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From Engineers to Engineering Education Researchers: Using Jigsaw Learning to Build Theoretical Understanding among Graduate Students

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Abstract

Grounding research in a sound theoretical framework is identified as one of the most significant challenges for engineering education PhD students. Meeting this challenge requires students to understand and appreciate theories related to learning and learner development, enabling them to design theoretical frameworks that lead to rigorous engineering education research. This study implemented the jigsaw method where students become "experts" on specific topics and teach peers, transforming them from passive consumers to active constructors of theoretical knowledge through structured collaboration. Two jigsaw learning cycles were conducted, with each cycle spanning three weeks. Students (n=5) were assigned readings and required to prepare individual reading notes before meeting in expert groups to discuss their understanding, co-create concept maps, and plan their teaching approach. Between sessions, the instructor provided feedback on reading notes and concept maps. Students then regrouped into jigsaw home groups where each expert taught their topic to peers using visual organizers, after which students engaged in group processing and completed individual reflections. To explore how jigsaw learning supports graduate students' learning, student perceptions were collected using a survey comprising Likert-scale and open-ended items. Findings revealed that 80% of the students found the jigsaw method to be an effective learning strategy, identifying expert group discussions, the opportunity to teach peers, and learning from diverse perspectives as valuable design features that supported their learning. While one student's resistance underscores that no instructional method works for all learners, the positive evaluation and identification of specific design features demonstrate that jigsaw learning provides an effective, replicable approach for addressing a critical pedagogical challenge in engineering education PhD preparation. This study contributes both empirical evidence of the jigsaw method's effectiveness for complex theory learning and practical guidance on essential design elements, equipping instructors who seek to implement student-centered learning approaches to support their students' theoretical development.

Introduction

Engineering faculty members typically enter academia with little formal preparation in pedagogy and learning sciences, relying instead on their own educational experiences when designing instruction [1, 2]. These challenges intensify when they engage in engineering education research, as faculty and engineering education students lack awareness of theoretical frameworks, measurement techniques, and research methods central to educational inquiry [3]. Engineering research typically relies on scientific laws to design and test physical or computational systems, while educational research examines human learning and behavior, requiring explicit theoretical frameworks to focus investigations on factors most likely to affect outcomes and to interpret results within broader scholarly conversations [1]. Deep understanding of theoretical foundations is essential for educational research and pedagogical decisions. Without such understanding, faculty risk creating 'lethal mutations', adaptations of evidence-based practices that reduce or negate their intended effectiveness [4].

To address these challenges, the course ENE 505 Developmental Theories and Engineering Thinking was designed to systematically develop engineering graduate students' theoretical understanding before they conduct engineering education research or assume faculty positions. The course explores how learning theories offer frameworks for understanding how individuals acquire knowledge across diverse contexts. By engaging directly with seminal works by foundational scholars, students trace how theories emerged in response to authentic problems within specific educational and cultural contexts, gain access to the reasoning, empirical evidence and contextual factors that shaped theoretical development. This direct engagement helps students understand not just what theories claim, but why they make those claims and under what conditions they apply.

However, engineering educators and engineering education students often report that educational theories and research literature are articulated using disciplinary conventions, theoretical language, and epistemological assumptions that differ substantially from engineering discourse, creating conceptual and linguistic barriers to engagement [5]. Given these challenges, developing deep theoretical understanding requires carefully designed pedagogical approaches. Traditional lecture-based approaches are insufficient for bridging this gap. Instead, two key principles guided our course design: (1) students must actively construct understanding by engaging extensively with scholarly literature rather than passive recipients of information, and (2) the course must leverage the diverse engineering expertise, teaching experiences and learning histories that graduate students bring to the classroom.

Engineering graduate students represent valuable intellectual assets in the learning process, as their varied engineering expertise, teaching experiences and learning histories can inform interpretations of educational theories, particularly within engineering education contexts. We structured the course around cooperative learning principles, in which students share diverse perspectives and collectively co-construct meaning through structured dialogue. Specifically, we employed the jigsaw method [6] with the aim of developing the theoretical understandings needed to address the practice gap documented above. Our work directly addresses recommendations from national reports calling for improved engineering education through evidence-based approaches. By equipping graduate students to ground research in educational theories and principles, this approach has the potential to enhance the overall quality and theoretical rigor of engineering education research.

