Chapter 2

The Application of the Cooperative Catalyst Method (C2M) in Diverse Subject Areas and Interdisciplinary Instruction

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This study introduces the Cooperative Catalyst Method (C2M), an instructional approach designed to support interdisciplinary learning through cooperative learning and social constructivist principles. In C2M, trained students act as catalysts who facilitate peer learning within heterogeneous groups. The method consists of four stages: selecting catalysts, forming groups, identifying disciplinary subtopics, and implementing instruction, with assessment conducted through tests and interviews.The study demonstrates the application of C2M in Chemistry, Social Studies, Geography, and Science courses using interdisciplinary topics such as gases, climate change, weather phenomena, and force and motion. By promoting active participation, collaboration, individual responsibility, communication, and critical thinking, C2M aims to improve academic achievement, conceptual understanding, knowledge retention, and interdisciplinary thinking. The findings indicate that C2M provides a flexible and effective framework for meaningful learning in contemporary education.

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1. Cooperative Learning

Cooperative learning is a student-centered instructional approach in which learners work collaboratively in small, heterogeneous groups to achieve shared academic objectives. This approach is grounded in the assumption that learning becomes more effective when students actively interact with one another, explain concepts to their peers, and assume responsibility for both their own learning and the learning of other group members (Doymuş, 2008). Active participation in discussion, inquiry, and collaborative problem-solving processes contributes significantly to the development of deeper conceptual understanding. Numerous studies have demonstrated that cooperative learning enhances academic achievement, long-term retention, and positive attitudes toward learning more effectively than traditional teacher-centered instructional methods.

The theoretical foundation of cooperative learning is primarily based on Lev Vygotsky's social constructivist theory of learning. According to Vygotsky, knowledge is constructed through social interaction and dialogue. With the assistance of peers, students are able to achieve cognitive development within the Zone of Proximal Development at levels that they could not attain independently. Building upon this theoretical framework, Johnson and Johnson (1999) identified five essential components of an effective cooperative learning environment: positive interdependence, individual accountability, promotive interaction, social skills, and group processing. Similarly, Doymuş (2007) emphasized that these components are fundamental for ensuring meaningful participation and effective collaboration among group members.

Positive interdependence constitutes the core principle of cooperative learning. This principle emerges when students perceive that their individual success is directly linked to the success of the group as a whole. Consequently, a sense of shared responsibility and mutual support develops among group members. Students recognize that achieving group goals requires cooperation and assistance among all participants. Doymuş (2008) reported that positive interdependence significantly increases student motivation and strengthens cooperative behaviors, particularly in science and chemistry education contexts.

Individual accountability refers to the responsibility of each student to master the learning material and contribute actively to group tasks. In the absence of this principle, some students may remain passive and become overly dependent on other group members. Teachers can enhance individual accountability by assigning specific roles, conducting individual assessments, and systematically monitoring participation within groups. Slavin (2014) emphasized that individual accountability is one of the most important factors influencing the positive effects of cooperative learning on academic achievement. Similarly, Doymuş (2010) found that students' academic performance and sense of responsibility improve significantly when each learner is held individually accountable throughout the learning process.

Cooperative learning is a student-centered instructional approach in which learners work collaboratively in small groups to achieve shared academic goals. One of the fundamental components of this approach is promotive interaction, a process in which students engage in face-to-face communication and actively encourage and facilitate one another's learning efforts. During this process, students explain their ideas, provide feedback, question reasoning, and construct new knowledge based on their peers' contributions. Such interactions foster higher-order thinking skills and promote conceptual change. Doymuş (2007) demonstrated that promotive interaction is particularly effective in eliminating misconceptions in chemistry instruction, where abstract concepts are common. Furthermore, this process contributes significantly to the development of students' communication and interpersonal skills.

A variety of structured techniques are employed within cooperative learning, including the Jigsaw method, Student Teams–Achievement Divisions (STAD), Team-Games-Tournament (TGT), and Group Investigation. Although these techniques organize student interaction in different ways, they all maintain the core principles of cooperative learning. Doymuş (2008) reported that the Learning Together and Reading–Writing–Application methods significantly improved students' academic achievement and conceptual understanding in science education.

One of the most significant advantages of cooperative learning is its positive effect on academic achievement. Numerous studies have shown that students taught through cooperative methods outperform those taught through traditional lecture-based instruction. Doymuş (2008) demonstrated that cooperative learning substantially enhanced students' conceptual understanding of challenging topics such as chemical equilibrium. In addition, meta-analytic studies conducted by Slavin (2014) confirmed that cooperative learning leads to considerable improvements in academic achievement across a wide range of subjects and educational levels.

Cooperative learning supports not only academic development but also students' social and affective growth. By working with peers who possess diverse characteristics and perspectives, students learn to communicate effectively, resolve conflicts constructively, and respect differing viewpoints. These experiences strengthen students' self-confidence, motivation, and positive attitudes toward school. Doymuş (2010) reported that cooperative learning reduced students' anxiety toward chemistry and increased their interest in the subject. Such findings are particularly important for the creation of inclusive and supportive classroom environments.

In cooperative learning environments, the role of the teacher shifts from that of a direct transmitter of knowledge to that of a facilitator who plans, organizes, and supports the learning process. Teachers are responsible for designing meaningful tasks, forming balanced groups, teaching cooperative skills, and continuously monitoring group activities. They also provide feedback and guide students in evaluating their group performance. Doymuş (2007) emphasized that detailed planning and effective classroom management are essential for the successful implementation of cooperative learning.

In conclusion, cooperative learning is a highly effective instructional approach that promotes academic achievement, conceptual understanding, and social development. Grounded in social constructivist theory and supported by a substantial body of research, this approach provides students with valuable opportunities to learn from one another and to construct knowledge collaboratively. The studies conducted by Doymuş have made significant contributions to the field by demonstrating the effectiveness of cooperative learning, particularly in science and chemistry education. Given the increasing emphasis placed by contemporary educational systems on collaboration, critical thinking, and active participation, cooperative learning methods continue to constitute one of the fundamental components of effective teaching practices.

2. Methods Used in Cooperative Learning

Cooperative learning is a student-centered instructional approach designed to enhance both academic achievement and social skills through structured collaboration in small, heterogeneous groups. In this approach, students work together toward common learning goals and assume responsibility not only for their own learning but also for the learning of their peers. Individual success contributes directly to group success. Cooperative learning is grounded in several key principles, including positive interdependence, individual accountability, face-to-face interaction, the development of interpersonal skills, and group process evaluation (Slavin, 2010; Johnson & Johnson, 2017; Doymuş, 2007). Among the most widely used cooperative learning methods are Student Teams–Achievement Divisions (STAD), Jigsaw, Group Investigation, Think–Pair–Share, and Numbered Heads Together.

2.1. Student Teams–Achievement Divisions (STAD)

Student Teams–Achievement Divisions (STAD), developed by Robert E. Slavin, is one of the most systematic and extensively implemented techniques in cooperative learning. In this method, students are assigned to heterogeneous groups of four or five members based on variables such as academic achievement, gender, and socio-cultural background. Initially, the teacher presents the lesson content to the entire class. Subsequently, students work collaboratively within their groups to reinforce and deepen their understanding of the topic. Following the group study phase, students complete individual quizzes or assessments, and their improvement scores are combined to form a team score (Slavin, 2010).

A defining feature of STAD is that students are evaluated according to their individual progress rather than solely on absolute performance. This approach prevents high-achieving students from consistently dominating group recognition while encouraging and rewarding the academic development of all students. Consequently, the method enhances student motivation and promotes active participation among all group members (Slavin, 2014).

During the collaborative learning phase, students explain concepts to one another, ask and answer questions, compare solutions, and address gaps in understanding. However, during the individual assessment stage, students are required to complete tasks independently without assistance from their peers. This structure effectively promotes both collaboration and individual accountability simultaneously (Johnson & Johnson, 2017).

STAD is particularly effective in subjects where answers can be clearly defined and objectively assessed, such as mathematics, science, social studies, and language instruction. Research conducted by Doymuş (2007, 2008) in chemistry education demonstrated that cooperative learning practices similar to STAD significantly improved students' academic achievement and conceptual understanding. Furthermore, the team reward system fosters a supportive classroom atmosphere by encouraging students to recognize that they are responsible not only for their own success but also for the learning progress of their teammates. As a result, STAD contributes substantially to the development of social skills such as cooperation, responsibility, communication, and empathy, in addition to academic achievement (Slavin, 2010).

2.2. Jigsaw Method

The Jigsaw method is an influential cooperative learning technique developed by Elliot Aronson that is based on students becoming specialists in different sections of a topic and subsequently teaching that knowledge to their peers. In this method, the instructional content is divided into several subtopics, and each student is assigned responsibility for mastering one specific part of the material (Aronson, 1978).

In the first stage of the process, students responsible for the same subtopic gather in "expert groups" to study and discuss the assigned content in depth. After developing expertise in their respective areas, students return to their original "home groups" and teach the material to their group members. In this way, each student assumes the dual role of learner and instructor.

The primary objective of the Jigsaw method is to strengthen positive interdependence among group members. Since each student possesses unique information essential to the group's overall understanding, successful learning depends on the active participation and contribution of every member. Consequently, students become mutually dependent on one another's knowledge and cooperation in order to achieve shared learning goals (Johnson & Johnson, 2017).

The Jigsaw method has been shown to enhance communication skills, presentation abilities, active listening, and peer interaction. In addition, it reduces competitive attitudes within the classroom and promotes empathy, tolerance, and mutual respect among students. Doymuş (2008) reported that the use of the Jigsaw technique in chemistry instruction significantly improved students' achievement in learning the topic of chemical equilibrium.

Jigsaw is especially effective for teaching broad and divisible subject matter. It is frequently employed in science, history, geography, and language education, where it supports students in constructing knowledge collaboratively, teaching their peers, and developing a comprehensive understanding of the content (Aronson, 1978; Slavin, 2010).

2.3. Group Investigation

The Group Investigation method is a project- and inquiry-based cooperative learning approach developed by Yael Sharan and Shlomo Sharan. In this method, students select a subtopic of interest, develop a research plan, and present their findings to the class (Sharan & Sharan, 1992). The method consists of six major stages: topic selection, planning, investigation, data analysis and synthesis, presentation, and evaluation. Throughout this process, students not only acquire knowledge but also improve their research, data collection, and information interpretation skills.

Group Investigation is regarded as an instructional approach that promotes higher-order thinking skills. Students collect information from multiple sources, compare and evaluate the information obtained, and draw meaningful conclusions. Consequently, the method contributes significantly to the development of critical thinking and problem-solving skills (Sharan & Sharan, 1992).

In this approach, the teacher assumes the role of facilitator and advisor rather than merely transmitting information. The teacher guides students in planning their investigations, accessing resources, and maintaining effective communication within the group. As a result, the learning environment becomes more democratic, collaborative, and student-centered. Group Investigation has been found to be particularly effective in science education, social studies, and interdisciplinary projects. Students' active involvement in research processes enhances their learning motivation and promotes deeper conceptual understanding (Slavin, 2010).

2.4. Think–Pair–Share

The Think–Pair–Share method is a simple yet highly effective instructional technique developed by Frank Lyman to increase classroom participation. The method consists of three sequential stages: thinking, pairing, and sharing (Lyman, 1981). In the first stage, the teacher asks an open-ended question and provides students with time to think individually. This stage encourages independent thinking and enables students to formulate their own ideas before interacting with others.

