World Applied Sciences Journal 7 (1): 34-42, 2009
ISSN 1818-4952

Effects of Two Cooperative Learning Strategies on Teaching and Learning Topics of Thermochemistry

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Abstract: The aim of this study was to determine the effect of group investigation and jigsaw techniques on students' achievement in the thermochemistry unit of a general chemistry course. This study included a total of 80 students studying chemistry in two different classes during the 2008-2009 academic years. One of these classes served as the group investigation group, using group investigation technique, while the other served as the jigsaw group, using jigsaw technique. The main instruments for obtaining data were the Thermochemistry Achievement Test (TAT) and The Particulate Nature of Matter Evaluation Test (PNMET), which were applied to treatments groups. The questions in the TAT are related to heat and work, heats of reaction and calorimeter, the first law of thermodynamics, Hess's law, standard enthalpies of formation, fuel as source of energy and exothermic and endothermic reactions. The PNMET designed to determine understanding of the concepts relevant to the thermochemistry unit. This is an instrument requiring the students to make drawings and give explanations. The results indicated that the instruction based on group investigation techniques, caused a significantly better achievement in terms of the TAT and PNMET compared to jigsaw technique designed chemistry instruction.

Key words: Cooperative Learning · Thermochemistry · Group Investigation · Jigsaw Technique

INTRODUCTION

In schools today, instructional strategies such as Classwide Peer Tutoring [1,2], cooperative and collaborative learning [3-6] and sport education [7] have been proposed as alternative approaches to the direct style of instruction in pedagogy texts and in college methods courses. Many of these strategies are rooted in the recognition that "one size does not fit all" in the complex learning environments found in educational settings. A theme common too many of these strategies has been the use of peers to assist each other in pursuing lesson objectives, which have comprised not only cognitive goals but also social and psychomotor goals. Cooperative learning (CL) has been defined as a set of alternative instructional methods in which students work in small groups to help one another learn academic material [8-10]. As a pedagogical technique, CL has been studied intensively in classrooms [11]. In general and special education settings, CL has yielded academic gains, such as increased student achievement and social gains, such as improved intergroup relations, acceptance of academically handicapped classmates and increased self-esteem [12,13]. There is ample evidence in the classroom literature demonstrating that CL methods are effective alternative approaches to the direct style of instruction in classrooms [11].

Cooperative learning (CL) is a possible instructional innovation that could be related to the affective aspects of reading. In fact, CL has been established as a promising instructional innovation that may improve the cognitive, social and affective outcomes of schooling [11]. At present, there are many CL methods and structures available. According to Johnson & Johnson [14], these methods and structures can be categorized into the following models: a) Student Teams and Achievement Divisions (STAD) [11], b) Teams-Games-Tournaments (TGT) [11], c) Learning Together (LT) [15], d) Jigsaw Technique (JT) [3,16,17], e) Group Investigation Technique (GIT) [18], f) Team Accelerated Instruction (TAI) [19] and g) Cooperative Integrated Reading and Composition (CIRC) [20]. In the present study, students learned about thermochemistry topics in a classroom environment in which the jigsaw and group investigation methods of cooperative learning were used for teaching and learning.

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Jigsaw Technique: There are currently six types of jigsaw strategies available for teachers to use in the classroom: a) Jigsaw, developed by Aronson and Shelley [21]; b) Jigsaw II, developed by Slavin [11]; c) Jigsaw III, developed by Stahl [22]; d) Jigsaw IV, developed by Holliday [23]; e) Reverse Jigsaw, developed by Hedeen [24]; and f) Subject Jigsaw, developed by Doymus [25]. The basic parts of the strategies are the same. In this research, we used the Subject Jigsaw. The Subject Jigsaw differs from the other jigsaws in that both course topics and students groups are divided.

In this jigsaw technique, each student prepares a part of the assignment out of class. On returning to the group, each student peer teaches the information to the rest of the members. All groups in a class may cover the same topic or different groups may have different parts of the topic. Groups are subsequently reorganized to peer teach the material [26]. The jigsaw cooperative learning structure enhances cooperative learning by making each student responsible for teaching some of the material to the group. In this structure, students are members of two different groups, the 'home group' and the 'jigsaw group'. Initially, students meet in their home groups and each member of the group is assigned a portion of the material to learn as an 'expert' [16,25]. The home groups then break apart, like pieces of a jigsaw puzzle and students move into jigsaw groups, which consist of members from the other home groups who have been assigned the same portion of the material. While in the jigsaw groups, the students discuss their particular material to ensure that they understand it. Students then return to their home groups, where they teach their material to the rest of their group [27].