Literature Review

The Jigsaw method, developed by Aronson et al. [6], is a cooperative learning approach that has demonstrated effectiveness across diverse educational contexts. In the original Jigsaw model, students are divided into small groups where learning experiences are structured to encourage peer interaction and collaborative learning. As the name suggests, each student in the home group holds an important piece of the puzzle (i.e., the learning material) and must become familiar with their assigned content individually before transitioning to an "expert group". The expert group comprises members from different home groups who have been assigned the same learning material. Within these expert groups, members collectively master the content and devise strategies for teaching it to their respective home groups. Subsequently, each student returns to their home group to teach peers about their assigned material. Upon completion of the jigsaw activity, all members of the home group should have gained a comprehensive understanding of the entire topic. Students may be assessed individually to determine their understanding of the materials.

The jigsaw method has attracted considerable research attention due to its relatively straightforward implementation and adaptability to diverse classroom settings [7]. By creating an interdependent learning environment that requires students to contribute and rely on peers for complete understanding, empirical studies have documented positive outcomes across multiple domains, including cognitive outcomes, social relations, and affective outcomes [8]. Empirical support for jigsaw method effectiveness on academic achievement spans multiple disciplines. In medical education, Moin et al. [9] conducted a quasi-experimental study with 80 medical students, finding that jigsaw instruction produced significantly higher achievement in a multiple-choice-questions assessment compared to a control group. In engineering education, Patil and Kumbhar reported that students' performance increased by 15% compared to students from a previous batch without using jigsaw method [10]. Meta-analytic evidence presents a mixed picture of jigsaw's effectiveness on academic achievement. Vives et al.'s systematic review found beneficial effects in 60% of studies overall. Disciplinary variation was substantial; positive effects were observed in 73% of language arts and social sciences studies but only 55% of STEM studies and 42% of vocational education studies [11]. Drawing on earlier work by Aronson and Patnoe [12], Vives et al. suggest that the jigsaw method may be better suited to subjects involving narrative or textual content [11], where semantic knowledge acquisition predominates over complex problem-solving or cognitively demanding procedural tasks.

Regarding affective outcomes, jigsaw method shows promise though evidence remains inconclusive. While Aronson and Bridgeman demonstrated enhanced self-esteem among minority students [7], Vives et al.'s recent meta-analysis found a small, nonsignificant pooled effect with only two of six reviewed studies reporting positive effects [11]. Evidence for motivational outcomes is more encouraging. Sanaie et al. demonstrated that jigsaw significantly improved nursing students' academic motivation compared to traditional lecture methods [13], while Muhammad reported enhanced motivation and more positive subject-specific attitudes [14].

Beyond academic and affective outcomes, jigsaw's cooperative structure theoretically supports development of essential teamwork and communication competencies alongside academic learning. Jeppu et al. reported significant improvements across multiple social dimensions following jigsaw implementation, including individual accountability, promotive interaction, positive interdependence, interpersonal skills, communication skills, and consensus-building abilities [15]. However, realizing these social benefits requires careful facilitation. Zacharia et al. caution that poorly implemented jigsaw sessions may generate mistrust and communication difficulties among group members [16], underscoring the importance of explicit instruction in collaborative skills and ongoing monitoring of group dynamics. While medical and nursing education dominate the jigsaw literature, recent interest has emerged in engineering contexts, where educators recognize jigsaw's potential for simultaneously developing technical knowledge and the teamwork competencies demanded by accreditation standards and industry [17].

Over the years, the jigsaw method has been adapted, and several variations have been developed to extend its pedagogical applications. Notably, Slavin introduced Jigsaw II [18], which incorporated two major modifications to Aronson's original design. First, rather than assigning each student a unique segment of material, all students receive the complete learning material, with each student assigned responsibility for mastering and teaching a specific section. Second, Jigsaw II incorporates individual quizzes following peer instruction in home groups, with individual scores contributing to team scores, similar to the Student Teams-Achievement Divisions (STAD) model. These modifications represent a shift from Aronson's original emphasis on social interdependence and interracial harmony toward a more competitive, achievement-oriented framework. This evolution demonstrates the jigsaw method's adaptability across diverse educational objectives. However, such modifications necessitate careful consideration of which variant aligns with specific instructional goals and learner populations.

