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BOARD # 173: Teaching elasticity through jigsaw classrooms: Impact on students' experiential learning

David Olubiyi Obada, Africa Centre of Excellence on New Pedagogies in Engineering Education (ACENPEE), Ahmadu Bello University, Zaria, Nigeria

David O. Obada holds a Ph.D. degree in mechanical engineering from the Ahmadu Bello University, Zaria, Nigeria, specializing in production/industrial engineering. His research interests include fracture mechanics, advanced materials, and condensed matter physics. Before joining the Atlantic Technological University, Ireland, David was a research fellow at the University of Ghana, National Environmental Engineering Research Institute, Nagpur, India, and the University of Birmingham, UK. Also, David was a research and teaching fellow at the Massachusetts Institute of Technology (MIT), USA, and holds a Kaufmann Teaching Certificate from MIT.

Ayodeji Nathaniel Oyedeji, Ahmadu Bello University

Ayodeji Nathaniel Oyedeji is an advanced manufacturing and materials science researcher. With exceptional performances in both his B.Sc and M.Sc studies in Mechanical Engineering at Ahmadu Bello University, Nigeria, he is now pursuing a PhD in Industrial Engineering at Stellenbosch University, South Africa. Alongside his scholarly pursuits, Ayodeji demonstrates a keen interest in engineering education. He has made significant contributions to his field through a prolific publication record and active participation in academic conferences. Possessing a diverse skill set, including strong communication abilities and analytical proficiency, Ayodeji is also an avid reader and enjoys nature. His trajectory reflects a commitment to continuous growth and making a meaningful impact within engineering and beyond.

Simeon Akindele Abolade

Simeon Akindele Abolade is a PhD student at the Atlantic Technological University (ATU) in Sligo, Ireland, and a member of the Mathematical Modelling and Intelligent Systems for Health and Environment (MISHE) research group. He holds a BSc (Hons) degree in Physics from the University of Ilorin, Nigeria, and MSc in theoretical physics from the University of Ibadan, Nigeria. He is currently on his PhD programme at ATU, Sligo, under the supervision of Dr Akinlolu Akande, Prof. Stefano Sanvito and Dr Fedwa El-Melouhi. His research interests include modeling novel materials for photovoltaics, photocatalytic, and thermoelectric applications using state-of-the-art computational tools based on Density Functional Theory and Machine Learning.

Mr. Shittu Babatunde Akinpelu, Atlantic Technological University, Ireland

Shittu Babatunde Akinpelu is a Ph.D. student at Atlantic Technological University (ATU) in Ireland. He completed his bachelor's degree in physics at the Federal University of Technology (FUTA), Akure, Nigeria. While pursuing his master's degree in condensed matter physics in 2021, Babatunde gained valuable research experience as a voluntary research assistant at FUTA. In 2022, Babatunde joined the Modelling and Computation for Health and Society (MOCHAS) cohort at ATU, Ireland for his Ph.D. His current research focuses on material modeling using machine learning and soft computing, with a particular interest in discovering novel materials with unique properties that could be applied in the fields of energy and health.

RAYMOND BACSMOND BAKO
Adrian Oshioname Eberemu

Adrian Oshioname EBEREMU is a Professor of Geotechnical/Geoenvironmental Engineering in the Department of Civil Engineering Ahmadu Bello University Zaria, Nigeria. He has been an academic for more than 18 years, before which, he spent his earlier years practicing as a geotechnical and civil engineer in the industry in Nigeria. He is a product of the DSC Technical High School, the 90set where a good academic foundation was laid. He had his Bachelor of Engineering in Civil Engineering from

Federal University of Technology Owerri, FUTO in 1997; MSc and PhD in 2003 and 2008, respectively from the Ahmadu Bello University Zaria.

He has taught and examined students both at the undergraduate and post graduate levels in several Nigerian Universities such as University of Maiduguri, Modibbo Adama University of Technology Yola, Kano State University of Technology, University of Agriculture Makurdi, Bayero University Kano, Abubakar Tafawa Balewa University Bauchi, Nnamdi Azikwe University Awka and Covenant University Ota, Federal University of Technology Minna, Michael Okpara University of Agriculture Umudike, Olusegun Agagu University of Science Technology Okitipupa and Universiti Technologi Malaysia.

His primary area of expertise are in geo-material site characterization, deep foundation, the beneficial reuse of waste materials in soil improvement, solutions to geo-environmental problems, waste containment barriers and covers, Biogeochemical Processes in Geotechnical Engineering (Microbial Induced Calcite Precipitation) and unsaturated soils (collapsible soils) and lately engineering education. He has many published works in peer-reviewed journals, conference proceedings and chapters as well as technical reports to his credit in the various research area.