In the second stage, students work in pairs to discuss their responses and compare their perspectives. This interaction allows students to consider alternative viewpoints and refine their ideas through discussion. In the final stage, pairs share their conclusions with the entire class. Through this process, the teacher can observe students' thinking processes and assess the overall conceptual understanding of the class.

Think–Pair–Share is particularly effective in encouraging the participation of shy or reluctant students, promoting critical thinking, and improving verbal communication skills. One of the major advantages of the technique is its flexibility, as it can be implemented across different educational levels and subject areas with ease (Johnson & Johnson, 2017).

2.5. Numbered Heads Together

The Numbered Heads Together technique is a structured cooperative learning method developed by Spencer Kagan that aims to ensure the active participation of all students (Kagan, 1994). In this technique, each member of a group is assigned a specific number. After the teacher poses a question, group members discuss the possible answers collaboratively to ensure that every student understands the response. The teacher then randomly calls a number, and the student assigned that number answers the question on behalf of the group.

Because students do not know in advance which member will be selected to respond, all group members are required to remain prepared throughout the activity. This process strengthens individual accountability while simultaneously promoting cooperation within the group. Numbered Heads Together is particularly effective for lesson reviews, concept checks, and short assessment activities. It also provides teachers with an efficient way to assess students' understanding of the subject matter in a short period of time. Research indicates that this technique improves academic achievement, increases student participation, and enhances communication and collaboration skills among group members (Kagan, 1994; Slavin, 2010).

3. Cooperative Catalyst Method (C2M)

Among the Cooperative learning methods most frequently used in classrooms are Complex Instruction (CI), Constructive Controversy (CC), Cooperative Integrated Reading and Composition (CIRC), Cooperative Structures (CS), Group Investigation (GI), Jigsaw, Learning Together (LT), Student Teams–Achievement Divisions (STAD), Teams–Games–Tournaments (TGT), and Team-Assisted Individualization (TAI) (Johnson, Johnson, & Stanne, 2000). However, there are uncertainties regarding which version of the Jigsaw technique should be implemented in educational settings (Doymuş, 2022). A review of the related literature indicates inconsistencies among the principal implementation procedures of the technique. To date, six different Jigsaw techniques have been employed in scientific studies: Jigsaw I developed by Aronson (1978), Jigsaw II developed by Slavin (1980), Jigsaw III developed by Stahl (1994), Jigsaw IV developed by Holliday (2000), Reverse Jigsaw developed by Hedeen (2003), and Topic Jigsaw developed by Doymuş (2007).

As education increasingly adopts an interdisciplinary perspective in the 21st century, educational institutions are expected to adapt to this transformation. Consequently, some currently used methods and techniques are considered insufficient for meeting the demands of contemporary educational systems. In this context, Cooperative learning methods have been found to produce effective outcomes. One of these approaches is the Cooperative Catalyst Method (C2M), developed by Doymuş in 2023.

3.1. Application of the Cooperative Catalyst Method

More than five methods and six techniques have been implemented in Cooperative learning research. The Cooperative Catalyst Method (C2M), developed by Kemal Doymuş in 2023 for use in 21st-century educational practices and research, is implemented in four main stages. The first stage involves identifying the catalysts within the study. The second stage consists of forming Cooperative learning groups. The third stage focuses on determining the topics or disciplines to be studied, and the fourth stage involves conducting the implementation process. These stages are explained below with brief descriptions and illustrative examples.

3.2. Identifying Catalysts

Catalysts are individuals who have previously received instruction in higher grade levels, possess substantial knowledge about the subject matter, or have been specifically trained by teachers or researchers within the same class. Before the implementation begins, the catalysts' knowledge regarding the assigned topics or disciplines is assessed. Any deficiencies in their knowledge are addressed through additional instruction and guidance. Subsequently, the catalysts are informed about the group structure and the implementation procedures of the study. Each catalyst focuses on a specific topic or discipline and supports the group by facilitating the learning process and helping to overcome difficulties encountered during group work. Teachers or researchers monitor both the effectiveness of the group process and the contributions made by the catalysts, while also addressing any deficiencies observed during the implementation.

3.3. Cooperative Learning Groups

Considering the number of students in the class and their academic achievement levels, the researcher or teacher forms heterogeneous Cooperative learning groups consisting of two to six students. Following the formation of the groups, students are provided with general information regarding the procedures and responsibilities involved in the learning process. Depending on the needs of the activity, each group may appoint a group leader, presenter, and reporter. In addition, students are informed that all group members are expected to participate actively and collaboratively throughout the learning process (Doymuş, 2008).

3.4. Determination of Subtopics or Disciplines

The subtopics of the unit to be studied are divided into sections according to the number of Cooperative groups formed in the classroom or research setting. If the number of Cooperative groups is high, the same subtopic may be assigned to more than one group. Conversely, when the number of subtopics exceeds the number of groups, related subtopics may be combined and assigned as a single unit. Students in each group proceed to the relevant catalyst station and begin working on the subtopics assigned to their groups. The teacher provides students with instructional materials related to the assigned subtopics and explains the general procedures for working at the catalyst stations. At the beginning of each relevant subtopic, all groups are assessed after completing their activities at the catalyst stations. In interdisciplinary studies, which have become increasingly important in the 21st century, fundamental resources from each related discipline are consulted to ensure the comprehensive integration of disciplinary perspectives throughout the learning process.

3.5. Examinations

Assessment in the Cooperative Catalyst Method (C2M) is conducted in three different forms:

1. Module Test: Each member of the group individually takes the module test. The questions are generally open-ended and are designed to include four questions related to each subtopic or discipline associated with the unit. The primary purpose of this test is to identify the subtopics or disciplines in which students experience learning deficiencies.

2. Academic Achievement Test: The questions in this test are prepared to cover the entire unit comprehensively. The aim is to determine the overall level of student learning and academic achievement. In interdisciplinary applications, the test also includes questions representing all related disciplines involved in the study.

3. Interview Test: In this assessment, two students are selected randomly from each group and asked questions related to the subtopics studied. The purpose of the interview test is to evaluate students' self-confidence, subject knowledge, and verbal expression skills. Test results are evaluated both individually and collectively. Assessment is conducted on both an individual and group basis, and groups demonstrating high levels of success are rewarded.

This type of instructional practice enables students to learn by establishing connections among ideas and concepts derived from different disciplines. Students who learn through interdisciplinary approaches are able to transfer knowledge acquired in one discipline to another, thereby deepening their overall learning experience. Effective interdisciplinary instruction allows students to construct their own interdisciplinary learning pathways by selecting topics that are meaningful and relevant to them. For example, themes that transcend disciplinary boundaries can easily be identified in fields such as literature, art, history, science, and mathematics. Examining topics thematically helps bring ideas together and promotes meaningful learning. This process can be strengthened by allowing students to select their own topics and reflect on the relationships among concepts encountered in different disciplines.

4. Interdisciplinary and Multidisciplinary Applications of the Cooperative Catalyst Method (C2M)

In this section, the implementation of the Cooperative Catalyst Method (C2M) is explained step by step through examples selected from Chemistry, Social Studies, Geography, and Science courses. Both intradisciplinary (within-discipline) and interdisciplinary applications of the method are presented in detail.

For each course and instructional unit in which the method is implemented, the interdisciplinary application process is first described systematically and comprehensively. This explanation includes all stages of the implementation process, such as identifying relevant disciplines, preparing catalyst stations, organizing group rotations, conducting Cooperative learning activities, and implementing assessment procedures. Subsequently, the intradisciplinary application of the C2M method within the same unit is presented step by step in order to demonstrate how the method can be used effectively both for integrating knowledge across disciplines and for deepening understanding within a single discipline.

4.1. Application Plan of the Cooperative Catalyst Model (C2M) in Chemistry Lessons

This study aims to implement the "Gases" unit for 10th-grade students within the context of Chemistry Education through the Cooperative Catalyst Method (C2M), a student-centered instructional model grounded in the principles of Interdisciplinary Education and Cooperative Learning. The implementation is designed for a class of 20 students with heterogeneous characteristics; however, the number of participants may be adjusted according to specific classroom conditions. The instructional process is organized into five class hours per week over a five-week period, resulting in a total of 20 instructional hours.

Throughout the implementation, students are expected to participate actively in the learning process, work cooperatively in small groups, exchange knowledge, solve problems collaboratively, and assume responsibility not only for their own learning but also for the learning of their group members. In this respect, the instructional design aims not only to facilitate the acquisition of conceptual knowledge but also to foster the development of communication, collaboration, critical thinking, and scientific reasoning skills.

The implementation was designed within an interdisciplinary framework because the "Gases" unit inherently encompasses multidimensional scientific concepts. Within the primary discipline of Chemistry, students examine gas laws, the ideal gas equation, the Kinetic Molecular Theory, and the physical behavior of gases. These core concepts are integrated with Physics through topics such as pressure, temperature, energy, and molecular motion; with Mathematics through formula analysis, graph interpretation, and proportional reasoning; with Geography through the structure and composition of the atmosphere, the distribution of atmospheric gases, and weather phenomena; and with Biology and health sciences through the respiratory system, gas exchange in the alveoli, and the balance between oxygen and carbon dioxide in living organisms. Through this holistic instructional structure, students are expected to conceptualize gases not merely as a chemical phenomenon, but as a comprehensive scientific system that can be understood through the integrated contributions of multiple disciplines.

4.1.1. Identifying Catalysts

In the Cooperative Catalyst Method (C2M), catalysts are students who play a central role in the learning process by facilitating the learning of their peers within their areas of expertise. In this study, five catalysts were identified, each representing a different disciplinary field: Chemistry, Physics, Mathematics, Geography, and Biology. Each catalyst was responsible for learning the fundamental concepts, principles, and applications related to the "Gases" unit within their assigned discipline and for transferring this knowledge to other students.

Catalysts were selected not only on the basis of high academic achievement but also according to characteristics such as strong communication skills, leadership abilities, responsibility, openness to cooperation, and the capacity to guide peers effectively. When necessary, upper-grade students with prior knowledge of the subject were also considered for the catalyst role. During the selection process, the teacher evaluated students' previous academic performance, level of classroom participation, problem-solving skills, instructional abilities, and effectiveness in collaborative group work. In addition, short interviews were conducted with candidate students to assess their sense of responsibility, willingness to teach, and motivation to support peer learning.

Following the selection process, each catalyst was assigned to the discipline they would represent. For example, the Chemistry catalyst specialized in the molecular structure of gases, gas laws, and kinetic theory; the Physics catalyst focused on the relationships among pressure, temperature, and energy; the Mathematics catalyst concentrated on graph interpretation, ratios and proportions, and equation solving; the Geography catalyst addressed atmospheric structure, weather phenomena, and altitude–pressure relationships; and the Biology catalyst focused on respiration, gas exchange, and the role of gases in living systems.