In summary, the jigsaw method demonstrates substantial empirical support as an effective cooperative learning strategy with flexibility to be adapted across diverse educational contexts. While the method has been extensively studied in K-12 and healthcare education settings, its application to graduate-level professional development remains largely unexplored. Many professional contexts, particularly in engineering education, require practitioners to develop deep understanding of theoretical frameworks and research capacity from disciplines outside their technical training. The present study addresses this gap by examining whether the jigsaw method can effectively scaffold engineering education graduate students' learning of educational theories. This application leverages jigsaw's documented strengths with conceptual content while extending the method to a professional development context where learners with diverse experiences transition from technical disciplines to engage with unfamiliar theoretical content, leveraging their varied perspectives as cognitive resources for collective meaning-making.

Theoretical Framework

This study draws on social constructivism [19] as the primary theoretical foundation. Social constructivism posits that learning is fundamentally a social process in which individuals construct knowledge through interaction and dialogue with others. The jigsaw method operationalizes this theory by creating a community of learners where students with diverse backgrounds engage in structured collaboration to collectively construct understanding of educational theories. To design effective cooperative experiences when employing jigsaw method, we draw on Johnson and Johnson's social interdependence theory [20]. Five essential elements of effective cooperative learning were derived from the theory: (1) positive interdependence, (2) individual accountability, (3) promotive face-to-face interaction, (4) social skills, and (5) group processing. When we designed the jigsaw learning experience, these theoretical principles were translated into actionable design features, ensuring that cooperative structures produce genuine collaboration rather than superficial group work.

Methodology

This study examined graduate students' experiences with the jigsaw method for learning educational theories. Specifically, we investigated:

1. To what extent graduate students perceive the jigsaw method as effective for learning educational theories?
2. What aspects of the jigsaw design do students identify as most valuable for their learning?

Participants

This study was conducted in ENE 505: Developmental Theories and Engineering Thinking, a graduate-level course designed to develop students' theoretical understanding and awareness before they conduct engineering education research or make pedagogical decisions. The 3 credit hour course met weekly for 150 minutes over a 15-week semester in Fall 2025. Five graduate students enrolled in the course, including two master's students and three doctoral students. To ensure balanced group sizes for effective jigsaw implementation, an additional engineering graduate student was invited to participate in the jigsaw learning activities.

Implementation of Jigsaw Method

The course implemented two complete jigsaw cycles, each lasting 3 weeks and focused on different set of educational theories. The first cycle, which started on week 4, focused on the key educational theorists and their seminal works, while the second cycle, which started on week 7, focused on motivational theories. To maximize the impact of the jigsaw method, two cycles of jigsaw were implemented. Johnson and Johnson [20] suggest single exposure may not allow students to internalize cooperative learning behaviors as students require time and practice to develop effective collaborative skills. On the other hand, implementing two cycles provided a metacognitive learning opportunity that enabled students to identify areas for improvement and deliberately apply those insights during second cycle.

Each cycle followed an identical three-phase structure designed to scaffold students' progression from individual comprehension to collaborative expertise development to peer teaching. Table 1 provides an overview of the three phases and their corresponding activities and deliverables.

Table 1. Overview of the three phases in Jigsaw

Phase	Key Activities	Deliverables
Individual Preparation	• Assigned to expert group (2 members) and teaching group (3 members) • Read assigned primary sources • Prepare individual notes with questions	Individual reading notes
Expert Group	• Discuss theory in expert groups using structured prompts • Clarify confusions • Devise teaching plan • Create shared concept maps and submit for instructor feedback	Shared concept map or graphic organizers
Home Group	• Review instructor feedback on concept map • Teach theory to peers (approximately 90 minutes) • Instructor facilitates as needed • Peer feedback: Plus-delta • Individual reflection	Individual reflection

At the beginning of each jigsaw, students were assigned to both a home group and an expert group. Rather than random assignment, the instructor intentionally composed groups to optimize learning conditions. This approach aligns with research suggesting that heterogenous grouping for cognitive diversity produces stronger collaborative outcomes [20]. Group membership changed between Cycle 1 and Cycle 2. The instructor employed strategic assignment for Cycle 2 groups, but with different configurations based on observations from Cycle 1 to expose students to diverse perspectives and allow them to apply learning from Cycle 1 with new group members.