He is currently the academic and research coordinator with the African Center of Excellence on New Pedagogies in Engineering Education (ACENPEE), Ahmadu Bello University Zaria; a World Bank funded Development Impact project with the aim of scaling up post graduate education at the MSc/PhD levels through regional specialization and collaboration in the West African Sub-region.

Adrian is a registered Engineer with Council for Regulation of Engineering Practice in Nigeria (COREN), a member of the Nigerian Society of Engineers, a member of the American Society for Civil Engineers as well as the International Society for Soil Mechanics and Geotechnical Engineering (ISSMG).

Akinlolu Akande

Dr. Akinlolu Akande is a computational material scientist and lecturer at the Atlantic Technological University (ATU) Sligo, Ireland. He is a Principal Investigator in the Mathematical Modelling and Intelligent Systems for Health and Environment (MISHE) and Modelling & Computation for Health And Society (MOCHAS) Research Groups at the ATU. He completed his PhD in Physics at Trinity College Dublin, Ireland, and subsequently worked as a postdoctoral research fellow at the same institution. During this time, he combined research in computational material sciences with teaching duties in undergraduate laboratories. Akinlolu then served as an assistant lecturer at the Dundalk Institute of Technology in Dundalk, Ireland, before joining the Institute of Technology Sligo (now ATU Sligo). At ATU Sligo, Akinlolu's teaching focuses on mathematics, data analysis and information technology at both undergraduate and postgraduate levels, while his research interests include modelling promising materials for photovoltaics, photocatalytic and thermoelectric applications using state-of-the-art computational tools and advanced techniques based on electronic structure theory. Akinlolu is a Senior Fellow of the Higher Education Academy (SFHEA), a recognition of his expertise in teaching and learning in higher education. In 2020, he was awarded a Teaching Hero, an award organised by the National Forum for the Enhancement of Teaching and Learning and the Union of Students in Ireland.

Teaching elasticity through jigsaw classrooms: Impact on students' experiential learning

David O. Obada[1,2,7,8*], Ayodeji N. Oyedeji[1], Simeon A. Abolade[2], Shittu B. Akinpelu[3], Adrian O. Eberemu[4,7], Fatai O. Anafi[1,7], Abdulkarim S. Ahmed[5,7], Raymond B. Bako[6,7], Akinlolu Akande[2,3]

[1]Department of Mechanical Engineering, Ahmadu Bello University, Zaria, 810222, Nigeria
[2]Mathematical Modelling and Intelligent Systems for Health and Environment Research Group, School of Science, Atlantic Technological University, Sligo, F91 YW50, Ireland.
[3]Modelling and Computation for Health and Society, Atlantic Technological University, Sligo, F91 YW50, Ireland.
[4]Department of Civil Engineering, Ahmadu Bello University, Zaria, 810222, Nigeria
[5]Department of Chemical Engineering, Ahmadu Bello University, Zaria, 810222, Nigeria
[6]Department of Educational Foundations and Curriculum, Faculty of Education, Ahmadu Bello University, Zaria, 810222, Nigeria
[7]Africa Centre of Excellence on New Pedagogies in Engineering Education, Ahmadu Bello University, Zaria, 810222, Nigeria
[8]Multifunctional Materials Laboratory, Shell Office Complex, Department of Mechanical Engineering, Ahmadu Bello University, Zaria, 810222, Nigeria
Corresponding author*: David O. Obada (doobada@abu.edu.ng)

Abstract
This article explores the effectiveness of integrating a modified jigsaw teaching approach within the framework of a new teaching pedagogy called CACPLA (Collaborate, Assessment, Communicate, Problem-based solving, Lecture, and Assessment) to assess its impact on student's academic performance and critical thinking abilities. The study involved 70 participants, with 31 students in the control group and 39 students in the experimental jigsaw group. The jigsaw group experienced a specific instructional process involving the formation of home groups, selection of homogeneous home groups based on pre-lecture test performance, collaborative discussions within home groups, expert group interactions to deepen understanding, and dissemination of acquired knowledge back to home groups. Online resources used in this study on materials science were obtained from https://www.compmatphys.org/topics/elastic-constants-definition/. The findings of the study indicate that students in the jigsaw group outperformed those in the control group. The improvement in post-lecture test scores within the jigsaw group signifies the efficacy of the jigsaw classroom teaching method in promoting better comprehension and retention of course content. A higher percentage of students (81%) scored above 7 out of a total of 10 for the jigsaw group, as against 34% in the control group. This suggests that the integration of the jigsaw teaching approach within the CACPLA framework led to improved academic performance and enhanced critical thinking abilities. The collaborative nature of the jigsaw method, where students worked together in small groups contributed to a deeper understanding of elasticity (the subject used as a case study), a sub-topic in materials science. The dataset resulting from this research could provide valuable information for educators and researchers interested in innovative pedagogical strategies to enhance learning outcomes across various academic disciplines.