Group Investigation Technique: The group investigation technique is proposed as a way of creating a social learning environment in which students work together to pursue inquiry tasks of their own [18,28]. In the group investigation technique, students are organized in small research groups and cooperate in planning projects, carrying out investigations, presenting the findings and evaluating their learning. When the group investigation technique is implemented, the classroom "becomes an 'inquiring community,' and each student is an investigator who coordinates his or her inquiry with the class's common purpose" [28]. Hence, the group investigation technique is well suited to a science lesson for which the goal is to engage students in practices of scientific inquiry and to encourage them to contribute to the learning of the whole class [29]. The group investigation technique also helps students to develop their cognitive abilities since the method involves higher-level thinking tasks such as identifying information relevant to their research topics, applying knowledge to new problems, using inferences to formulate answers and evaluating the inquiry performances of others [28]. Research has reported, with a high degree of consistency, the effectiveness of the group investigation technique in achieving positive learning outcomes in several domains [30]. Oh & Shin [18] used the group investigation technique combined with a peer tutoring strategy in high school biology classrooms and found that students from the group investigation technique settings were superior to those taught by whole-class methods in terms of academic achievement, process skills, perceptions of learning environment and self-esteem. Shachar & Sharan's [31] study also revealed that the group investigation technique was more effective than the whole-class presentation–recitation method in producing active verbal and social interactions among students as well as larger gains on achievement tests. Oh & Yager [30] found that the degree of positive student attitudes toward science learning increased as the students learned science by using the group investigation technique on more occasions. In particular, their study showed that the relevancy of the topics, addressed in the group investigation technique activities, to students' day-today experiences was the most significant factor for the positive changes in student attitudes. Despite such learning benefits, the group investigation technique may include weaknesses that other CL methods have in common. For example, it has been reported that some students have difficulty in taking advantage of social learning processes because of uncooperative group members [32]. Students as well as teachers may consider inquiry-based approaches such as the group investigation technique inappropriate for them because they feel pressure to cover everything included in the curriculum and because they may have seldom learned science by investigative methods [33]. Therefore, it is important to gain insights into how students perceive their learning activities with the group investigation technique in order to understand the ways the cooperative inquiry affects student learning and to find implications for better educational practices in science classrooms. However, few studies have examined students' ideas about their experiences with CL methods in schools [34].

The primary goal of this study was to investigate the effectiveness of jigsaw technique and group investigation technique of instruction on students' academic achievement and understanding particle nature of matter in the general chemistry course.

MATERIAL AND METHODS

Sample: The sample of this study consisted of a total of 80 undergraduates from two different classes enrolled in the general chemistry course for the 2008–2009 academic years. One of the classes was defined as the Group Investigation Group (GIG) (n=40) and was taught by the group investigation technique, while the Jigsaw group (JG) (n=40) was taught through jigsaw technique. Pre-service science teachers are admitted to this department only after they have successfully passed a university entrance exam. The mean age of the participants was 19.23 (SD=1.38). Neither age nor gender differed significantly among the groups. Ages ranged from 18 to 23 years. Volunteers were given background information regarding the study prior to consent. During the training period, instruction for both groups was delivered by the researchers.

Instruments: In this research, Thermochemistry Achievement Test (TAT) and Particle Nature of Matter Evaluation Test (PNMET) were used.

The TAT consists of 25 multiple-choice questions, with each question worth five points. TAT was created by researchers. The questions in the test were related to heat and work, heats of reaction and calorimeter, the first law of thermodynamics, Hess's law, standard enthalpies of formation, fuel as a source of energy and exothermic and endothermic reactions. This test was given to students who were not involved in the study but had previously taken the course in which the thermochemistry topics mentioned above had been taught. With respect to the reliability, TAT was administered to a group of forty-two students who took General Chemistry-II course the year before. The KR20 was used for determining the reliability of TAT and reliability coefficient was found as (α= 0.68). This level of reliability coefficient for an achievement test indicates that the test could be considered satisfactorily reliable [35]. Also, for the validity of TAT developed, opinions of the chemistry lecturers and researchers on the subject have been taken into consideration. Researchers have pointed out that the gains of TAT related to the subjects of thermochemistry have been high towards measurement.