To ensure that catalysts could perform their roles effectively, a special preparation program was implemented by the teacher prior to the instructional process. During this preparation phase, each catalyst received discipline-specific lectures, worksheets, sample problems, concept maps, and instructional guidance. Furthermore, catalysts were trained in effective communication, questioning techniques, explanation strategies, identifying and correcting misconceptions, providing feedback, and managing group discussions. Through this process, catalysts became not only knowledgeable students but also student leaders who facilitated learning, increased group interaction, and contributed to the academic development of their peers. At the end of the preparation process, the competencies of the catalysts were evaluated through short quizzes, practice presentations, and teacher observations. Catalysts who demonstrated sufficient mastery of the subject were assigned to the relevant discipline stations. During the implementation process, each catalyst instructed student groups within their disciplinary area, guided activities, answered questions, and supported the learning of group members. Through this structure, students developed a multidimensional understanding of the "Gases" unit by examining the topic from the perspectives of different disciplines. At the same time, catalysts had the opportunity to deepen their subject knowledge through teaching, develop leadership skills, and assume academic responsibility. Figure 1 presents the catalysts identified for the "Gases" unit.

The responsible discipline is Catalysts.				
C1 	**C2** 	**C3** 	**C4** 	**C5** 
Chemistry	*Physics*	*Mathematics*	*Geography*	*Biology*

Figure 1. Catalysts identified for the Gases unit (Source: Authors)

4.1.2. Formation of Cooperative Groups

Since the topic of gases is addressed through five different disciplines—Chemistry, Physics, Mathematics, Geography, and Biology—the students are divided into five heterogeneous Cooperative groups, each consisting of four members. In forming these groups, several factors are taken into consideration, including students' academic achievement levels, interest in the subject, communication skills, leadership qualities, and levels of social adaptability.

To ensure heterogeneity within the groups, a Prior Knowledge Test may be administered before the implementation in order to determine students' existing knowledge related to the topic of gases. In addition, students' achievement scores from previous semesters in Chemistry, Physics, Mathematics, Geography, and Biology may also be considered during the group formation process. Based on the data obtained, attention is given to achieving a balanced distribution of students with high, medium, and low levels of academic achievement across all groups.

Furthermore, the distribution of male and female students, students' willingness to assume responsibility, and their aptitude for collaborative work are also considered to structure each group in a manner that promotes active participation in the learning process. Through this arrangement, students have the opportunity to collaborate with peers possessing different abilities and levels of knowledge, thereby enhancing both their own learning and the learning of their group members. In this way, the fundamental principles of Cooperative Learning—positive interdependence, individual accountability, face-to-face interaction, and shared responsibility for success—are effectively implemented.

4.1.3. Identifying Subtopics and Disciplines

The Gases unit is organized in accordance with an interdisciplinary teaching approach that integrates five different disciplines. Each discipline addresses a distinct dimension of the topic, thereby contributing to students' understanding of gases from a multidimensional perspective.

Within the discipline of Chemistry, the fundamental properties of gases and the Ideal Gas Law, expressed as $PV=nRT$, are examined. In Physics, the relationships among pressure, temperature, and gas behavior are discussed, and the physical principles underlying gas behavior are explained. In Mathematics, calculations based on the Ideal Gas Law are performed, and the resulting data are interpreted through graphical representations. In Geography, the effects of atmospheric pressure and altitude on gases are examined, with connections established to everyday life phenomena. In Biology, the exchange of oxygen (O_2) and carbon dioxide (CO_2), as well as respiration processes, are discussed in order to explain the role of gases in living systems. Through this interdisciplinary structure, students are able to learn the topic of gases not merely as a chemical concept, but in a holistic manner that incorporates its physical, mathematical, geographical, and biological dimensions.

4.1.4. Implementation of the Application

The implementation process of this discipline is organized on a weekly basis to ensure that the study is conducted in a systematic and well-structured manner. As illustrated in Figure 2, the activities, learning objectives, and implementation procedures for each week are specified in detail.

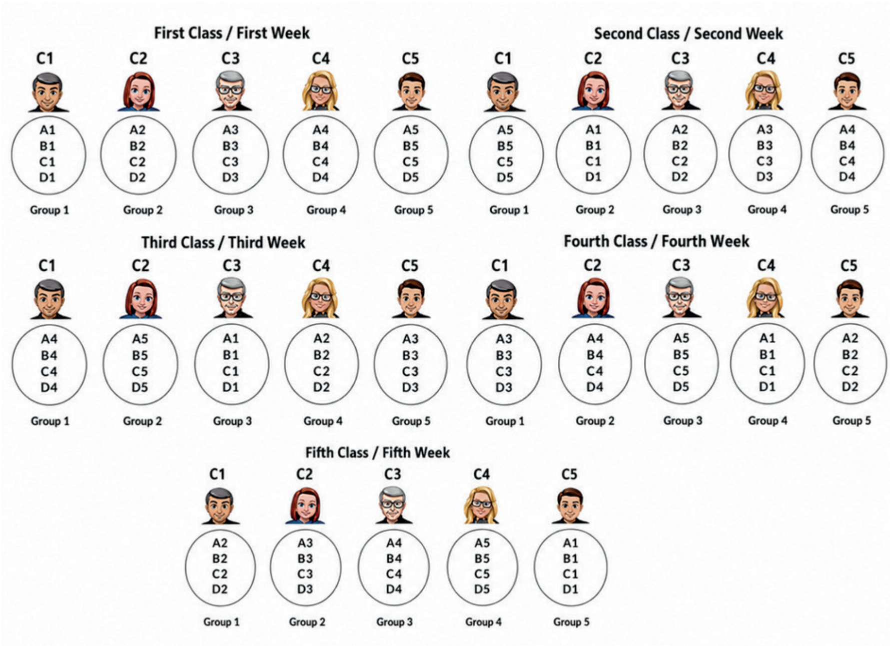

Figure 2. Interdisciplinary application scheme for the Gases unit in the Chemistry course (Source: Authors).

First Week Implementation (Week 1 / Lesson 1)

During the first week of implementation, each student group is introduced to foundational knowledge within the discipline corresponding to its assigned catalyst. At this stage, students begin to construct an interdisciplinary conceptual framework by examining the topic of "Gases" through distinct disciplinary perspectives. The group structure remains fixed, and each group works exclusively with its designated catalyst.

Group 1 studies the topic of gases from a chemistry perspective through Catalyst C1. In this phase, students focus on fundamental concepts related to gas laws, including Boyle's Law, Charles's Law, and the Ideal Gas Law, as well as the basic principles of the kinetic molecular theory.

Group 2 explores the behavior of gases from a physics perspective through Catalyst C2. Students examine the effects of pressure, temperature, and energy on the behavior of gases.

Group 3 addresses the mathematical aspects of gases through Catalyst C3, focusing on formula application, graph interpretation, and ratio–proportion calculations.

Group 4 investigates the role of gases in geography through Catalyst C4, emphasizing the structure of the atmosphere, the distribution of gases, and the formation of weather phenomena.

Group 5 examines the biological relevance of gases through Catalyst C5, focusing on the respiratory system, oxygen–carbon dioxide exchange, and mechanisms of gas exchange in living organisms.

By the end of the first week, each group has acquired foundational knowledge limited to its own disciplinary perspective. This stage establishes a strong conceptual basis for understanding how the topic of gases is addressed across different disciplines. In the subsequent weeks, groups continue the learning process by rotating across catalysts without physically changing their seating arrangements.

2nd Week Implementation (Week 2 / Lesson 2)

In the second week, students remain in their original groups; however, each group is directed to a different catalyst. Having completed the initial week by acquiring foundational knowledge in their assigned discipline, students now continue their learning by engaging with a new disciplinary perspective on the topic of gases.

Group 1 examines biological aspects of gases, focusing on the respiratory system and gas exchange processes within Catalyst C5.

Group 2 studies chemical principles of gases, including gas laws and kinetic molecular theory, within Catalyst C1.

Group 3 explores physical properties of gases, such as pressure, temperature, and energy relationships, within Catalyst C2.

Group 4 focuses on mathematical representations of gases within Catalyst C3, including formulas, graphical analysis, and ratio–proportion relationships.

Group 5 investigates geographical dimensions of gases within Catalyst C4, including atmospheric structure and weather-related gas phenomena.

As a result of this implementation, by the end of the second week, each group has had the opportunity to examine the topic of gases from a second disciplinary perspective, thereby strengthening their interdisciplinary understanding.

3rd Week of Implementation (Third Lesson / Third Week)

In the third week, students remain in their existing cooperative groups, while the groups rotate to the next catalyst according to the predetermined rotation system.

Group 1 studies atmospheric structure and weather phenomena within the discipline of Geography.

Group 2 examines the respiratory system and gas exchange processes within the discipline of Biology.

Group 3 focuses on gas laws and kinetic theory within the discipline of Chemistry.

Group 4 explores the relationships among pressure, temperature, and energy within the discipline of Physics.

Group 5 investigates mathematical representations, including formulas, graphs, ratios, and proportions within the discipline of Mathematics.

By the end of this stage, each group will have examined the topic of gases from three different disciplinary perspectives.

4th Week of Implementation (Fourth Lesson / Fourth Week)

In the fourth week, groups continue to rotate among catalysts in accordance with the rotation system.

Group 1 focuses on mathematical representations, including formulas, graphs, ratios, and proportions within Mathematics.

Group 2 studies atmospheric structure and weather phenomena within Geography.

Group 3 examines the respiratory system and gas exchange processes within Biology.

Group 4 explores gas laws and kinetic theory within Chemistry.

Group 5 investigates the relationships among pressure, temperature, and energy within Physics.

By the end of the fourth week, each group will have evaluated the topic of gases through four different disciplinary perspectives.

5th Week of Implementation (Fifth Lesson / Fifth Week)

In the fifth and final week, each group is assigned to the remaining catalyst corresponding to the discipline they have not yet studied.

Group 1 examines the relationships among pressure, temperature, and energy within Physics.

Group 2 studies mathematical representations, including formulas, graphs, ratios, and proportions within Mathematics.

Group 3 explores atmospheric structure and weather phenomena within Geography.

Group 4 examines the respiratory system and gas exchange processes within Biology.

Group 5 studies gas laws and kinetic theory within Chemistry.

By the end of the five-week implementation process, each group will have examined the topic of gases from the perspectives of five different disciplines—Chemistry, Physics, Mathematics, Geography, and Biology—thereby enabling a holistic and integrated understanding through an interdisciplinary learning approach.

4.1.5. Measurement and Evaluation

The topic of gases is integrated across the disciplines of chemistry, physics, mathematics, geography, and biology/health, with the aim of enabling students to develop a multifaceted and interdisciplinary understanding of the subject. In this context, the learning process is evaluated through three main assessment instruments.

The first instrument is the Academic Achievement Test (AAT), which is designed to determine students' knowledge levels, conceptual understanding, and problem-solving skills related to the topic of gases. The second instrument consists of Discipline-Based Module Tests, which are used to assess the extent to which discipline-specific learning outcomes have been achieved within each subject area. The third instrument is the Semi-Structured Interview Form, which aims to explore how students establish interdisciplinary connections, relate the topic to real-life contexts, and perceive the overall learning process.

Each of these instruments serves a distinct purpose and, when used together, provides a comprehensive evaluation of students' knowledge, skills, conceptual understanding, and ability to construct interdisciplinary relationships. The Academic Achievement Test (AAT) is presented in detail in Table 1, the Discipline-Based Module Tests in Table 2, and the Semi-Structured Interview Form in Table 3.

Table 1. Purpose, Structure, Administration Time, and Scoring Characteristics of the Academic Achievement Test (AAT) (Source: Authors).