Keywords
Jigsaw classrooms; Collaborative learning; Peer-facilitated tutorials; Materials science education; Academic achievement, CACPLA pedagogy.

1. Introduction

The Jigsaw method, developed by Aronson et al. in 1978 [1] was based on improving social relations among children by assembling a jigsaw puzzle with each member providing an essential piece. Since 1978, several models exist, with Jigsaw I being the basis of each model (Table 1). The Jigsaw method involves four steps: 1) Students belong to a Jigsaw group, which exhibits within-group heterogeneity and between-group homogeneity and includes 3-8 students each. 2) Students join temporary "expert" groups, where they learn from more competent peers. 3) Students return to their original Jigsaw groups, teaching and explaining their skills to their group members, to make them competent. 4) Homegroup students work together to produce a final joint work through integration and evaluation.

Table 1: Historical Evolution of the Jigsaw Method [2]

Version of the Jigsaw Method	Creators	Characteristics
Jigsaw I	Aronson et al. [1]	Students work in both home groups and expert groups, with their roles and resources being complementary.
Jigsaw II	Slavin [3]	The structure of Jigsaw II is identical to Jigsaw I, but with a group reward based on individual performance within the group.
Jigsaw III	Stahl [4]	A quiz group is added before step 4 (correction)
Jigsaw IV	Holliday [5]	A quiz and a test are added between each step
Subject Jigsaw	Doymus [6]	This version is specific to sciences like physics and chemistry, allowing each student to access all pre-expert content.

The Jigsaw strategy is a cooperative teaching method where learners work in small teams and take responsibility for each other's learning. The Jigsaw cooperative learning strategy is based on allowing students to assist one another in comprehending and completing educational tasks. This approach involves grouping learners into small teams with varying levels of skill. Every team member aims to become an expert on the assigned classroom materials and then shares their knowledge with others in the group. This strategy aims to enhance students' comfort levels in their respective roles. The effectiveness of the jigsaw technique can be evaluated by having teams work together and fostering a sense of responsibility among learners for their team's performance in the classroom [7]. Each learner in the Jigsaw style prepares a portion of the assignment before the lesson. Afterward, they share their knowledge with their teams and peers, passing on valuable information to others. A study conducted by Cochon Drouet et al. [8] revealed that the duration of implementation influences the effectiveness of the Jigsaw method. Although certain meta-analyses have indicated beneficial outcomes of cooperative learning in scientific fields, Stanczak's study [9] found no significant differences regarding its impact on achievement. Therefore, it is crucial to identify the effects of the Jigsaw method in current and future pedagogical practices.

Some materials science courses are often perceived as “not interesting” due to their didactic pedagogical strategy and limited practical sessions [10]. The students often struggle with understanding the subject due to their theoretical perspective. Science and engineering educators aim to balance the vast amount of knowledge needed to impart to students in preparing them for industry practice. Traditional lecture-based teaching methods, which involve passive engagement, can be challenging for students to develop a profound understanding. Additionally, the cost-effectiveness of giving a single lecture to a large class can lead to cognitive overload [11]. A shift towards student-centered learning and active engagement is advocated to promote self-directed learning in materials science education. An area of study within materials science is the elasticity of materials. It is widely believed that the properties of materials can help students gain a deeper understanding of the theory behind them and how they are applied [12]. Nevertheless, the development of lesson content alone is insufficient to enhance student engagement. Therefore, it is essential to supplement the lessons with effective teaching methods and assess the impact of these methods on the academic performance of students.

The main motivation for this study stems from the fact that in the African context, traditional teaching methods are quite popular, and teachers and educators need to change the paradigm to adopt new teaching pedagogies [13]. Jigsaw classrooms have been in existence for decades, however, the contribution in this study is threefold:

1. Promote teaching pedagogies in Africa as reports on Jigsaws are scarce on the continent.
2. Encourage the use of open courseware to support teaching and learning in the region.
3. Emphasize the modified Jigsaw classroom used in this study to suit the peculiarities. The modification is that a pre-lecture test is administered to the students to share them into groups based on their academic achievements in such a way that the “good” and “average” students form the groups to remove any bias.

