student motivation and engagement, and general learning satisfaction.
- The jigsaw classroom model was first presented by Aronson et al. (1978). It is a groundbreaking pedagogical strategy in which students are split up into tiny, different groups, each of whom is in charge of learning and instructing a distinct course segment. It has been demonstrated that this approach fosters mutual support and cooperative learning, which improves student social connections and academic achievement. A more inclusive and cooperative learning environment was promoted and intergroup biases were lessened thanks to the jigsaw classroom. This approach fosters critical abilities like empathy and teamwork by highlighting each student's role in the group's achievement, improving academic results and interpersonal connections.
- During the International Conference on Interactive Collaborative Learning, Pow-Sang (2014) investigated the use of the jigsaw technique in object-oriented design instruction. Complex design principles were broken down into discrete chunks for the study, and each was given to a different student for in-depth analysis before being taught to peers. It was discovered that this cooperative method improved students' understanding and interaction with object-oriented design concepts. The findings showed that the jigsaw method promoted a more thorough comprehension of the subject matter, improved peer teaching skills, and fostered a more interactive and supportive learning environment. The study highlights the value of the jigsaw method in promoting active learning and peer collaboration, crucial for mastering intricate technical concepts.
- The Journal of Engineering Education Transformations' special issue 2020 focuses on innovative methods and transformations in engineering education. Topics include a vast array, ranging from upgrading education practices and new pedagogies to the issues facing the discipline. The papers address developments in pedagogical practices, curricular design, and utilization of technology in engineering education. All lead to improving student learning outcome, participation, and generally educational experience and thus reflect the ongoing efforts towards shifting engineering education to be responsive to the changing needs of industry and the expectation thereafter of professional success in navigating complex situations.
- Susanti, 2019) studied integration of the jigsaw method with a metacognitive approach to develop problem-solving ability in social statistics. For this study, collaborative learning was combined with metacognitive strategies: students were taught different aspects of subject matter by peers and they reflected on the learning process. Problem-solving ability was shown to be developed in students, thus it proved effective to combine activities of both collaborative and reflective learning. This approach fosters more critical understanding of statistical concepts as well as the importance of a learner's integration of collaborative as well as metacognitive techniques in education.
- Ogunfunmi and Rahman (2010) developed a concept inventory for an electric circuits course presented at the IEEE International Symposium on Circuits and Systems. It is an assessment tool, and the purpose is meant to improve students' knowledge about the fundamental concepts that underlie electric circuits and identify common misconceptions students make in the context of understanding key concepts. The study highlighted the requirement of diagnostic tools in engineering education to identify critical areas and provide targeted educational interventions toward students who may struggle. In this approach, robustness in comprehension of core concepts is supported, and with that, more effective strategies for teaching are facilitated in the context of technical education in general.

III. Overlap between JIGSAW and PBL

- The Jigsaw method and Project-Based Learning (PBL) share a focus on collaborative, student-centered learning, yet they differ in structure, purpose, and application. Both methods encourage active participation and group work, where students are not passive recipients of information but rather engage critically, learning from and with one another. This approach promotes essential skills like communication, collaboration, problem-solving, and critical thinking, with students taking ownership of their learning journey. However, Jigsaw is a strategy primarily designed for short-term content division within a single class or a few sessions. Each group member becomes an "expert" on a segment of the material and then teaches it to others, so that the group as a whole understands the content comprehensively. In contrast, PBL is typically more long-term, centered around complex, real-world problems or projects that require weeks or even

months to complete. PBL's purpose is to solve a real problem or create a meaningful product, allowing students to engage deeply with interdisciplinary skills and knowledge.

Jigsaw can be particularly useful as a preparatory phase within PBL, especially when building the foundational knowledge needed for the project. For instance, at the beginning of a PBL project, students could use Jigsaw to divide the research, with each student focusing on a specific component that contributes to the project's larger goals. In a project to design a sustainable community garden, one student might research soil and plant types, another might study water conservation techniques, a third could explore community engagement strategies, and another might assess environmental impacts. Each student, having become an "expert" in their area, would then share their findings with the group. The group can subsequently integrate and synthesize these areas of knowledge to build a well-rounded, comprehensive solution or design. Using Jigsaw in this way within a PBL framework enhances efficiency in research and helps build interdependence, reinforcing PBL's emphasis on teamwork and collective problem-solving. This combined approach allows students to efficiently distribute research tasks while creating a strong foundation for collaborative work towards a unified project outcome.