Component	Description
Purpose of the Test	The Academic Achievement Test (AAT) was developed to determine students' interdisciplinary and holistic learning levels regarding the topic of gases. The test is administered before and after the instructional intervention to evaluate the effectiveness of the teaching process.
Structure of the Test	The test consists of a total of 40–50 multiple-choice questions. Each discipline includes 8–10 questions. The questions cover cognitive levels including knowledge, comprehension, application, analysis, and interpretation.
Administration Timing	The pre-test is administered before the implementation begins, the post-test after all modules are completed, and the retention test 4–6 weeks after the implementation.
Scoring	Each correct answer is scored as 1 point and each incorrect answer as 0 points. Raw scores are converted to a 100-point scale.

Table 2. Structure and Characteristics of Discipline-Based Module Tests (Source: Authors)

Module Test	Content	Question Types	Sample Learning Outcomes
Chemistry Module Test	• Gas laws • Kinetic Molecular Theory • Ideal gas behavior	• Multiple-choice • Fill-in-the-blank • Concept matching	• Explains Boyle's Law. • Interprets the particulate nature of gases. • Compares ideal and real gases.
Physics Module Test	• Pressure, temperature, and energy • Mechanical behavior of gases	• Multiple-choice • Fill-in-the-blank • Concept matching	• Explains the pressure–temperature relationship. • Interprets energy changes in gases. • Relates concepts to examples from daily life.
Mathematics Module Test	• Formulas, graphs, and proportional reasoning • Equation solving	• Multiple-choice • Fill-in-the-blank • Problem solving	• Calculates unknowns in gas equations. • Interprets linear and nonlinear graphs. • Uses proportional reasoning.
Geography Module Test	• Atmosphere and weather phenomena• Relationship between altitude and pressure	• Multiple-choice • Fill-in-the-blank • Concept matching	• Explains the layers of the atmosphere. • Interprets changes in atmospheric pressure. • Relates meteorological events to gas laws.

Biology/ Health Module Test	• Respiratory system• Gas exchange	• Multiple-choice• Fill-in-the-blank• Concept matching	• Explains gas exchange in the lungs. • Interprets the concept of partial pressure. • Provides health-related examples.
Note: Module tests are designed to assess the specific knowledge and skills students acquire at the end of each disciplinary module. Each test consists of approximately 10–15 questions aligned with discipline-specific learning outcomes. The administration time ranges from 20 to 30 minutes. These tests are administered immediately after the completion of each module. Through these assessments, students' knowledge, comprehension, application, and interpretation skills are evaluated in detail, and discipline-specific learning levels are determined.			

Table 3. Semi-Structured Interview Forms, Data Analysis Process, and Expected Contributions Used in the Interdisciplinary Teaching of the Gases Unit (Source: Authors)

Section	Subsection	Description
1. Semi-Structured Interview Forms	Purpose of the Interview	To examine in depth how students establish interdisciplinary connections, develop conceptual understanding, and relate concepts to daily life.
	Participants	• Students selected from all achievement levels • 10–20 students
	Duration	• 20–30 minutes
	Recording Procedures	• Audio recording • Written notes • Voluntary participation and ethical consent
2. Sample Interview Questions by Discipline	Chemistry	• Where do gas laws appear in daily life? • How does the particulate nature of gases explain their behavior?
	Physics	• How does the energy of gases change when temperature increases? • Explain the relationship between pressure and volume.
	Mathematics	• How are the variables in the equation $PV = nRT$ interpreted? • What information do graphs provide?
	Geography	• Why does atmospheric pressure decrease with increasing altitude? • How are weather phenomena related to gas behavior?
	Biology/ Health	• How do oxygen and carbon dioxide exchange in the lungs? • Why is breathing more difficult at high altitudes?

3. Data Analysis	Quantitative Data	• Mean • Standard deviation • Paired and independent samples t-tests • ANOVA • Effect size
	Qualitative Data	• Content analysis • Thematic analysis • Coding and categorization
4. Expected Contributions	Contributions to the Research	• Reveals students' overall academic achievement. • Determines the contribution of each discipline to learning. • Assesses interdisciplinary thinking skills. • Demonstrates conceptual change and retention of learning. • Enables holistic interpretation of quantitative and qualitative data.

4.2. Implementation Plan of the Cooperative Catalyst Model (C2M) in Social Studies Lessons

This study aims to implement the "Climate Change and Its Impacts on Society" unit within the field of Social Studies Education for 6th-grade students through the Cooperative Catalyst Method (C2M), which is grounded in the principles of Interdisciplinary Education and Cooperative Learning and framed within a student-centered learning approach. The implementation is designed for a total of 16 students with heterogeneous characteristics; however, the number of students may vary depending on classroom conditions. The instructional process is organized as four instructional hours per week over a four-week period, corresponding to a total of 16 class hours. Throughout the process, students are expected to work in small cooperative groups, engage in collaborative problem-solving, share knowledge, and assume responsibility for both their own learning and that of their peers. In this way, the approach aims not only to enhance cognitive learning outcomes but also to foster communication, collaboration, critical thinking, decision-making, and social responsibility skills.

The implementation is designed within an interdisciplinary framework due to the multifaceted nature of the "Climate Change and Its Impacts on Society" unit. As the core discipline, Social Studies addresses human activities, human–environment interactions, and the social, economic, and cultural consequences of climate change. This core content is integrated with Geography through topics such as climate systems, natural hazards, and map interpretation skills; with Environmental Science and Science Education through concepts such as the greenhouse effect, global warming, and atmospheric change processes; and with Mathematics through graphical representation, data analysis, and statistical interpretation skills. This holistic approach enables students to understand climate change not only as an environmental issue but also as a complex global phenomenon with significant social implications.

For assessment purposes, three complementary evaluation tools are planned to examine students' learning outcomes comprehensively. Module-based tests will be administered to assess discipline-specific achievement, an Academic Achievement Test will be used to evaluate interdisciplinary conceptual integration and overall academic performance, and semi-structured interviews will be conducted to explore students' reasoning processes, their ability to establish cause-and-effect relationships, and their proposed solutions in depth. Overall, this instructional design seeks to demonstrate the potential of the Cooperative Catalyst Method (C2M) in enhancing academic achievement in social studies education, improving environmental awareness, and fostering informed and responsible individuals capable of addressing global challenges such as climate change.

4.2.1. Identification of Catalysts

Within the framework of the Cooperative Catalyst Method (C2M), catalysts are students who occupy a central role in the learning process and facilitate their peers' learning within their respective areas of expertise. In this study, a total of five catalysts are identified, each representing a distinct disciplinary field: Social Studies, Geography, Science, Mathematics, and an additional integrative discipline aligned with the unit focus. Each catalyst is responsible for mastering the fundamental concepts, principles, and applications related to the unit "Climate Change and Its Effects on Society" within their assigned discipline and for subsequently transferring this knowledge to their peers.

Accordingly, catalysts are selected not only from high-achieving students but also from those who demonstrate strong communication skills, leadership potential, a sense of responsibility, openness to collaboration, and the ability to guide peers effectively. When necessary, upper-grade students with prior knowledge of the subject may also be assigned as catalysts to strengthen instructional support.

During the selection process, the teacher considers students' previous academic achievement, level of classroom participation, problem-solving abilities, presentation skills, and effectiveness in group work. In addition, short semi-structured interviews are conducted with candidate students to assess their sense of responsibility, willingness to teach, and motivation to support peer learning. Following the selection process, each catalyst is assigned to a specific disciplinary area. For example, the Social Studies catalyst focuses on human activities, societal structures, and environmental interactions; the Geography catalyst addresses climate systems, pressure dynamics, natural hazards, and map interpretation; the Science catalyst concentrates on the greenhouse effect and global warming; and the Mathematics catalyst focuses on data representation and graphical analysis.

To ensure the effective functioning of catalysts, a structured preparatory program is implemented by the teacher prior to instruction. During this preparation phase, each catalyst is provided with discipline-specific instructional materials, worksheets, sample problems, concept maps, and relevant pedagogical strategies. Guidance is also offered on effective communication, questioning techniques, explanatory skills, misconception correction, feedback provision, and group facilitation. In this way, catalysts are developed not only as knowledgeable students but also as learner-leaders who facilitate interaction, enhance group dynamics, and contribute to the academic development of their peers.

At the end of the preparation process, catalysts' competencies are evaluated through short assessments, practice presentations, and systematic teacher observations. Students who demonstrate sufficient mastery of the subject matter are considered ready to perform their roles within their respective disciplinary stations. During the implementation phase, each catalyst delivers instruction to student groups within their domain, facilitates activities, responds to questions, and supports collaborative learning processes.

Through this structure, students develop a multidimensional understanding of the unit "Climate Change and Its Effects on Society" from different disciplinary perspectives, while catalysts simultaneously deepen their own learning through teaching, strengthen their leadership skills, and assume academic responsibility. Figure 3 presents the catalysts identified for the unit "Climate Change and Its Effects on Society."

The responsible discipline is Catalysts.			
C1 	C2 	C3 	C4 
Social Studies	*Geography*	*Science*	*Mathematics*

Figure 3. illustrates the catalysts identified for the "Climate Change and Its Effects on Society" unit (Source: Authors).

4.2.2. Formation of Cooperative Groups

Since the topic *Climate Change and Its Effects on Society* is addressed within four different disciplines, the class will be divided into four heterogeneous cooperative groups, each consisting of four students. The formation of these groups will take into account students' academic achievement levels, interest in the subject, communication skills, and collaborative capacity. A prior knowledge test on the subject may be administered to assess students' initial understanding; alternatively, students' previous academic performance records may be used for this purpose. Accordingly, attention will be paid to ensuring a balanced distribution of students with varying achievement levels across all groups. In addition, students' social adaptability, sense of responsibility, and aptitude for group work will also be considered in order to establish an effective cooperative learning environment. This structure is expected to both support students' individual learning processes and enhance knowledge retention through peer interaction.

4.2.3. Identification of Subtopics and Disciplines

The topic *Climate Change and Its Effects on Society* is organized across four main disciplines in accordance with an interdisciplinary teaching approach. Within the Social Studies discipline, the relationships among human activities, society, and the environment are examined, with particular emphasis on the role of individuals in environmental processes. In Geography, the spatial dimension of environmental change is addressed through topics such as climate systems, natural hazards, and map interpretation. In Science, the greenhouse effect and global warming processes are explored, and the scientific foundations of climate change are explained. In Mathematics, data related to climate change are analyzed and interpreted through the use of graphs and data visualization techniques. This interdisciplinary structure enables students to develop a comprehensive and multifaceted understanding of climate change.

4.2.4. Implementation of the Application

The implementation process is organized on a weekly basis to ensure that the study is conducted in a systematic and well-structured manner. As shown in Figure 4, the activities, learning objectives, and implementation steps for each week are specified in detail.

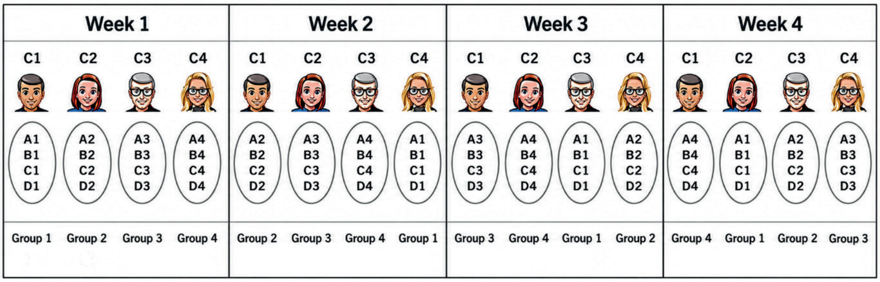

Figure 4. Interdisciplinary application scheme for the Climate Change and Its Effects on Society unit in the Social Studies course (Source: Authors).