This study investigates the effectiveness of a modified Jigsaw learning approach implemented through peer-facilitated tutorials in materials science. A recent study by Obada et al. [14] only assessed the impact of the Jigsaw method on an experimental group. In contrast, this study compares the effects of the methodology on both control and experimental groups. For context, study materials related to elasticity were divided into various sections and assigned to a group of postgraduate students (master's and PhD) at the Africa Centre of Excellence on New Pedagogies in Engineering Education (ACENPEE) at Ahmadu Bello University in Zaria, Nigeria. The participants were split into control and experimental groups to evaluate the impact of the teaching method on their experiential learning. The following sections outline the experimental design and methods, describe the data, provide a narrative on the modifications made to the Jigsaw classroom, and present an overview and discussion of the results.

2. Experimental Design, Materials and Methods

The study utilized a mixed-methods approach, integrating quantitative assessment results with a learner's satisfaction survey and qualitative word cloud analysis to gain an understanding of the impact of the Jigsaw teaching method. Two student groups participated in the study: the Jigsaw group (39 students) and the control group (31 students). The inclusion of both groups enables a comparative analysis to assess the impact of the Jigsaw teaching method. The participants were post-graduate students from various engineering departments, including Chemical Engineering, Civil Engineering, Mechanical Engineering, and Water Resources and Environmental Engineering. This diverse background enhances the generalizability of the study findings across different engineering disciplines. A pre-test was given to all the students to ensure that there was no bias in the allocation of students to the control and experimental jigsaw groups. The pretest consisted of 10 multiple-choice questions. The Likert scale was used to gather students' perceptions of the teaching methods and learning experiences. The IBM Statistical Package for Social Sciences (SPSS) software was employed for data analysis. An independent sample t-test was performed as part of the data analysis process. This statistical test is appropriate for comparing means between two independent groups operating under different conditions. The qualitative analysis was gathered through a learner satisfaction survey and analyzed using a word cloud analysis (WCA). The WCA allows for the visualization of frequently occurring words or themes in students' responses, providing a qualitative perspective on their experiences. The words that made up the word cloud were generated from the questions asked during the learner's satisfaction survey.

2.1 Treatment of the control and experimental groups

The control group was taught with the CACPLA teaching method described in Fig.1. Learning materials were distributed to students via their WhatsApp platforms. Students explored and interacted with the materials, collaborated as a unit, and engaged in problem-solving activities. Synchronous sessions were conducted, and assessments were performed based on learning outcomes.

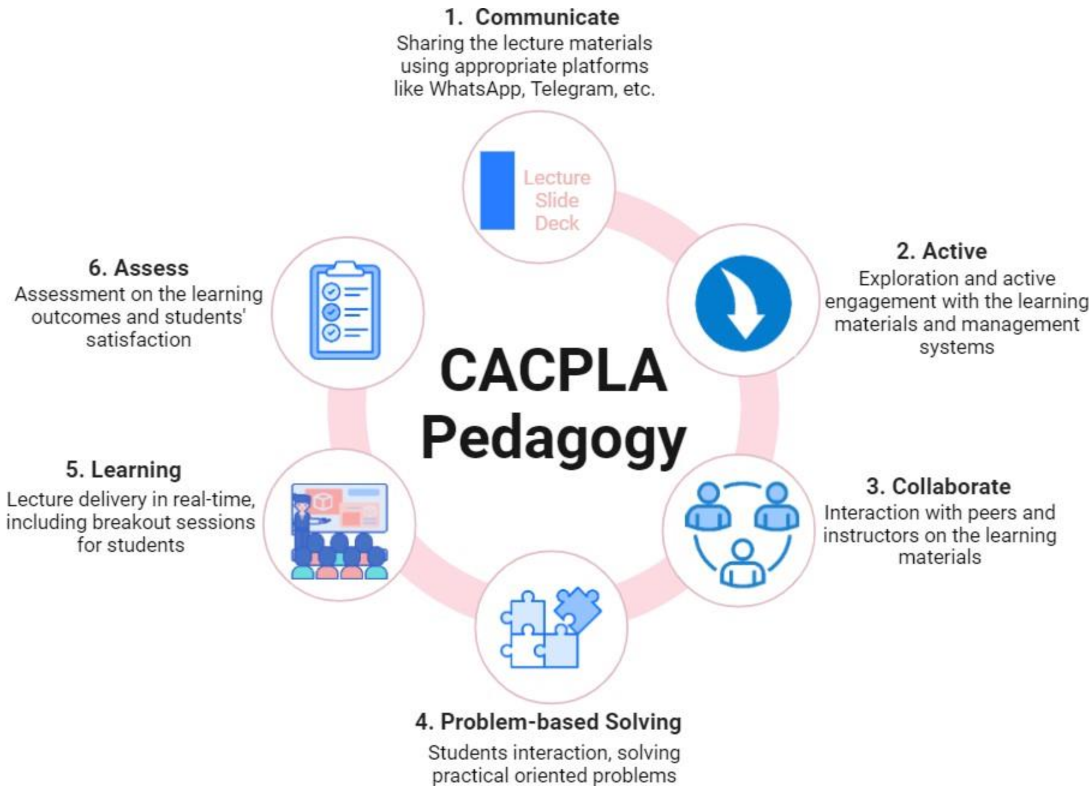

Figure 1: Schematic of the CACPLA teaching method [13]