The Particulate Nature of Matter Evaluation Test (PNMET) was designed to determine understanding of the concepts relevant to the thermochemistry unit. This is an instrument requiring the students to make drawings and give explanations. The validity of the test was checked by a professor and two other chemistry teachers. A panel expert established the content validity, while the percent agreement for multiple graders on papers randomly chosen established the inter-rater reliability. The percentage agreement of the PNMET was established at 80% or higher. The responses for the PNMET were established by a panel of experts. PNMET scores were given to responses given in terms of molecules, atoms, ions and so on. Responses are those that repeat questions or give irrelevant or unclear responses were not taken into consideration. The criteria and scale used in this study were developed by adapting the scale used for misconceptions by Haidar and Abraham [36] and Williamson [37]. For statistical analysis, numeric scores of '10' were assigned to "satisfactory understanding" responses and '0' to all other categories of responses. The maximum score for each task used in this test was 10.

Procedure: In both groups, this study was conducted over a five-week period during which thermochemistry was taught as part of the regular curriculum in the general chemistry course. Classroom instruction for both groups consisted of four class hours per week. A total of 80 students from two classes were involved in the study. One of the classes was the GIG and the other class was the JG. To examine the effect of the jigsaw technique and group investigation technique on academic achievement, to determine the students' previous learning in chemistry, the TAT was administered to both groups as a pre-test before the jigsaw technique and group investigation technique was applied. Next, the thermochemistry unit was studied in two groups. Two different instructors were involved in the teaching. While one of the teachers actually taught the course, the second teacher, an expert (the author) in cooperative learning, observed the teaching process in both the GIG and JG.

Forming and Re-Forming Jigsaw Groups: The jigsaw group students were randomly divided into two parts (20 students + 20 students). Figure 1 represents one of these parts (20 students). The other part was organized in the same way as the first. These students were divided into five "home groups" since the thermochemistry topic is divided into five subtopics [a) heat, work and fuel as source of energy, b) heats of reaction and calorimeter,

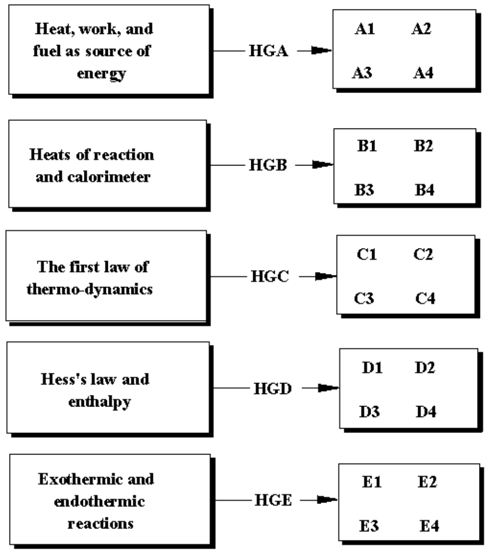

Fig. 1: Subtopics of the Thermochemistry Unit and Home Groups Representing (A1, A2, A3 etc. Stands for an Individual Student from a Group)