First Week Implementation (Lesson 1 / Week 1)

During the first week of implementation, each student group is introduced to foundational knowledge related to the specific discipline assigned to its respective catalyst. At this stage, students construct an interdisciplinary conceptual framework by examining the topic of *"Climate Change and Its Effects on Society"* through different disciplinary perspectives. The groups remain fixed, and each group works exclusively within its assigned catalyst.

Group 1 examines the relationship between *Climate Change and Its Effects on Society* and the discipline of Social Studies within Catalyst C1. In this catalyst, students learn fundamental concepts related to the interaction between human activities, society, and the environment.

Group 2 examines the relationship between *Climate Change and Its Effects on Society* and Geography within Catalyst C2. This catalyst introduces basic concepts related to climate systems, natural disasters, and map interpretation.

Group 3 examines the relationship between *Climate Change and Its Effects on Society* and Science within Catalyst C3. This catalyst focuses on fundamental concepts related to the greenhouse effect and global warming.

Group 4 examines the relationship between *Climate Change and Its Effects on Society* and Mathematics within Catalyst C4. This catalyst addresses basic concepts in graph interpretation and data analysis.

By the end of the first week, each group will have acquired foundational knowledge limited to its own discipline. This phase provides students with a strong conceptual starting point for understanding how *Climate Change and Its Effects on Society* is addressed across different disciplines. In subsequent weeks, students continue the learning process by rotating across catalysts without changing group membership.

2nd Week Lesson Implementation (Week 2)

In the second week, students remain in their original groups; however, each group rotates to a different catalyst. According to the implementation plan, Group 1 moves to C4, Group 2 to C1, Group 3 to C2, and Group 4 to C3. This rotation enables each group to examine the topic of climate change from a new disciplinary perspective.

Group 1 (C4 – Mathematics): Students engage with concepts related to graph interpretation, table construction, data analysis, and basic statistical evaluation.

Group 2 (C1 – Social Studies): Students examine human activities, the relationship between society and the environment, sustainable living, and environmental responsibility.

Group 3 (C2 – Geography): Students focus on climate systems, natural disasters, weather phenomena, and map-reading skills.

Group 4 (C3 – Science): Students study core concepts such as the greenhouse effect, global warming, atmospheric gases, and energy balance.

3rd Week Lesson Implementation (Week 3)

In the third week, groups rotate again to new catalysts. As shown in the implementation diagram, Group 1 moves to C3, Group 2 to C4, Group 3 to C1, and Group 4 to C2. This stage further broadens students' interdisciplinary understanding of climate change.

Group 1 (C3 – Science): Focus on the greenhouse effect, global warming, and the role of atmospheric gases.

Group 2 (C4 – Mathematics): Engage in graph interpretation, data analysis, and statistical evaluation.

Group 3 (C1 – Social Studies): Explore human activities, societal structures, and environmental interactions.

Group 4 (C2 – Geography): Study climate systems, natural hazards, and map interpretation.

4th Week Course Implementation (Week 4)

In the fourth and final week, groups rotate once more and move to the remaining catalysts they have not yet experienced. According to the plan, Group 1 moves to C2, Group 2 to C3, Group 3 to C4, and Group 4 to C1. By the end of this phase, each group will have worked with all four disciplinary perspectives.

Group 1 (C2 – Geography): Study climate, natural disasters, and map interpretation.

Group 2 (C3 – Science): Examine the greenhouse effect, global warming, and atmospheric gases.

Group 3 (C4 – Mathematics): Engage with graph interpretation, data analysis, and statistical reasoning.

Group 4 (C1 – Social Studies): Focus on human activities, societal systems, and environmental relationships.

4.2.5. Measurement and Evaluation

The topic of *Climate Change and Its Effects on Society* is integrated across the disciplines of Social Studies, Geography, Science, and Mathematics, with the aim of enabling students to understand the subject from a multifaceted and interdisciplinary perspective. In this context, the learning process is evaluated through three main assessment instruments: the Academic Achievement Test (AAT), Discipline-Based Module Tests, and Semi-Structured Interview Forms. The Academic Achievement Test (AAT) is designed to measure students' overall knowledge and conceptual understanding of the subject matter. The Discipline-Based Module Tests assess the extent to which students achieve the learning outcomes within each specific discipline. In addition, the Semi-Structured Interview Forms are used to explore students' ability to establish interdisciplinary connections, their reflections on the learning process, and their interpretive understanding of the topic. Together, these instruments provide a comprehensive evaluation of students' knowledge, skills, conceptual understanding, and capacity to integrate knowledge across disciplines. The Academic Achievement Test (AAT), Discipline-Based Module Tests, and Semi-Structured Interview Forms are presented in detail in Table 4, Table 5, and Table 6, respectively.

Table 4. Academic Achievement Test (AAT): Structure and Characteristics (Source: Authors)

Discipline	Assessed Content	Purpose	Question Types	Number of Questions	Skills Measured	Scoring
Social Studies	Human activities and environment	Effects of human activities	Multiple choice, scenario-based	10	Causal reasoning	1 point each
Geography	Climate and disasters	Interpretation skills	Map interpretation, MCQ	10	Spatial thinking	1 point each
Science	Greenhouse effect	Scientific understanding	Cause-effect MCQ	10	Scientific explanation	1 point each
Mathematics	Graph analysis	Data interpretation	Problem solving	10	Analytical thinking	1 point each

Table 5. Discipline-Based Module Tests (Source: Authors).

Discipline	Test Topic	Purpose	Question Types	Number of Questions	Application Time	Skills Measured	Evaluation
Social Studies Module Test	Human activities, society and environment relations	To determine students' learning level	Multiple choice, short answer, scenario analysis	10–15	After Social Studies module	Causal reasoning, social awareness	End-of-module scoring
Geography Module Test	Climate, natural disasters, map interpretation	To measure geographical knowledge	Map questions, table interpretation, multiple choice	10–15	After Geography module	Map reading, spatial thinking	Correct-answer scoring
Science Module Test	Greenhouse effect and global warming	To measure concept application	Multiple choice, cause-effect, matching	10–15	After Science module	Concept understanding	Short-term assessment
Mathematics Module Test	Graph and data analysis	To measure data interpretation skills	Graph interpretation, table analysis	10–15	After Math module	Analytical thinking	Achievement level

Table 6. Semi-Structured Interview Form (Source: Authors)

Discipline	Interview Purpose	Question Content	Question Type	Sample Question	Measured Dimensions	Usage Purpose
Social Studies	Perception of society-environment relation	Human activities and environment	Open-ended	How do human activities affect society?	Conceptual understanding	Deep analysis
Geography	Understanding climate impacts	Climate change and disasters	Open-ended	How does climate change affect disasters?	Spatial reasoning	Evaluation
Science	Scientific understanding	Greenhouse effect	Open-ended case-based	How does greenhouse effect occur?	Scientific reasoning	Concept depth
Mathematics	Data interpretation skills	Graphs and tables	Problem solving	What can you infer from this graph?	Analytical thinking	Decision making

4.3. Implementation Plan of the Cooperative Catalyst Model (C2M) in a Geography Lesson

This study aims to teach the "Climate and Weather Events" unit in Geography to ninth-grade students through a student-centered and interdisciplinary approach. The instructional process is structured according to the Cooperative Catalyst Model (C2M), a pedagogical framework grounded in the principles of active learning and cooperative learning. The implementation is planned for a class of 25 students, although the number of participants may vary depending on classroom conditions. The instructional program will be conducted over a period of five weeks, with four class hours per week, totaling 20 instructional hours. Throughout the implementation, students are expected to actively engage in the learning process, assume responsibility for their own learning, and construct knowledge through collaborative interaction within their groups.

The Cooperative Catalyst Model is a structured cooperative learning approach in which students who develop expertise in specific subject areas facilitate the learning of their peers. Within this framework, students are provided with opportunities to integrate knowledge from multiple disciplines and to analyze complex concepts from diverse scientific perspectives. Because the "Climate and Weather Events" unit is inherently multidimensional, it is not limited to Geography alone but is also integrated with Physics, Chemistry, Mathematics, and Biology. Within this interdisciplinary structure, Geography addresses climate elements and climate types; Physics focuses on pressure, temperature, and energy transfer; Chemistry examines the composition of the atmosphere and greenhouse gases; Mathematics emphasizes the graphical representation and analysis of climate data; and Biology investigates the effects of climate on living organisms. Through this integrated framework, students are enabled to examine climate systems from multiple scientific perspectives and to develop a comprehensive understanding of the relationships among disciplines.

The primary objective of the implementation is to enhance students' conceptual understanding of climate and weather events, strengthen their analytical thinking skills, and enable them to evaluate real-world problems from a multidisciplinary perspective. To assess students' academic development and learning experiences, three complementary assessment tools will be employed. These include module tests to monitor learning progress throughout the instructional process, an Academic Achievement Test administered before and after the intervention to determine changes in achievement levels, and semi-structured interviews designed to elicit students' perceptions and experiences in greater depth. This comprehensive assessment framework will enable a systematic examination of the effects of the Cooperative Catalyst Model on students' academic achievement, conceptual understanding, and interdisciplinary thinking skills.

4.3.1. Identifying Catalysts

Within the Cooperative Catalyst Method (C2M), catalysts are students who actively support the academic development of their group members throughout the learning process. They possess foundational knowledge and skills related to the subject matter and demonstrate strong communication and leadership competencies. Catalysts are not merely information transmitters; rather, they function as peer mentors who regulate group interactions, facilitate discussions, clarify misconceptions among peers, and ensure the learning process progresses effectively. Consequently, the identification of catalysts constitutes a critical stage for the successful implementation of the model.

In selecting catalysts, several criteria are taken into account, including students' academic achievement levels, communication skills, sense of responsibility, cooperative learning aptitude, and willingness to support peers. To this end, teacher observations, prior examination results, levels of classroom participation, and, when appropriate, student self-reports are considered. Catalysts may be selected from high-achieving students within the same class, or alternatively, from senior students who have previously mastered the relevant content. It is particularly important that selected students are volunteers and demonstrate a positive disposition toward collaborative learning.

In the present study, since the topic of "Climate and Weather Events" is addressed through an interdisciplinary framework, a total of five catalysts were selected, each specializing in a distinct disciplinary field. The geography catalyst is responsible for climate elements, climate types, weather events, and related natural processes. The physics catalyst explains atmospheric pressure, temperature variation, energy transfer, and radiation processes. The chemistry catalyst focuses on the chemical composition of the atmosphere, greenhouse gases, and the chemical foundations of global warming. The mathematics catalyst is responsible for analyzing temperature and precipitation data using tables and graphs, calculating averages, and interpreting trends. The biology catalyst examines the effects of climate on living organisms, ecosystems, biodiversity, and adaptation processes.