The collaborate section of the CACPLA pedagogy was elaborated for the Jigsaw groups and several processes were implemented as described in Fig. 2 (a general schematic of the modified Jigsaw procedure adopted in the study). The 39 students in the jigsaw group were divided into home groups based on their pre-lecture test scores. Four of these groups consisted of 6 students each, while the remaining three groups had 5 students each to engage in discussion on different subtopics using the Jigsaw Strategy. This arrangement was made to accommodate the total number of students (n = 39) who participated in the pre-lecture assessments. The home groups then worked collaboratively on specific subtopics. Furthermore, assignments were assigned to each group. Each group was allocated a certain subtopic within the subject of elasticity as outlined in Table 1.

Table 1: Table showing the group and their corresponding topics

Group	**Topic**
1	Stress and Strain in Engineering Materials
2	Elastic Hysteresis
3	Hooke's Law
4	Stress Tensors
5	Bulk Modulus
6	Wheel Balance Application
7	Young Modulus and Constant of Elasticity

Each jigsaw home group was tasked with creating three PowerPoint slides that presented the key concepts of their assigned subtopics. When the slides referred to as "Jigsaw pieces" were combined by the champions from all the groups, they formed a complete picture of elasticity. These champions then collaborated across different groups to develop expert perspectives while ensuring alignment with the focus of their home group. After this collaborative process, the champions returned to their home groups to provide feedback from the other groups, enriching their content. Ultimately, they shared this enhanced learning with the entire class.

As part of the treatment for both groups, all students (control and experimental groups) were asked to view a video and review the downloadable slides located at: https://www.compmatphys.org/topics/elastic-constants- definition/. Following these activities, post-lecture and critical thinking tests were given to the two groups to assess their performance after the academic activities. Scores were recorded as percentages and used for quantitative analysis. The purpose of the Learner's Satisfaction Survey (LSS) was to assess students' perceptions of the effectiveness of the Jigsaw method.

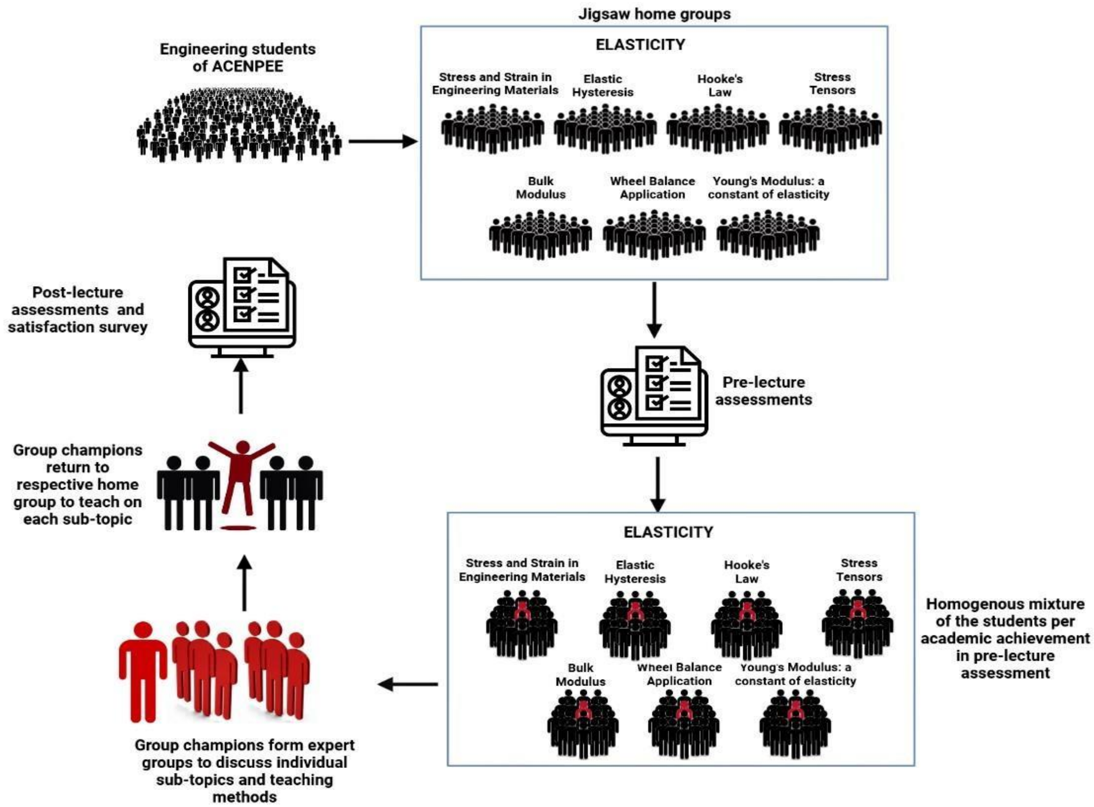

Figure 2: Schematic of the modified jigsaw classrooms integrated in CACPLA [14]