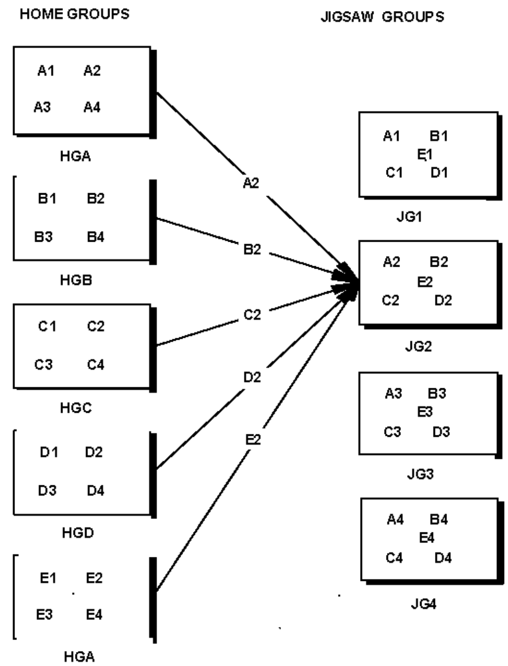

Fig. 2: Forming of Jigsaw Groups from Home Groups

c) the first law of thermodynamics, d) Hess's law and enthalpy and e) exothermic and endothermic reactions]. In this instance, each home group contained four students; however, the number of home groups in a class can be increased or decreased so that every student in the class can participate in the jigsaw method.

These Groups Are as Follows: Home Group A (HGA), representing heat and work. The students in HGA prepared the subjects 'main concepts in thermochemistry', 'heat', 'work' and 'experimental determination of specific heats' and presented these subjects to the class.

Home Group B (HGB), representing heats of reaction and calorimeter. The students in HGB prepared and presented the subjects 'heat capacities at constant volume and pressure and their relationship', 'definition of internal energy and enthalpy', 'bond dissociation energy and its calculation from thermochemistry data', 'temperature dependence of enthalpy', 'bomb calorimeter' and 'coffee-cup calorimeter'.

Home Group C (HGC), representing the first law of thermodynamics. The students in HGC prepared and presented the following subjects to the class: 'pressure-volume work', 'internal energy', 'enthalpy and energy' and 'functions of state'.

Home Group D (HGD), representing Hess's law and standard enthalpies of formation. The students in HGD prepared and presented the following subjects to the class: 'the process occurs in stages on steps', 'the enthalpy change for the overall (net) processes' and 'the sum of the enthalpy changes for the individual steps'.

Home Group E (HGE), representing fuel as a source of energy and exothermic and endothermic reactions. The students in HGD prepared and presented the following subjects to the class: 'exothermic and endothermic solutions', 'potential energy and reaction coordinates' and 'exothermic and endothermic reactions'.

Each home group studied their subjects on their own out of class. Then each group was given 30 min to present their work to the class and 20 min for discussion with the class. During this discussion, the home group answered the questions asked by the class. The home groups then broke apart, like pieces of a jigsaw puzzle [38,39] and the students moved into jigsaw groups consisting of members from the other home groups who were assigned the same portion of the material. Then the students in the home groups, following the presentation of all subtopics in thermochemistry, formed jigsaw groups containing JG1, JG2, JG3 and JG4, with one student from each of the home groups (Fig. 2). In these jigsaw groups, the teacher asked them to familiarize themselves with their subtopic. They prepared summary reports and then each jigsaw group prepared a teaching strategy for its members to use to explain their subtopic to the rest of the class. Each jigsaw group presented their own topic to the class for 30 min

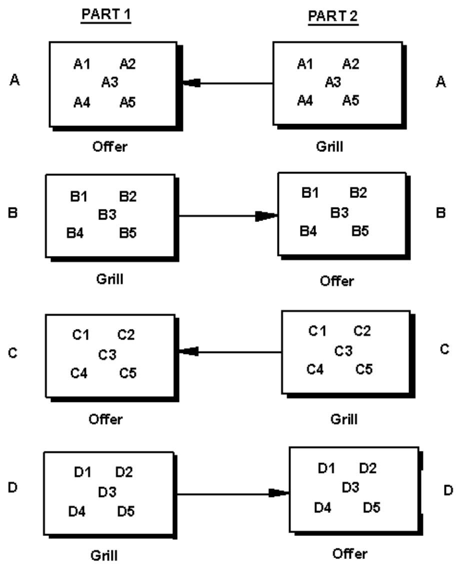

Fig. 3: Forming of grill and offer groups from parts I and II.

and then discussed the related topics for 20 min. The students then went back to the home groups. These home groups then consisted of one student from each jigsaw group and these students were called "expert students." The experts were then in charge of teaching their specific subtopic to the rest of the students in their learning group.