To ensure that catalysts can perform their roles effectively, a structured preparatory training program is conducted by the teacher prior to implementation. During this training, catalysts are provided with core concepts, sample applications, instructional materials, and explanatory strategies relevant to their respective disciplines. In addition, peer teaching techniques, effective communication skills, questioning strategies, feedback delivery, motivation of group members, and conflict resolution skills are emphasized. Through this process, catalysts not only acquire subject-matter knowledge but also develop the ability to transfer this knowledge to their peers in a clear and effective manner.

Following the preparatory training, catalysts' competency levels are assessed through short quizzes, practical activities, or teacher interviews. When necessary, additional support is provided to ensure full mastery of the content. During the implementation process, the teacher continuously monitors the catalysts' performance, provides guidance when needed, and evaluates their overall effectiveness at the end of the process.

Through this systematic preparation process, catalysts become effective learning leaders who facilitate interdisciplinary knowledge transfer, strengthen group collaboration, and contribute to meaningful student learning outcomes. Figure 5 illustrates the catalysts identified for the "Climate and Weather Events" unit.

The responsible discipline is Catalysts.				
C1 	**C2** 	**C3** 	**C4** 	**C5** 
Geography	*Physics*	*Chemistry*	*Mathematics*	*Biology*

Figure 5. illustrates the catalysts identified for the Climate and Weather Phenomena unit (Source: Authors).

4.3.2. Formation of Collaborative Groups

Given the multifaceted nature of the topic *Climate and Weather Phenomena*, which integrates knowledge and skills from multiple disciplines, the class is organized into five heterogeneous collaborative groups, each consisting of five students, to ensure effective cooperation during the instructional process. The formation of these heterogeneous groups takes into account students' academic achievement levels, learning styles, communication skills, and social characteristics. To this end, a Prior Knowledge Test on Climate and Weather Phenomena may be administered to determine students' baseline understanding of the topic. Alternatively, students' previous academic achievement scores and teacher observations may be utilized in the group formation process. This approach ensures that students with varying abilities and achievement levels are distributed across groups, thereby promoting peer learning, information sharing, and shared responsibility. Such a structure fosters an effective learning environment aimed at enhancing both individual and group achievement within the framework of the Cooperative Catalyst Method (C2M).

4.3.3. Identification of Subtopics and Disciplines

The topic of *Climate and Weather Phenomena* is addressed through five distinct disciplines to enable students to develop a comprehensive and holistic understanding from an interdisciplinary perspective. Each discipline is designed to explain a specific dimension of the topic. Within the Geography discipline, climate elements and climate types are examined, with particular emphasis on the roles of key factors such as temperature, precipitation, humidity, wind, and atmospheric pressure in the formation of different climate zones. Within the Physics discipline, the concepts of pressure, temperature, and energy transfer are addressed, and the physical foundations of atmospheric processes are explained. Within the Chemistry discipline, the composition of the atmosphere and greenhouse gases are explored, with a detailed focus on the properties of atmospheric gases and the mechanisms underlying the greenhouse effect. The Mathematics discipline emphasizes the graphical analysis of climate data, aiming to develop students' skills in interpreting temperature, precipitation, and other meteorological data through tables and graphs. Finally, within the Biology discipline, the effects of climate on living organisms are examined, including its influence on ecosystems, species distribution, and biological processes. Through this interdisciplinary structure, students are expected to understand climate and weather phenomena by establishing meaningful connections among geographical, physical, chemical, mathematical, and biological dimensions.

4.3.4. Implementation of the Application

The application process of this discipline is structured into weeks to ensure that the research is conducted systematically and in a planned manner. As shown in Figure 6, the activities, learning objectives, and application steps for each week are defined in detail.

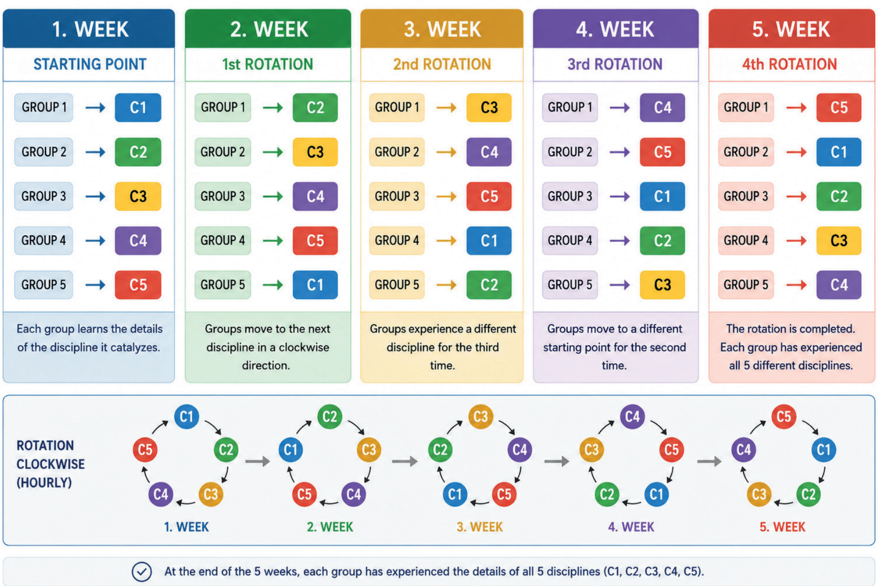

Figure 6. Interdisciplinary Application Scheme for the Climate and Weather Phenomena Unit in the Geography Course (Source: Authors).

First Week Implementation (First Lesson / First Week)

In the first week's implementation, each student group learns the basic information related to the relevant discipline in the catalyst assigned to their group. At this stage, students create an interdisciplinary conceptual foundation by examining the topic of "Climate and Weather Phenomena" from the perspective of different disciplines. In the first week of implementation, the groups remain the same and each group works only in its own catalyst.

Group 1 examines the relationship between Climate and Weather Phenomena and the geography discipline in Catalyst C1. Basic concepts related to climate elements and climate types are learned in this catalyst.

Group 2 examines the relationship between Climate and Weather Phenomena and the physics discipline in Catalyst C2. Basic concepts related to pressure, temperature, and energy transfer are learned in this catalyst.

Group 3 examines the relationship between Climate and Weather Phenomena and the chemistry discipline in Catalyst C3. Basic concepts related to the composition of the atmosphere and greenhouse gases are learned in this catalyst.

Group 4, in Catalyst C4, examines the relationship between Climate and Weather Events and the discipline of mathematics. In this catalyst, fundamental concepts related to the graphical analysis of climate data are learned.

Group 5, in Catalyst C5, examines the relationship between Climate and Weather Events and the discipline of biology. In this catalyst, fundamental concepts related to the effects of climate on living organisms are learned.

By the end of the first week, each group will have learned only the basic information and concepts related to their own discipline. Thus, students make a strong start in understanding how the topic of Climate and Weather Events is addressed in different disciplines. In subsequent weeks, students continue the learning processes in other disciplines without switching places, only the groups are directed to different catalysts.

2nd Week Implementation (Second Lesson / Second Week)

In the second week's implementation, groups are shifted clockwise to the next catalyst according to the rotation system. Each group continues to examine the topic of "Climate and Weather Events" from the perspective of a different discipline. The aim at this stage is for students to experience interdisciplinary conceptual diversity.

Group 1, in Catalyst C2, relates the topic of Climate and Weather Events to the discipline of physics; they learn fundamental concepts such as pressure, temperature, and energy transfer. Group 2, in Catalyst C3, examines fundamental concepts related to atmospheric composition and greenhouse gases within the discipline of chemistry.

Group 3, in Catalyst C4, gains basic skills in graphical analysis of climate data in relation to the discipline of mathematics.

Group 4, in Catalyst C5, learns about the effects of climate on living organisms within the discipline of biology.

Group 5, in Catalyst C1, acquires basic knowledge about climate elements and climate types within the discipline of geography. By the end of this week, each group will have been introduced to a second disciplinary field and will begin to see the counterparts of the topic in different scientific fields.

3rd Week Implementation (Third Lesson / Third Week)

In the third week's implementation, the rotation system continues in the same way, and the groups move on to their third catalyst experience. At this stage, students have the opportunity to examine the topic from the perspective of a third different discipline.

Group 1 learns about atmospheric composition and greenhouse gases within the discipline of chemistry in Catalyst C3.

Group 2 works on the analysis and interpretation of climate data within the discipline of mathematics in Catalyst C4.

Group 3 examines the effects of climate on ecosystems and living things within the discipline of biology in Catalyst C5.

Group 4 learns about climate types and climate elements within the discipline of geography in Catalyst C1.

Group 5 examines the relationship between pressure, temperature, and energy in atmospheric events within the discipline of physics in Catalyst C2.

By the end of this week, students will have experienced the third disciplinary dimension of the subject.

4thWeek Implementation (Fourth Lesson / Fourth Week)

In the fourth week's implementation, the groups move to their fourth catalyst according to the rotation system. Students have now experienced a large part of the subject through different disciplines.

Group 1 performs graphical analysis and interpretation of climate data within the discipline of mathematics in Catalyst C4.

Group 2, in Catalyst C5, examines the effects of climate on living organisms within the discipline of biology.

Group 3, in Catalyst C1, learns about climate elements and climate types within the discipline of geography.

Group 4, in Catalyst C2, analyzes the relationship between pressure, temperature, and energy in the atmosphere within the discipline of physics.

Group 5, in Catalyst C3, examines the composition of the atmosphere and greenhouse gases within the discipline of chemistry.

With this week, students are approaching completion of four different disciplinary dimensions.

5th Week Implementation (Fifth Lesson / Fifth Week)

In the fifth and final week of implementation, students complete their final rotations, and all groups complete the learning processes in five different catalysts. This week is important in terms of integrating the learned information.

Group 1, in Catalyst C5, examines the effects of climate on living organisms within the discipline of biology. They learn about the effects of climate.

Group 2, within the discipline of geography, examines climate elements and climate types in Catalyst C1.

Group 3, within the discipline of physics, learns about the relationship between pressure, temperature, and energy in Catalyst C2.

Group 4, within the discipline of chemistry, examines atmospheric composition and greenhouse gases in Catalyst C3.

Group 5, within the discipline of mathematics, works on the graphical analysis and interpretation of climate data in Catalyst C4.

At the end of five weeks, each group will have experienced the topic of "Climate and Weather Events" from five different disciplinary perspectives and will have developed a holistic interdisciplinary conceptual understanding.

4.3.5. Measurement and Evaluation

The topic of Climate and Weather Events is addressed through an interdisciplinary integration of Geography, Physics, Chemistry, Mathematics, and Biology, enabling students to develop a multifaceted and holistic understanding of the subject. Within this framework, the primary objective is not only to facilitate students' acquisition of fundamental concepts but also to enhance their ability to recognize, interpret, and explain relationships among different scientific disciplines.

The learning process is assessed using three main measurement tools: the Academic Achievement Test (AAT), Discipline-Based Module Tests, and Semi-Structured Interview Forms. The Academic Achievement Test is designed to determine students' overall knowledge level and interdisciplinary understanding of the subject. The Discipline-Based Module Tests are used to evaluate the extent to which discipline-specific learning outcomes have been achieved. The Semi-Structured Interview Forms aim to explore students' cognitive processes in depth, including their conceptual understanding and ability to establish connections across disciplines.