In Fig. 3, an initial perspective is established by comparing pre-lecture test scores and delineating the baseline knowledge levels of the jigsaw and control groups. The pre-lecture scores from the groups revealed a close trend in the student results, especially for the lowest score of 3 and the highest scores of 9 and 10. This demonstrates a close broad distribution of scores among each group, indicating that the groups comprised of students with varying levels of prior understanding.

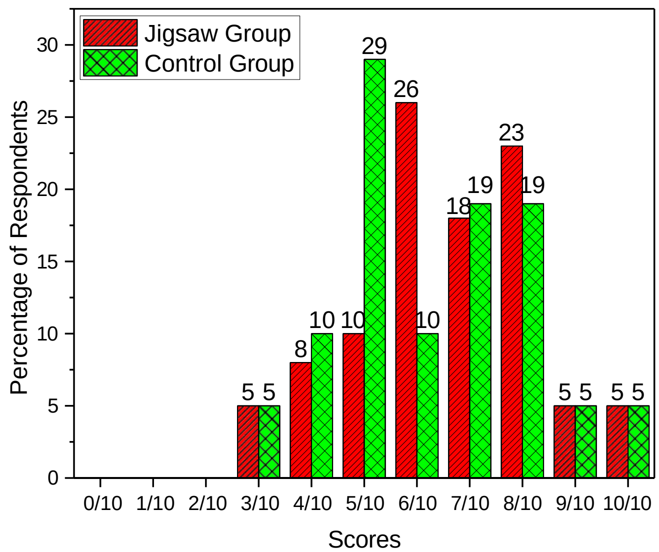

Figure 3: Comparison of the performance of the students of the groups for the pre-lecture test

3. Results and Discussion

The results presented in Fig. 4 demonstrate the positive impact of the Jigsaw classroom method on the students' academic achievement in the post-lecture test. The achievement scores depicts that the Jigsaw group outperformed the control group, with a greater number of students in the Jigsaw group achieving higher scores on the test. Notably, only students from the Jigsaw group received the highest possible score of 10. This finding suggests that collaborative learning, facilitated by the Jigsaw approach, enhances students' understanding of the concepts [15–17]. Additionally, the results imply that students teaching their peers reinforces their understanding, aligning with the saying, "to teach is to learn twice" [16,18]. It can be inferred that breaking down the topic of elasticity into subtopics and having students in home groups deliver, prepare, and discuss these subtopics outside of class greatly benefited those who had difficulty grasping the concept of elasticity. The interaction between students and the lecturer significantly reinforced the concepts learned during the Jigsaw activities. A larger percentage of students received scores between 8 and 10. Teaching and preparing to teach the material(s) encourage students to engage with the three-step theory of verbal learning. This theory includes paying attention to the material, making it personally relevant, and connecting it to previously stored information. These elements were likely enhanced during the lecture sessions. Therefore, the importance of the Jigsaw activities cannot be overstated. Research on cooperative learning has shown that students who benefit the most from collaborative activities are those who provide detailed and comprehensive explanations to their peers [19,20].

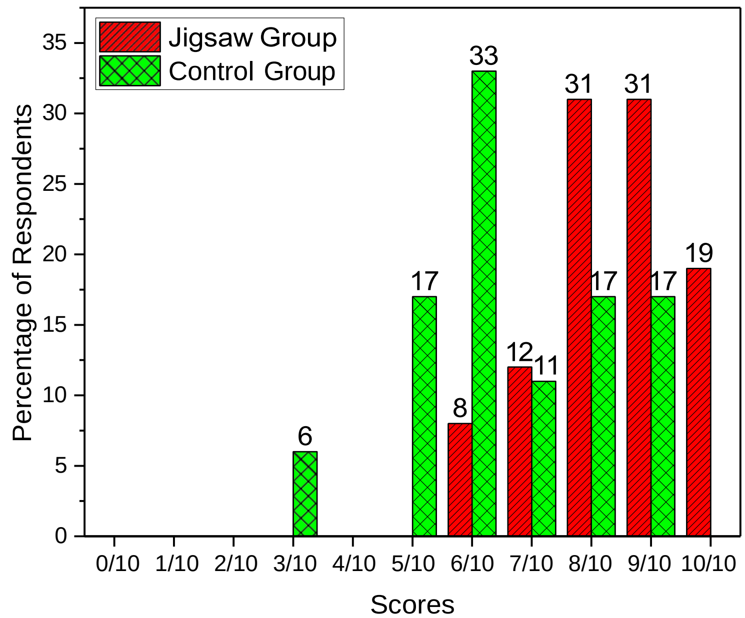

Figure 4: Comparison of the performance of the students for the post-lecture test