Each member in the home group was assigned seminal primary source readings that focused on key educational theorists (Cycle 1) and motivational theories (Cycle 2). When students are required to read more than one article, the reading lengths of assigned articles were balanced to ensure the students received approximately equal amounts of material. Students prepared individual reading notes guided by structured prompts designed to scaffold their engagement with complex theoretical texts.

In the following week, students came to the expert group sessions with their notes and questions prepared, establishing individual accountability before collaborative work began. Expert groups met during class time to collectively deepen their understanding of the assigned theory. During expert group discussions, students clarified conceptual confusions, negotiated divergent interpretations of the primary sources, and co-constructed shared expertise for later dissemination to their home groups. Throughout these discussions, the instructor circulated among groups to provide facilitative support.

Following their discussions, expert groups collaboratively created a concept map or visual organizer to visually represent the key concepts, relationships and connections in the assigned scholarly publications. Groups were encouraged to devise a teaching plan for instructing their peers in their respective home groups. After that, expert groups submitted their concept maps or graphic organizer which the instructor reviewed and provided written feedback focusing on accuracy of theoretical representation and completeness of key concepts. This feedback loop ensured expert groups had accurate understanding before teaching their peers, thereby preventing the transmission of misconceptions.

During the third week, home groups met during class time for peer teaching. Each member of the home group taught their assigned theory to the other members. Teaching sessions were student-led, with the instructor serving as a facilitator when needed. Student experts employed various strategies, including fill-in-the-blank concept map, interactive questioning, connecting theories to their experiences and creating analogy to engage their peers and subsequently enhance their comprehension. These strategies emerged from students' teaching experiences and were refined from Cycle 1 to Cycle 2 based on plus-delta feedback. While teaching sessions were student-led, the instructor circulated between jigsaw groups to monitor for accuracy of theoretical representation, prompt deeper thinking through probing questions and clarify misconceptions when necessary.

Immediately following the teaching sessions, students engaged in structured group processing using the plus-delta approach. Students provided written feedback identifying what went well (plus) and what could be improved (delta) for both their expert group and their home group teaching and learning experiences [21]. This metacognitive reflection encouraged students to recognize effective collaborative practices and identify areas for improvement. The jigsaw learning cycle concluded with students' individual reflection, wherein each student completed a written reflection guided by prompts to consolidate learning from the peer teaching experience.

Data Collection and Analysis

This study collected data to examine students' perceptions of jigsaw effectiveness. At the conclusion of the semester, students completed an anonymous survey containing both Likert-scale items and open-ended questions. Likert items (5-point scale from Strongly Disagree to Strongly Agree) assessed students' perceptions of jigsaw's effectiveness for learning theoretical content and engaging with complex readings, as well as their ratings of specific design features (expert group discussions, peer teaching, learning from peer). Open-ended questions prompted students to identify which design features most supported their learning, and what improvements they would recommend for future course offerings. This survey served as our primary data source for addressing the research questions about student perceptions. Quantitative data were analyzed using descriptive statistics. Open-ended responses were summarized, with selected quotes included to represent the range of student perspectives.

Findings

The section reports findings from an anonymous end-of-semester survey administered to all enrolled students (n=5, 100% response rate) examining their perceptions of the jigsaw method for learning educational theories. Findings are organized to address the two research questions. First, students' perceptions of jigsaw learning effectiveness through descriptive statistics (RQ1) were reported. Second, the specific aspects of jigsaw learning instructional design that students found most valuable were identified, using quantitative statistics as the primary evidence supplemented by relevant student comments from open-ended responses (RQ2).

RQ 1: To what extent graduate students perceive the jigsaw method as effective for learning educational theories?

To answer RQ 1, graduate students rated their agreement with seven statements about different aspects of jigsaw learning effectiveness using a 5-point Likert scale. These items assesses their perceptions of jigsaw learning's impact on cognitive outcomes, social outcomes and overall evaluation. Table 1 presents descriptive statistics and frequency distributions for all seven items.