Taken together, these assessment instruments serve complementary purposes, contributing to a comprehensive evaluation of students' knowledge, skills, understanding, and interdisciplinary reasoning abilities. The Academic Achievement Test (AAT) is presented in detail in Tables 7 and 8, the Discipline-Based Module Tests in Tables 9 and 10, and the Semi-Structured Interview Forms in Tables 11 and 12.

Table 7. General Characteristics of the Academic Achievement Test (Source: Authors)

Feature	Description
Test Name	Academic Achievement Test (AAT)
Purpose of the Test	To determine students' interdisciplinary knowledge levels regarding climate and weather events
Scope	Geography, Physics, Chemistry, Mathematics, and Biology
Administration Time	Before the implementation (pre-test) and after the implementation (post-test)
Total Number of Items	40–50 items
Number of Items per Discipline	8–10 items
Item Types	Multiple-choice, true-false, matching, and graph interpretation questions
Administration Duration	60–75 minutes
Scoring	Each correct answer is awarded 1 point
Total Score	40–50 points
Reliability Analysis	KR-20 or Cronbach's Alpha
Validity Procedures	Expert review, pilot testing, and item analysis
Cognitive Levels Assessed	Knowledge, comprehension, application, and analysis
Data Analysis	Paired-samples t-test, independent-samples t-test, ANOVA, and ANCOVA

Table 8. Distribution of the Academic Achievement Test Across Disciplines (Source: Authors)

Discipline	Learning Outcomes Assessed	Number of Items
Geography	Climate elements, climate types, and global climate zones	8–10
Physics	Pressure, temperature, energy transfer, and radiation	8–10
Chemistry	Atmospheric composition, greenhouse gases, and chemical processes	8–10
Mathematics	Graph analysis, table interpretation, and statistical evaluation	8–10
Biology	Effects of climate on living organisms and ecosystems	8–10

Table 9. Common Characteristics of the Module Tests (Source: Authors)

Feature	Description
Number of Tests	Five tests (one for each discipline)
Administration Time	At the end of each module
Number of Items	10–15 items
Administration Duration	20–30 minutes
Item Types	Multiple-choice, short-answer, and graph interpretation questions
Scoring	Each correct answer is awarded 1 point
Assessment Purpose	To evaluate discipline-specific learning outcomes
Data Analysis	Mean, standard deviation, and percentage of achievement

Table 10. Discipline-Based Module Tests (Source: Authors)

Module	Discipline	Content Assessed	Number of Items
Module 1	Geography	Climate elements, climate types, and map interpretation	10–15
Module 2	Physics	Pressure, temperature, and energy transfer	10–15
Module 3	Chemistry	Atmospheric composition, greenhouse gases, and chemical reactions	10–15
Module 4	Mathematics	Graph construction and interpretation, and data analysis	10–15
Module 5	Biology	Adaptation, ecosystem impacts, and biodiversity	10–15

Table 11. General Characteristics of the Interview Form (Source: Authors)

Feature	Description
Data Collection Instrument	Semi-Structured Interview Form
Purpose	To examine conceptual understanding and interdisciplinary thinking in depth
Participants	Students selected from low, medium, and high achievement levels
Number of Participants	10–15 students
Interview Duration	20–30 minutes
Administration Time	After the implementation
Recording Method	Audio recordings and written notes
Data Analysis	Content analysis and descriptive analysis
Reliability	Inter-coder agreement

Table 12. Sample Interview Questions by Discipline (Source: Authors)

Discipline	Sample Question
Geography	How would you explain the role of temperature and precipitation in the formation of climate types?
Physics	How do atmospheric pressure and energy transfer affect weather events?
Chemistry	Explain the effect of greenhouse gases on global warming from a chemical perspective.
Mathematics	What conclusions can you draw from graphs of climate data?
Biology	How does climate change affect the lives of living organisms?
Interdisciplinary	Evaluate the greenhouse effect from the perspectives of geography, physics, chemistry, mathematics, and biology.

4.4. Implementation Plan of the Cooperative Catalyst Model (C2M) in Science Lessons

This study is designed within the scope of science education to enhance 11th-grade students' understanding of the "Force and Motion" unit through an interdisciplinary approach. The implementation is grounded in student-centered, active learning, and cooperative instructional principles. The primary instructional strategy is the Cooperative Catalyst Method (C2M), an approach in which selected students assume the role of "catalysts" and facilitate their peers' learning by sharing their specialized understanding within collaborative group structures. This method not only promotes cognitive achievement but also aims to develop higher-order skills such as communication, problem-solving, leadership, and responsibility.

The implementation is conducted within the science curriculum under the "Force and Motion" unit and involves 25 students; however, the number of participants may vary depending on classroom conditions. The instructional process is planned for five weeks, with four class hours per week, totaling 20 instructional hours. The primary objective is to enable students to understand the concepts of force, motion, and energy from a multidimensional perspective and to construct meaningful learning by relating these concepts to different disciplines. Accordingly, the instructional process is organized within an interdisciplinary framework, and the assessment process includes module tests, an academic achievement test, and semi-structured interviews.

The "Force and Motion" unit is integrated with five different disciplines to allow students to examine the topic from multiple perspectives. Science education provides the fundamental scientific explanations of force, motion, and energy. Mathematics contributes through measurement, data analysis, and graphical interpretation of quantitative data. Within the scope of technology and design, students develop simple mechanical models to transform theoretical knowledge into tangible products. Physical education examines real-life and sports-related examples of motion, thereby strengthening the experiential dimension of the concept. Finally, Turkish language supports students' scientific communication skills through the preparation of experimental reports and presentations.

Through this interdisciplinary structure, students are expected not only to acquire theoretical knowledge of force and motion but also to develop a comprehensive understanding by integrating mathematical analysis, design-based learning, physical application, and academic communication skills. Consequently, the instructional process becomes a holistic learning environment in which different disciplines complement one another, thereby contributing to both students' academic achievement and the development of 21st-century skills.

4.4.1. Identifying Catalysts

Identifying catalysts is a critically important and strategically structured phase aimed at enhancing the efficiency of the collaborative learning process. In this context, catalysts are selected from students who demonstrate a high level of prior knowledge of the subject matter, strong academic competence to guide learning processes, and well-developed leadership skills. In addition, volunteers or teacher-recommended upper-grade students may also be assigned to this role. Before the implementation of the course, a structured pre-training program is provided to selected catalysts to ensure that they are adequately prepared in both subject content knowledge and group facilitation and communication skills. This training is designed to enable catalysts to effectively perform responsibilities such as distributing tasks within groups, facilitating discussions, establishing interdisciplinary connections, and promoting academic interaction among students.

Within the Science discipline, catalysts primarily focus on understanding the fundamental principles of force, motion, and energy and transferring this understanding into group activities. In Mathematics, they guide the systematic analysis of data through measurement, data interpretation, and graphing skills. In Technology and Design, they support the development of simple models and the creation of tangible product designs. In Physical Education, they contribute to the concretization of abstract concepts by relating movement-based activities to real-life examples. In the Turkish language discipline, they assist in structuring experimental reports, preparing academic presentations, and developing scientific communication skills, thereby supporting students in expressing their ideas clearly and effectively. Through this multifaceted structure, catalysts occupy a central role in the interdisciplinary learning process, thereby enhancing both academic achievement and social learning outcomes. Figure 7 illustrates the catalysts identified for the "Force and Motion" unit.

The responsible discipline is Catalysts.				
C1 	C2 	C3 	C4 	C5 
Science	*Mathematics*	*Technology and Design*	*Physical Education*	*Turkish Language*

Figure 7. Catalysts identified for the "Force and Motion" unit (Source: Authors)

4.4.2. Formation of Collaborative Groups

Since the topic of Force and Motion is addressed across five different disciplines, the class is divided into five heterogeneous collaborative groups, each consisting of five students, to ensure an effective and efficient instructional process. The primary purpose of forming these groups is to bring together students with varying academic achievement levels, learning paces, and cognitive abilities in order to promote interaction and peer learning.

To establish a balanced group composition, a Prior Knowledge Test may be administered to assess students' understanding of Force and Motion, or alternatively, students' academic levels may be determined based on their previous course performance scores. Based on the data obtained, students are evenly distributed into high-, medium-, and low-achievement categories so that each group includes learners with different proficiency levels. This structure enhances the quality of collaborative learning and encourages students to learn from one another, assume responsibility within the group, and strengthen group interaction.

4.4.3. Identification of Subtopics and Discipline

The process of identifying subtopics and associated disciplines for the theme "Force, Motion, and Energy" is grounded in an interdisciplinary approach. Within this framework, the Science course provides the core conceptual foundation of the topic, fostering students' understanding of the relationships among force, motion, and energy through both theoretical and experimental perspectives.

The Mathematics course contributes through measurement, data analysis, and graphing skills, enabling students to interpret experimental data, represent relationships between variables visually, and develop quantitative reasoning skills. The Technology and Design field encourages students to design simple tools and models, helping them to concretize abstract concepts and transform theoretical knowledge into practical applications.

The Physical Education course addresses the concept of motion in relation to daily life, allowing students to experience the relationship between force and motion through their own physical activities, thereby making learning more concrete and experiential. The Turkish Language course supports students in expressing the knowledge and experiences gained across all disciplines within an academic framework, with a focus on developing skills in writing laboratory reports and preparing presentations. Through this integrated structure, students' cognitive and practical skills are developed within an interdisciplinary learning environment.

4.4.4. Implementation of the Application

The implementation process of this discipline is organized on a weekly basis to ensure that the study is conducted in a systematic and well-planned manner. As illustrated in Figure 8, the activities, learning objectives, and implementation steps for each week are specified in detail.

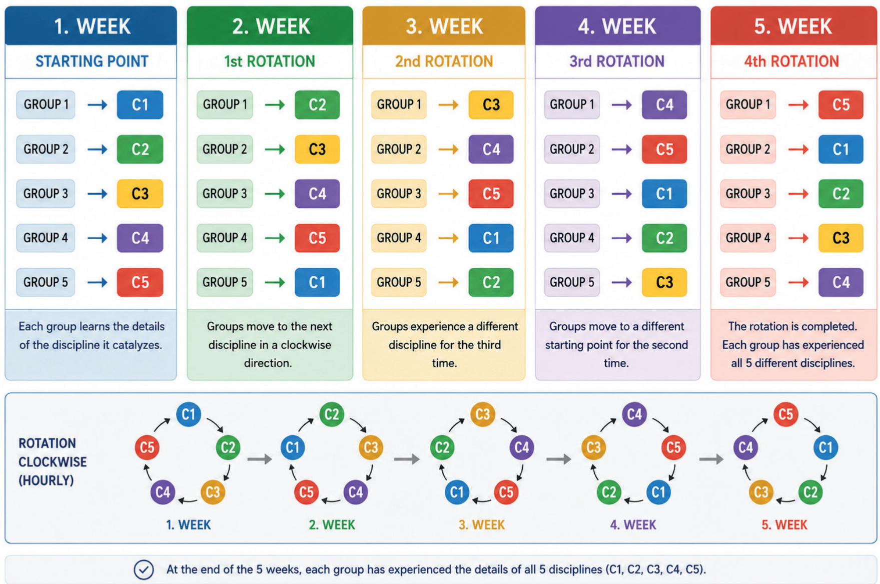

Figure 8. Interdisciplinary application scheme for the Force and Motion unit of the science course (Source: Authors)

First Week Implementation (Week 1 / First Lesson)

During the first week of implementation, each student group engages with the foundational knowledge of the discipline assigned to its respective catalyst. At this stage, students establish an interdisciplinary conceptual foundation by examining the topic of “Force and Motion” from multiple disciplinary perspectives. The group composition remains fixed throughout the week, and each group works exclusively within its assigned catalyst.