The critical thinking assessment is a vital component of the CACPLA teaching method which aims to develop problem-solving and independent thinking skills that are desirable in engineering students. Fig. 5 illustrates the test scores of different groups, highlighting the method's effectiveness in promoting higher-order cognitive skills. A critical thinking test measures students' abilities to apply concepts and engage in advanced thinking processes. The Jigsaw group performed better in the critical thinking test, demonstrating the method's success in enhancing students' learning. Specifically, 37% of the students in the Jigsaw group scored above 7 out of a total of 10, compared to only 28% in the control group. This outcome suggests that students in the Jigsaw group improved their capacity to analyze and apply knowledge to real-world situations by collaboratively combining various perspectives.

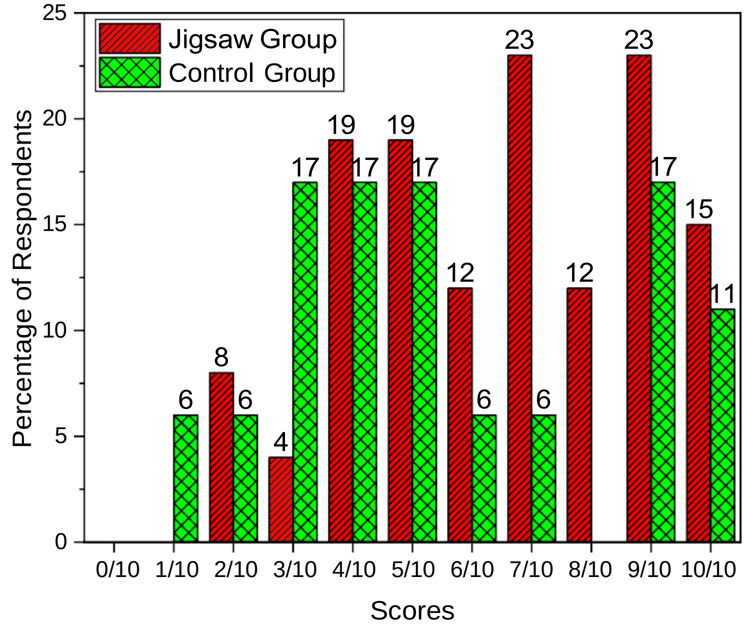

Figure 5: Comparison of the performance of the students of the groups for the critical thinking test

Fig. 6 presents a detailed overview of the LSS related to the implementation of the Jigsaw classroom teaching method within the CACPLA pedagogy. The survey focused on several key areas, including the effectiveness of the Jigsaw learning method in achieving educational outcomes, the ease of answering assessment questions after engaging with both group champions and home groups, and students' perceptions of the method and its potential applications in teaching materials science. The Likert scale was utilized to gather students' perceptions of teaching methods and learning experiences. The survey included questions regarding the effectiveness of the Jigsaw classroom method, assessment quality, time management, and its applicability to engineering courses. The positive responses from the LSS reaffirm the value of integrating the Jigsaw classroom method with the CACPLA framework. Students strongly agreed that the Jigsaw method was effective in achieving learning outcomes (question 1 [Q1]), and that validates its alignment with educational objectives. The satisfaction expressed with the post-lecture questions and collaborative approach (Q2) indicates the importance students place on engaging in active discourse and sharing knowledge. Furthermore, the affirmation that assessment quality, time management, and applicability to engineering courses were satisfactory (Q3-Q6) reflects the approach's potential to meet students’ learning needs and aspirations.