Table 1. Student Perceptions of Jigsaw Learning Activities (N = 5)

Survey Items	**Mean**	**SD**	**1 (SD)**	**2 (D)**	**3 (N)**	**4 (A)**	**5 (SA)**
Q1: The jigsaw activities helped me critically analyze key theories.	4.0	1.22	0 (0%)	1 (20%)	0 (0%)	2 (40%)	2 (40%)
Q2: Becoming an "expert" deepened my understanding more than lectures.	4.0	1.22	0 (0%)	1 (20%)	0 (0%)	2 (40%)	2 (40%)

Q3: Teaching peers enhanced my ability to synthesize knowledge.	4.2	1.10	0 (0%)	1 (20%)	0 (0%)	1 (20%)	3 (60%)
Q4: Learning from peers exposed me to diverse perspectives.	4.2	1.10	0 (0%)	1 (20%)	0 (0%)	1 (20%)	3 (60%)
Q5: Expert group discussions helped me collaborate effectively.	4.4	1.14	0 (0%)	1 (20%)	0 (0%)	1 (20%)	3 (60%)
Q6: Jigsaw structure was effective for learning complex content.	3.8	1.64	1 (20%)	0 (0%)	0 (0%)	2 (40%)	2 (40%)
Q7: I would recommend continuing jigsaw activities.	4.0	1.58	1 (20%)	0 (0%)	0 (0%)	1 (20%)	3 (60%)

Note: SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

Graduate students predominantly perceived the jigsaw method as an effective approach for learning educational theories, with 80% of students rating the method positively across all measured items. Four in five students (80%) reported that jigsaw learning activities helped them critically analyze key theories in the course (M = 4.0, SD = 1.22) and deepen their understanding when they were assigned the ‘expert’ role (M = 4.0, SD = 1.22), which required them to engage more deeply with the assigned readings. Similarly, graduate students in the expert role indicated that the activities encouraged them to synthesize knowledge (M = 4.2, SD = 1.10) and extract meaningful information from complex theoretical texts. These findings suggested that students valued jigsaw learning activities for developing their content understanding and critical thinking which are essential cognitive outcomes for graduate-level coursework.

The majority of students (80%) perceived that learning from peers during jigsaw learning activities exposed them to diverse interpretations and applications of learning theories (M = 4.2, SD = 1.10). Students brought varied disciplinary backgrounds, teaching experiences and learning histories, offering multiple lenses for understanding theoretical concepts. The jigsaw learning activities were intentionally designed to enable students to construct knowledge collaboratively. The findings corroborate this intention, the majority of the students (80%) agreed that they collaborated more effectively in small group setting (M = 4.4, SD = 1.14). This suggests that students co-constructed understandings through collaborative dialogue in expert group discussions, where they negotiated meaning and built shared interpretations of complex theories. Overall, students perceived jigsaw learning activities as effective for learning complex theoretical content (M = 3.8, SD = 1.64) and recommended that this instructional approach be sustained in future course offerings (M = 4.0, SD = 1.58).

Nevertheless, not all students viewed the jigsaw method as beneficial to their learning. One student consistently disagreed that jigsaw method helped him/her develop understanding and other competencies measured in the survey. This consistent pattern of negative ratings across all items suggests that this student’s concerns were not limited to specific design features in jigsaw learning but reflected a more fundamental incompatibility between the method and his/her learning needs or preferences. Notably, this student provided no explanation for his/her negative perceptions in open-ended responses, making it difficult to identify the specific barriers he/she experienced. Possible explanations for such resistance to jigsaw learning, drawn from the cooperative learning literature are explored in the discussion section.

RQ 2: What aspects of the jigsaw design do students identify as most valuable for their learning?

The second research question focuses on understanding which design features students believed made the method effective. This study utilized two data sources: (1) students' ratings of the jigsaw structure and (2) open-ended comments explaining which specific features supported their learning and why these features were valuable. Expert group discussion was identified as the most valued feature that facilitated their learning (M = 4.4), students' comments from open-ended responses also highlighted the significance of expert group discussions. Students appreciated having dedicated time to discuss theories with a peer studying the same content before teaching others. One student specifically noted the value of expert discussions for perspective-taking:

"The jigsaw activities were very helpful, especially in our expert discussion because I was able to understand the theory a little bit better from a different perspective."
(Respondent 001)

Students also valued the teaching component of jigsaw activities (M = 4.2), with 60% selecting "strongly agree" that teaching peers enhanced their ability to synthesize theoretical knowledge. In the jigsaw learning activities implemented, students assumed responsibility for teaching their assigned content to their peers, which required them to synthesize complex theoretical content, organize it coherently for presentation, articulate concepts in accessible ways and create examples or analogies to facilitate peer comprehension. The positive ratings suggest that students perceived these teaching demands enhanced their own learning.