The Group Investigation Technique Implemented: The GIG students were randomly divided into two parts (Part I=20 students + Part II=20 students). The students in these parts were divided into four "home groups" as shown in Figure 3. In this instance, each home group contained five students; however, the number of home groups in a class can be increased or decreased so that every student in the class can participate in the GIG. The group investigation technique was employed over five weeks to research the thermochemistry unit. The overarching goal of the action research was to create constructivist classroom environments in which students could practice scientific inquiry as they worked together to pursue their own learning goals. The main features of the modified group investigation technique are presented in three phases [18], namely 1) in-class discussion, 2) out-of-class investigation and 3) in-class presentation.

In-class discussion; 'students are organized into research groups', 'students get together in their groups for discussion', 'each group sets an inquiry topic within a given unit and makes a plan for investigation', 'during the discussion, group members use their science books to identify their own problems, questions, or issues and select a topic to study' and 'the teacher participates in the group discussion and the teacher's roles include encouraging students to select authentic topics that can be addressed in multiple ways'.

In out-of-class investigation; 'each student group carries out its investigation', 'the teacher helps students with their investigations', 'the teacher's roles include presenting sources of information, providing instruments for experiments and assisting students with difficulties' and 'each research group prepares an in-class presentation'.

In-Class Presentation: Week I; group A in part I was the presentation (offer) group while group A in part II was the inquiry (grill) group. While group A in part I presented the thermochemistry unit, group A in part II questioned the group about their presentation and determined their weaknesses. Other students in the classroom also joined the discussion. Week II; group B in part II was the offer group while group B in part I was the grill group. While group B in part II presented the thermochemistry unit, group B in part I questioned the group about their presentation and determined their weaknesses. Other students in the classroom also joined the discussion. Week III; group C in part I was the offer group while group C in part II was the grill group. Week IV; group D in part I was the offer group while group D in part II was the grill group. The same course structure in weeks I and II was used in weeks III and IV.

RESULTS

Prior to the experiment, an independent t-test was employed to determine whether a statistically significant mean difference existed between the JG and GIG with respect to thermochemistry achievement measured by TAT. No statistically significant mean difference was found between the two groups before the jigsaw technique and group investigation technique were applied ($t = 1.158$, $p = .250$) (Table 1).

Then an independent t-test was carried out to compare the effect of the type of instruction on students' thermochemistry achievement measured by TAT as a post-test. The data indicated that there was a significant difference in chemistry achievement between the JG and the GIG ($t = 2.414$, $p = .018$ (see Table 1). Students in the GIG scored significantly higher than those in the JG after the instruction.

Table 1: Independent t-Test Analyses of Pre- and Post-Test TAT Scores

Group (N)	Mean[a]	SD	t	P
Pre-Test				
GIG (40)	50.37	11.637	1.158	0.250
JG (40)	47.56	10.023		
Post-Test				
GIG (40)	68.00	10.019	2.414	0.018
JG (40)	62.43	10.583		

[a]Maximum scores for these tests was 100 points.

Table 2: Comparative t-Test Analyses of PNMET Tasks Scores

Task No	Group (N)	Mean[a]	SD	*t*	*p*
1	JG (40)	6.25	4.903	2.338	0.022
	GIG (40)	8.50	3.616		
2	JG (40)	0.75	2.667	3.152	0.002
	GIG (40)	3.50	4.830		
3	JG (40)	0.25	1.581	1.020	0.311
	GIG (40)	0.75	2.667		
4	JG (40)	0.25	1.581	0.582	0.562
	GIG (40)	0.50	2.207		
5	JG (40)	9.00	3.038	1.385	0.171
	GIG (40)	9.75	1.581		
6	JG (40)	7.50	0.693	3.606	0.001
	GIG (40)	10.00	0.000		

[a]Maximum score for each task was 10 points.