Group 1 explores the relationship between Force and Motion and the Science discipline in Catalyst C1, focusing on fundamental concepts related to force, motion, and energy.

Group 2 examines the relationship between Force and Motion and the Mathematics discipline in Catalyst C2, focusing on basic concepts related to measurement, data analysis, and graphical representations.

Group 3 investigates the relationship between Force and Motion and the Technology and Design discipline in Catalyst C3, focusing on basic principles of simple vehicle models.

Group 4 explores the relationship between Force and Motion and the Physical Education discipline in Catalyst C4, focusing on fundamental concepts illustrated through examples of motion in daily life.

Group 5 examines the relationship between Force and Motion and the Turkish Language discipline in Catalyst C5, focusing on preparing experiment reports and presentations.

By the end of the first week, each group will have acquired basic disciplinary knowledge related only to its assigned catalyst. This provides students with a strong initial understanding of how the topic of Force and Motion is addressed across different disciplines. In the subsequent weeks, students continue the learning process in other disciplines without changing their group membership; instead, groups rotate through different catalysts.

2nd Week Implementation (Week 2 / Second Lesson)

During the second week of implementation, each student group rotates collectively from its previously completed catalyst to the next assigned catalyst. At this stage, students broaden their interdisciplinary conceptual connections by examining the topic of "Force and Motion" from a different disciplinary perspective. Group membership remains unchanged; only the assigned catalysts are rotated.

Group 1 moves to Catalyst C2, where it explores the relationship between Force and Motion and the Mathematics discipline, focusing on measurement, data analysis, and graphical representations.

Group 2 moves to Catalyst C3, focusing on the relationship between Force and Motion and the Technology and Design discipline, with emphasis on simple vehicle models.

Group 3 moves to Catalyst C4, exploring the Physical Education discipline through examples of motion in daily life.

Group 4 moves to Catalyst C5, focusing on the Turkish Language discipline, particularly in relation to preparing experiment reports and presentations.

Group 5 moves to Catalyst C1, revisiting the Science discipline, with emphasis on foundational concepts of force, motion, and energy.

By the end of the second week, each group will have been exposed to foundational knowledge from two different disciplines. This enables students to develop a more comprehensive understanding of how the topic of Force and Motion is addressed across disciplines. In the following weeks, students continue the learning process through additional disciplinary rotations without changing group composition, only the catalyst assignments are updated.

3rd Week Implementation (Third Lesson / Third Week)

In the third week of implementation, each student group rotates collectively from the catalyst in which they worked during the previous week to the next assigned catalyst. At this stage, students further strengthen their interdisciplinary conceptual understanding by examining the topic of *Force and Motion* from the perspective of a third discipline. During this week, students do not change their physical positions; rather, groups are directed to different catalysts.

Group 1 examines the relationship between *Force and Motion* and the Technology and Design discipline in Catalyst C3, where students acquire basic concepts related to simple vehicle models.

Group 2 explores the relationship between *Force and Motion* and Physical Education in Catalyst C4, focusing on basic concepts related to examples of motion in daily life.

Group 3 investigates the relationship between *Force and Motion* and the Turkish Language discipline in Catalyst C5, where students learn fundamental skills related to preparing experiment reports and presentations.

Group 4 examines the relationship between *Force and Motion* and Science in Catalyst C1, focusing on fundamental concepts of force, motion, and energy.

Group 5 explores the relationship between *Force and Motion* and Mathematics in Catalyst C2, with emphasis on measurement, data analysis, and graphing.

By the end of the third week, each group will have acquired foundational knowledge and concepts from three different disciplines. Consequently, students begin to develop a deeper understanding of how *Force and Motion* is addressed across various disciplinary contexts. In subsequent weeks, students continue their learning process in the remaining disciplines without changing physical locations; only the group–catalyst assignments are rotated.

4th Week Implementation (Fourth Lesson / Fourth Week)

In the fourth week of implementation, each student group again rotates collectively from their current catalyst to the next assigned catalyst. At this stage, students begin to integrate their interdisciplinary learning by examining the topic of *Force and Motion* from the perspective of a fourth discipline. As in previous weeks, students do not change their physical locations; only group assignments to catalysts are reorganized.

Group 1 examines the relationship between *Force and Motion* and Physical Education in Catalyst C4, focusing on examples of motion in daily life.

Group 2 explores the relationship between *Force and Motion* and the Turkish Language discipline in Catalyst C5, focusing on preparing experiment reports and presentations.

Group 3 examines the relationship between *Force and Motion* and Science in Catalyst C1, focusing on fundamental concepts of force, motion, and energy.

Group 4 investigates the relationship between *Force and Motion* and Mathematics in Catalyst C2, focusing on measurement, data analysis, and graphs.

Group 5 examines the relationship between *Force and Motion* and Technology and Design in Catalyst C3, focusing on simple vehicle models.

By the end of the fourth week, each group will have developed foundational knowledge and conceptual understanding across four different disciplines. Accordingly, students begin to evaluate the topic of *Force and Motion* from a more holistic and integrative perspective across disciplines. In the following week, students complete the learning process by engaging with the final discipline, while maintaining the same physical arrangement and rotating only between catalysts.

5th Week Implementation (Fifth Lesson / Fifth Week)

In the fifth week of the implementation, each student group moves as a group from the catalyst they worked on in the previous week to the next and final catalyst. At this stage, students complete the interdisciplinary learning process by examining the topic of "Force and Motion" from the perspective of the final discipline. During this week, students do not change seats; only the groups are assigned to different catalysts.

Group 1 examines the relationship between the topic of "Force and Motion" and the Turkish Language discipline in Catalyst C5. In this catalyst, students learn basic concepts related to preparing experiment reports and presentations.

Group 2 examines the relationship between "Force and Motion" and the Science discipline in Catalyst C1, focusing on fundamental concepts of force, motion, and energy.

Group 3 explores the relationship between "Force and Motion" and the Mathematics discipline in Catalyst C2, focusing on measurement, data analysis, and graphing.

Group 4, in Catalyst C3, examines the relationship between "Force and Motion" and Technology and Design, focusing on basic concepts related to simple vehicle models.

Group 5, in Catalyst C4, examines the relationship between "Force and Motion" and Physical Education, focusing on examples of motion in daily life.

By the end of the fifth week, each group will have been exposed to the core knowledge and concepts of all five disciplines. Accordingly, students are expected to develop a holistic understanding of how the topic of "Force and Motion" is addressed across different disciplines and to relate this knowledge to real-life contexts.

4.4.5. Measurement and Evaluation

The topic of Force and Motion is addressed through an interdisciplinary integration of Science, Mathematics, Technology and Design, Physical Education, and the Turkish Language, enabling students to examine the subject from a multifaceted and holistic perspective. Within this interdisciplinary framework, the aim is not only to support students' acquisition of fundamental concepts but also to foster their ability to recognize and interpret relationships across different disciplinary fields.

The learning process is evaluated using three primary assessment tools: the Academic Achievement Test (AAT), Discipline-Based Module Tests, and Semi-Structured Interview Forms. The Academic Achievement Test is employed to determine students' overall knowledge level and interdisciplinary understanding of the topic. The Discipline-Based Module Tests assess the extent to which discipline-specific learning outcomes have been achieved within each field. The Semi-Structured Interview Forms are used to explore students' cognitive processes in depth, including their conceptual understanding and their ability to establish meaningful connections among different disciplines.

Accordingly, each assessment tool serves a distinct evaluative purpose, collectively providing a comprehensive account of students' knowledge, skills, conceptual understanding, and interdisciplinary reasoning abilities. The Academic Achievement Test (AAT) is presented in detail in Tables 13 and 14, the Discipline-Based Module Tests in Tables 15 and 16, and the Semi-Structured Interview Forms in Tables 17 and 18.

Table 13. General Characteristics of the Academic Achievement Test (Source: Authors)

Feature	Description
Test Purpose	To measure interdisciplinary academic achievement related to the concepts of force, motion, and energy
Scope	Science, Mathematics, Technology and Design, Physical Education, Turkish Language
Administration Time	Pre-test and post-test (before and after implementation)
Number of Items	30–40 items
Duration	40–60 minutes
Item Types	Multiple-choice, short answer, graph interpretation, open-ended questions
Measured Skills	Conceptual knowledge, analysis, interpretation, problem-solving, interdisciplinary reasoning
Scoring	Correct/incorrect scoring for multiple-choice items; rubric-based scoring for open-ended items
Validity Study	Expert review, content validity, pilot study
Reliability Study	KR-20 or Cronbach's Alpha coefficient
Intended Use	To determine achievement differences between experimental and control groups

Table 14. Distribution of the Academic Achievement Test by Discipline (Source: Authors)

Discipline	Measured Learning Outcomes	Sample Number of Items
Science	Force, motion, energy transformations	8
Mathematics	Measurement, tables, and graph analysis	6
Technology and Design	Design and functioning of simple tools	6
Physical Education	Movement patterns and performance relationships	5
Turkish Language	Writing experimental reports and oral presentations	5
Total	Interdisciplinary holistic achievement	**30**

Table 15. Common Characteristics of Module Tests (Source: Authors)

Feature	Description
Test Purpose	To evaluate specific learning outcomes of each discipline
Administration Time	After completion of each module
Number of Items	10–15 items
Duration	20–30 minutes
Item Types	Multiple-choice, short answer, applied tasks
Assessment Type	Formative and summative assessment
Scoring	Separate scoring for each discipline
Intended Use	To identify students' learning deficiencies at the module level

Table 16. Module Tests by Discipline (Source: Authors)

Discipline	Content Assessed	Item Types	Number of Items
Science	Types of force, motion types, energy	Multiple-choice, experiment interpretation	12
Mathematics	Length–time measurements, tables and graphs	Graph interpretation, problem solving	10
Technology and Design	Simple tool models, design process	Drawing, explanation, application	10
Physical Education	Movement examples, speed and coordination	Observation, short answer	10
Turkish Language	Experimental reports, presentation texts, expression	Open-ended, written expression	10–12

Table 17. General Characteristics of Interview Forms (Source: Authors)

Feature	Description
Interview Purpose	To reveal students' conceptual understanding and experiences
Participants	Students selected from low, medium, and high achievement levels
Number of Participants	10–15 students
Administration Time	After the intervention
Duration	20–30 minutes
Number of Questions	8–10 open-ended questions

Data Recording	Audio recording and written notes
Analysis Method	Content analysis and descriptive analysis
Validity	Expert review and pilot interviews
Reliability	Inter-coder agreement

Table 18. Themes of Interview Questions (Source: Authors)

Theme	Sample Question
Conceptual Understanding	How do you explain the relationship between force and motion?
Interdisciplinary Connections	How did mathematics graphs help you understand experiments in science class?
Daily Life Relevance	How do you observe force and motion concepts while doing sports?
Design Process	Which physical principles did you use in your model?
Communication Skills	How did preparing an experimental report affect your learning?
Implementation Reflections	In which aspect did this study help you the most?

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