Learning from peers' expert presentations also received high ratings (M = 4.2), students appreciated hearing how peers with different backgrounds and experiences interpreted and applied theories. One student explicitly highlighted diverse perspectives:

"I enjoyed the class discussions in this class and seeing all the different perspectives. These discussions helped me understand the learning theories better than just reading them."
(Respondent 001)

While not directly measured in Likert items, multiple students emphasized that jigsaw worked effectively in combination with other activities rather than as standalone exercises. One student described the progressive building of understanding across activities:

"The way the activities built on each other (jigsaw activity to make a concept map, then reflect on the theories) really helped me deepen my understanding." *(Respondent 005)*

Another student highlighted the integrated learning activities supported their learning effectively:

"The use of concept maps, jigsaw activities, the class discussions and the reflections were great to learn and understand these theories." *(Respondent 001)*

From the open-ended responses, student's metacognitive awareness was observed. One student demonstrated metacognitive awareness by recognizing jigsaw method's transferability and suggesting future applications:

"I was wondering if reviewing theoretical frameworks from research articles maybe as a jigsaw activity could help students grasp how researchers use theories." (Respondent 005)

This quote indicated that this student not only experienced jigsaw method as an effective instructional approach but also understood why they worked and where else they could be applied. He/she recognized that if jigsaw help learn theories from primary sources, they could also help analyze how researchers construct and present theoretical framework collaboratively. While only one student explicitly articulated this awareness, it suggests that jigsaw learning activities can foster reflection on learning processes themselves, aligning with the course's goal of developing students' understanding of how people learn.

Discussion

To address the persistent learning challenges among engineering education graduate students, this research aims to examine the effectiveness of cooperative learning approach – jigsaw method in facilitating students' learning of educational theories, and identify which aspects of the instructional design played a significant role in scaffolding their learning. A survey comprising both Likert-scale and open-ended items was used to examine students' perceptions of the learning method, as students' perceived value of learning activities influences their engagement, motivation and willingness to invest cognitive effort [22] which directly contribute to their learning process. Additionally, student perspectives provide insights into implementation effectiveness that may not be captured through performance measures alone, revealing which design features meaningfully support learning and make the learning more accessible to students [23].

The findings of the study indicated that majority of the students (80%) rated the jigsaw method as effective approach which not just developed their content understanding as well as enhanced their competencies in critical analysis, synthesizing meaningful ideas, and exposed them to diverse perspectives. Our findings align with a subset of evidence in Cochon Drouet et al.'s systematic review [8]. Among 48 studies on student achievement, 18 specifically examined student perceptions, with majority reporting that students perceived improvements in learning. For example, Tarhan et al. found 83% of students believed they were meeting learning objectives [24], and Aydin and Biyikli found 33% perceived tasks as easier under jigsaw conditions [25]. These positive remarks can be understood through a social constructivist lens. Vygotsky [19] argued that learning is fundamentally a social process in which knowledge is co-constructed through dialogue and collaborative meaning-making. In the expert groups, students were not simply receiving information but actively negotiating understanding with peers studying the same theoretical content. The expert group discussions created what Vygotsky termed a "zone of proximal development" [19], where peers supported each other in reaching levels of understanding that might have been difficult to achieve independently.

Among the design features that scaffolded students' learning, learning from peers received high ratings ($M = 4.2$), with students reporting that peer discussions helped them understand educational theories from diverse perspectives. Students explicitly valued hearing from different viewpoints and noted that peer discussions enhanced their comprehension of theories beyond what they achieved through reading alone. The multiple lenses that students brought to discussions reflect a key principle in cooperative learning research [20], they found that heterogenous grouping, particularly diversity in perspectives, experiences and approaches, consistently produces stronger learning gains than homogenous grouping.

Students highly valued the opportunity of becoming an expert (M = 4.0) and teaching peers (M = 4.2) in jigsaw activities. These findings reflect two core principles of effective cooperative learning that must work in concert: individual accountability and social interdependence [20]. The jigsaw structure creates positive interdependence through its fundamental design, each student becomes the expert on a different theory, making them the sole source of that content for their home group. This creates what Johnson and Johnson [20] call “resource interdependence”, students literally depend on each other for access to the full course content. In this way, students’ learning goals become linked, individual success requires all group members successfully master and teach their assigned content. Simultaneously, the teaching requirement creates strong individual accountability. The teaching role not just required students for learning content, but for learning it deeply enough to make it teachable. Research confirms that students feel their learning is enhanced when teaching others [26], precisely because the teaching responsibility demands synthesis of complex material, coherent organization and clear articulation that transform superficial familiarity into robust understanding.