III. Case Study: Jigsaw Method in Electronics Devices and Circuits

In the context of Electronics Devices and Circuits, the Jigsaw method can be particularly effective due to the subject's complexity and the need for a deep understanding of various components and their interactions. This course typically covers topics such as semiconductor physics, diode and transistor characteristics, amplifier design, and digital circuits, all of which require a solid grasp of underlying principles and the ability to apply them in practical scenarios.

Implementation of the Jigsaw Method:

In implementing the Jigsaw method for Electronics Devices and Circuits, students are divided into small groups, with each member assigned a specific topic or sub-topic. For instance, one group might focus on the characteristics and applications of diodes, another on transistors, and another on amplifier circuits. Each student becomes an "expert" in their assigned area, studying the material in depth and preparing to teach it to their peers.After the initial study phase, students regroup into mixed teams where each member presents their topic to the others. This process ensures that all students gain a comprehensive understanding of the entire course material through peer teaching and discussion. Instructors facilitate the process, providing guidance and support to ensure accurate and thorough understanding.

9 Advantages of the Jigsaw Method in Electronics Devices and Circuits

The Jigsaw method offers several advantages in teaching Electronics Devices and Circuits:

1. **Enhanced Understanding:** By teaching each other, students reinforce their own understanding and retention of complex concepts.
2. **Active Engagement:** The interactive nature of the method keeps students engaged and motivated.
3. **Critical Thinking:** Students develop critical thinking skills as they explain and discuss technical topics with their peers.
4. **Collaboration Skills:** The method promotes teamwork and communication, essential skills for engineering professionals.
5. **Inclusive Learning Environment:** By relying on peer teaching, the method fosters an inclusive learning environment where all students contribute to the group's success.

Challenges and Recommendations

Implementing the Jigsaw method can present challenges, particularly in large classrooms or with diverse student backgrounds. Some potential issues include uneven participation, varying levels of understanding, and the difficulty of managing group dynamics. To address these challenges, the following recommendations are proposed:

1. **Structured Guidelines:** Provide clear guidelines and expectations for both the study and teaching phases.
2. **Instructor Support:** Instructors should actively monitor and support groups, ensuring that all students participate and understand the material.
3. **Diverse Grouping:** Form groups with a mix of abilities to balance strengths

METHODOLOGY

This study was conducted at KG Reddy College of Engineering and Technology, Hyderabad, focusing on Electrical and Electronics Engineering students enrolled in the Power Systems course. The primary learning outcomes were to "List the advantages of GIS over Air-insulated substations" and "Draw the Line diagram of Distribution substations." A step-by-step Jigsaw method was implemented to achieve these outcomes.

First, students were divided into four diverse groups of five or six members each, ensuring a mix of gender, ability, and knowledge. A leader was appointed in each group based on maturity, regularity, and academic performance. The lesson on "Diode and its Applications, Bipolar Junction Transistor, and Small Signal Analysis of BJT Amplifiers" was divided into six segments: Diode basics, Diode applications, Bipolar Junction Transistor (BJT) basics, BJT applications, Small signal model of BJTs, and Analysis of BJT amplifiers. Students were allowed to select their segments, promoting fair distribution and conflict resolution skills.

In the preparation phase, students studied their assigned segments using notes, textbooks, and journals. Prior notice about the activity ensured they came prepared. Temporary expert groups were formed with students from different groups studying the same segment to discuss key points and clarify doubts. These expert groups then returned to their original groups to teach their segment, with each student presenting their part and fielding questions from peers. The instructor monitored the class to ensure effective communication and engagement, with group leaders aiding in maintaining order.

Groups were formed based on a preliminary quiz related to the Jigsaw activity topics. The top scorers became team leaders, and subsequent scorers were evenly distributed to balance abilities. Adjustments were made to ensure balanced participation, especially if groups were overly passive or active. Potential challenges included ensuring access to materials, managing absenteeism, and encouraging engagement from all students. These were mitigated by giving prior intimation for preparation, re-arranging groups as needed, and having group leaders assist less engaged members.

Name of the Course: Electronic Devices and Circuits

Name of the Course module	**Number of students participated in tha activity**
Diode and its applications	**57**
Bipolar Junction Transisitor	**59**
Small signal analysis of BJT Amplifiers.	**57**

The effectiveness of the Jigsaw method in the Electronics Devices and Circuits course was evident in enhanced student understanding, active engagement, and improved critical thinking and collaboration skills. Challenges such as student preparation and group dynamics were managed through strategic planning and instructor support. Future implementations should focus on structured guidelines, active monitoring, and continuous improvement based on feedback to maximize the benefits of this collaborative learning approach.