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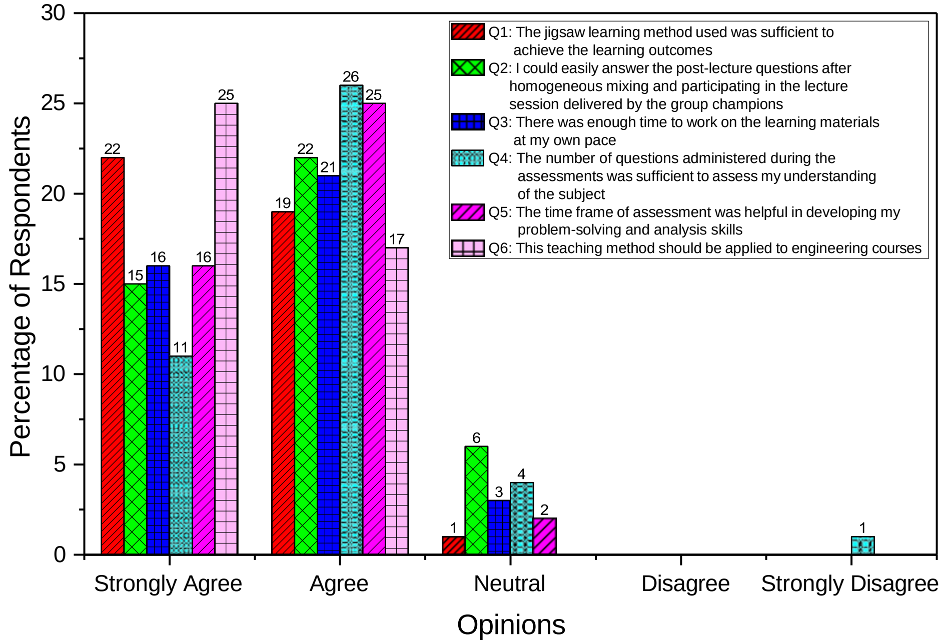

Figure 6: Learner's satisfaction survey

The word cloud analysis (Fig. 7) of student opinions captured recurring themes and sentiments related to the online learning experience. Prominent terms such as "opportunity," "engineering," "Jigsaw," "teaching," "learning," "time," and "thank" appeared frequently. This analysis highlights the positive aspects of the Jigsaw classroom method and its alignment with engineering education. The inclusion of "thank" suggests that students appreciated this innovative approach, possibly indicating gratitude for enhanced engagement and understanding.

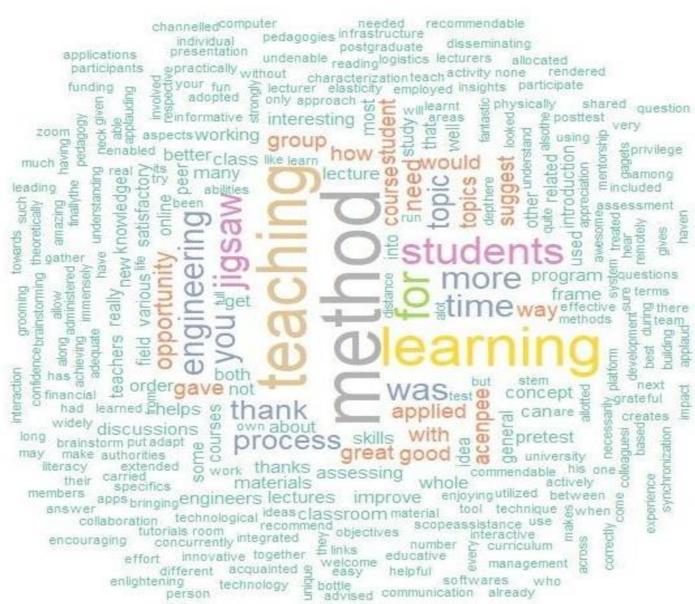

Figure 7: Word cloud analysis of the opinion of the students on teaching methods

The purpose of this research was to investigate the impact of Jigsaw classrooms on students' experiential learning. The hypothesis proposed that teaching a topic to peers would improve students' performance. The study's results supported this hypothesis, revealing several positive outcomes related to students' confidence, mastery, and understanding of the assigned Jigsaw topics. The improvements were influenced by collaboration with group members, as well as an increased ability to express complex ideas and assist peers in problem-solving. These findings are also supported by evidence regarding the impact of Jigsaw classrooms on experiential learning experience [2,21–23]**.**

3. Conclusion

Students may have challenges with some subjects in materials science because the traditional teaching method positions the teacher as the primary active participant while students remain passive listeners. This study employed cooperative learning, where students took on an active role and the teacher assumed a more passive one. The topic of elasticity was effectively taught using the Jigsaw method and it enhanced the students' understanding of the subject. The evaluation of answers to post-lecture and critical thinking sessions indicated that the Jigsaw method is an effective way to enhance students' knowledge of the subject. In conclusion, this method is beneficial for improving students' academic performance and clarifying misunderstandings about specific topics making students more engaged in their learning. The fact that students in the Jigsaw groups provided more correct answers to the test questions illustrates that they were able to share their knowledge, build on prior research, and actively participate in the learning process through both in-class and out-of-class discussions.

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