Although metacognitive awareness was not explicitly measured in the survey, evidence of its development emerged from students’ open-ended responses. One student demonstrated metacognitive awareness by suggesting that the jigsaw method could be transferred beyond learning theoretical content to analyzing theoretical frameworks in educational research articles. This observation reveals that the student recognized not only that jigsaw facilitated their learning but also why it was effective and where else it could be applied. This finding aligns with research showing that jigsaw implementation can significantly enhance students’ metacognitive awareness [27]. The structure of jigsaw method inherently promotes metacognitive processes. Preparing to serve as the expert on an assigned task requires students to plan how they will learn, organize and subsequently explain the content, all these activities demand students to utilize metacognitive planning and self-monitoring. Moreover, students need to alternate between learner and teacher roles in jigsaw learning. This role alternation creates opportunities for metacognitive reflection. As learners, students experience different teaching approaches from their peers, allowing them to observe which strategies facilitate their own understanding. As teachers, they experiment with instructional strategies and receive immediate feedback on their effectiveness. Changing between roles promotes awareness of what constitutes effective learning and helps students identify which approaches work best for their own learning needs.

Although the majority of the students rated the jigsaw method positively, one student consistently disagreed that the method supported his/her learning. This student provided no explanation in the open-ended responses, limiting our ability to identify specific barriers encountered. Research suggests multiple possible explanations for resistance to cooperative learning in higher education. Students may resist due to beliefs about learning, concerns about fairness and grades, negative past experiences with group work and social or emotional factors [28]. High-achieving students in particular may experience frustration when perceiving they must carry less motivated peers, viewing this as unfair and demotivating [29]. This frustration reflects perceived inequity [30]. When high-achieving students invest substantial effort while perceiving minimal peer contribution, they experience an imbalance between their inputs and outcomes. Additionally, high-achieving students may perceive peer discussions as less efficient than instructor-led discussions, reasoning that engagement with an expert provides greater depth, nuance and accuracy than peer exchanges.

The jigsaw method incorporated several design features to address common sources of resistance to cooperative learning: individual accountability (each student was the sole expert on specific content), expert group discussions providing scaffolding that prepared them for peer teaching and instructor's facilitation and feedback on concept maps ensured accuracy before students taught their peers. Despite these intentional design considerations proving effective for the majority, student resistance is common in cooperative learning implementation, resistance can occur even when the implementation is strong. This finding should reassure instructors that encountering one or two resistant students does not indicate flawed design or poor facilitation. Rather, it reflects the reality that individual differences in learning preferences, prior experiences, pedagogical beliefs or life circumstances, mean some students will genuinely struggle with collaborative structures regardless of design quality. For instructors implementing cooperative learning strategies such as jigsaw learning, this suggests two things. First, anticipate that while majority of the students will benefit from well-designed instructional activities, a small minority may resist or struggle. Second, this resistance should not be interpreted as reason to abandon the method; rather, it may call for instructional flexibility, such as offering additional support for students who need more scaffolding to engage productively with student-centered learning.

Conclusion

This study examined graduate students' perceptions of jigsaw method for complex educational theories in a graduate-level engineering education course, revealing that the majority of the students rated the method positively, with expert group discussions, individual accountability through teaching and learning from peers with diverse perspectives identified as most valuable design features. While one student's resistance underscores that no instructional method works for all learners, the strong overall endorsement demonstrates well-designed jigsaw learning effectively supports students' learning. For instructors implementing cooperative learning, these findings demonstrate that encountering resistance from a small minority is normal and does not indicate pedagogical failure, but rather reflects inevitable individual variation in a diverse student population. The design framework employed in this study offers a replicable model that other instructors can adapt to their own course and content areas without requiring specialized resources or extensive preparation. By demonstrating both empirical evidence of jigsaw learning's effectiveness and a practical, replicable design framework, this study provides instructors with the insights and tools needed to implement student-validated cooperative learning to improve student outcomes in their own graduate course.

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