IV. ASSESSMENT AND EVALUATION

Grading for the Jigsaw Activity:

To help students understand their performance and improve for future activities, the grading for the jigsaw activity is designed as follows:

Individual Grading

- Prior to the activity, students are given a set of questions to assess their initial knowledge and skills.
- After the activity, students are asked to answer the same questions, along with additional ones, to evaluate their improvement.
- Performance is measured by comparing the results from the pre-activity and post-activity quizzes.
- Feedback is collected to identify any difficulties encountered during the activity.

Individual performance is assessed based on several criteria, including:

- Coordination
- Debate skills
- Listening skills
- Communication skills
- Depth of subject knowledge
- Handling of materials

Team Grading:

- The jigsaw activity topic is: "List the advantages of Gas Insulated Substations over Air Insulated Substations for higher voltages." After completing the activity, teams are required to submit a report on the topic.
- Teams are graded based on the quality of their reports.

Additionally, team performance is evaluated according to the feedback provided by the team leader, covering:

- Coordination and teamwork
- Contribution to the group's discussion and debate
- Effective communication
- Understanding of the subject matter
- Utilization of materials

V. RESULTS AND DISCUSSION

The effectiveness of the enhanced jigsaw method in improving student performance can be seen from the results over the academic years. The comparison of pass percentages from conventional teaching methods versus the enhanced jigsaw method is as follows:

Academic Year	Number of Students Appeared	Number of Students Passed	% Pass
2019-2020 (Conventional teaching method)	108	55	50.9
2020-2021 (Conventional teaching method)	95	46	47.91
2021-2022 (Conventional teaching method)	54	39	72.22
2022-2023 (Enhanced Jigsaw method)	59	57	96.61

It is evident in the table that there is a rise of pass percentage when the advanced jigsaw method is employed. The pass percentage went up to 96.61% for the year 2022-2023. In all the past years, the range of pass percentage lies between 47.91% and 72.22%. It can hence be concluded that the jigsaw method has positively influenced the student's learning outcome and engagement

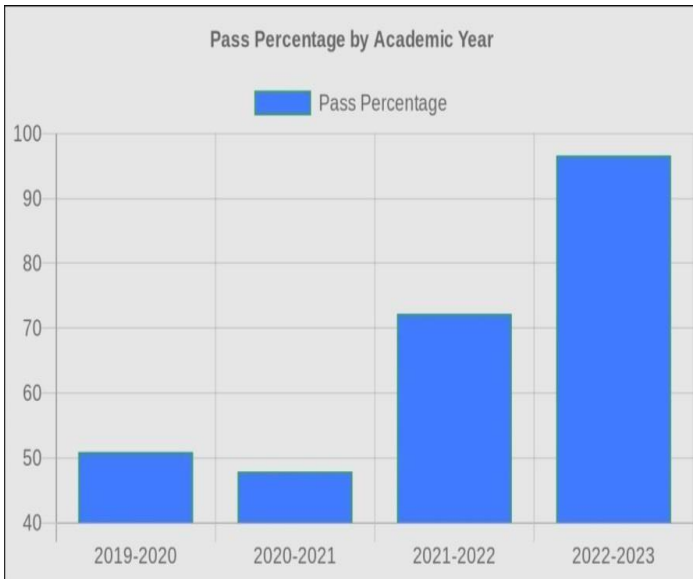

Fig: Pass percentage Comparison by Academic year wise

CONCLUSION:

This can be seen from the clear analysis of data that with the latest version of jigsaw method, students certainly do much better. This year 2022-23, the pass percentage worked out to be 96.61%. Which can be seen that in previous years, even the pass percentages were lesser, ranging between 47.91% and 72.22%. These big changes reflect that jigsaw method is the better method for comprehension, interest and retention than any traditional method of teaching. Further individual understanding can help bring the teamwork, coordination, communication, which are highly skills in themselves. Therefore these findings show that jigsaw method is a gold mine for pedagogy by which learners' active involvement can be made to acquire knowledge through collaboration. Educational institutions are also motivated to ponder the idea of adopting similar models considering the principle of maximizing student performance and engagement in academics. More research on collaborative learning methods may also identify some long-term benefits, which can be applied to various subjects and disciplines.

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