Table 3: Written Expressions Related to Task Number 2,3 and 4 on PNMET and the frequencies for These Expressions

Written expressions obtained from the incorrect students' drawings	JG	GIG
[Task 2] Students' drawings show that $NaNO_3$ dissolves in water as OH^- and H^+ ions, which are belongs the ionized water, are surrounded by the Na^+ and NO_3^- ions respectively (Figure 4).	6	4
[Task 2] Students' drawings show that when an amount of salt ($NaNO_3$) is added to water, salt and water reaction produce NaOH and HNO_3.	6	4
[Task 2] Students' drawings show that as $NaNO_3$ dissolves in water, there isn't any interaction between molecules of water and salt. Also they represent the $NaNO_3$ solution as only form Na^+ and NO_3^- ions.	7	3
[Task 3] Students' drawings show that as A_2(g) and B_2(g) react even though the energy needed for this reactions is provided, A_2(g) and B_2(g) keep their initial position at any point of after forming activated complex (Figure 5).	5	4
[Task 4] Students' drawings show that as ice at –20°C is heated there is only ice particles at a point between -20°C and 0°C temperatures (Figure 6).	30	30

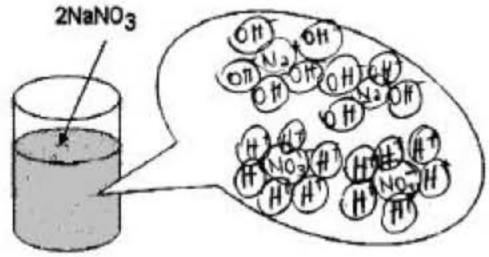

Fig. 4: One example from students' responses concerning with the Task 2 (Group Investigation Group; Part 1; student code A4)

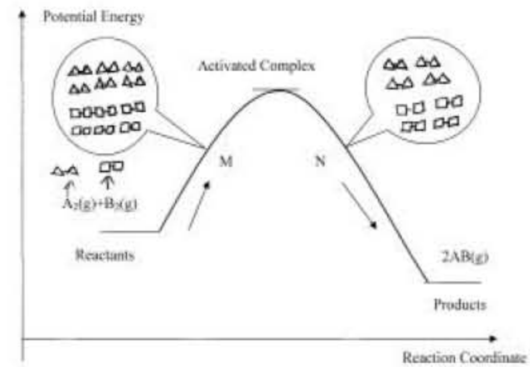

Fig. 5: One example from students' responses concerning with the Task 3 (Jigsaw Group; student code B3)

The PNMET was administered at the end of four weeks in both the GIG and JG students after the instruction. The results of the PNMET given in Table 2 clearly show that a significant difference exists between the mean scores of the GIG and JG with respect to scores in Task 1 ($t = 2.338$; $p < .05$), Task 2 ($t = 3.152$; $p < .05$) and Task 6 ($t = 3.606$; $p < .05$). Also, the data given in Table 2 indicated that there was no a significant difference between the JG and the GIG in the mean scores in Task 3 ($t = 1.020$; $p > .05$), Task 4 ($t = 0.582$; $p > .05$) and Task 5 ($t = 1.385$; $p > .05$). It is clear that the mean score of the GIG was higher than that of the JG in Tasks 1-6. The mean scores of the GIG and JG were higher for Task 1, 5 and 6 when compared to those for Task 2, 3 and 4.

Both GIG and JG scores for tasks 2, 3 and 4 are low (Table 2). We are to examine why the scores for tasks 2, 3 and 4 are low, the content analysis was carried out for students' responses belong to Task 2, 3 and 4. The written expressions obtained from the student drawings for the Task 2, 3 and 4 and the frequencies of these expressions are given in Table 3 and some students' drawings are given in Figure 4, 5 and 6.

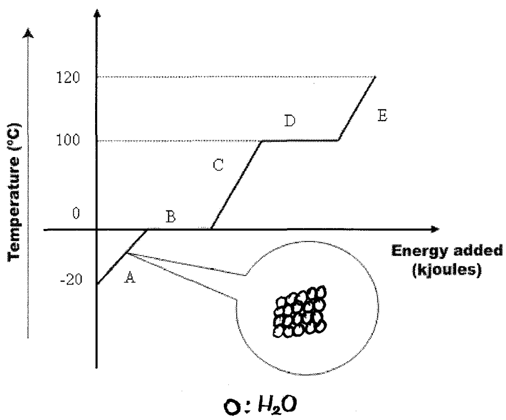

Fig. 6: One example from students' responses concerning with the Task 4 (Jigsaw Group; student, code C1)

The reasons for the scores of tasks 2, 3 and 4 low could be listed as follows: 1) Students did not have a sound understanding of exothermic and endothermic solutions (Task 2), 2) Students did not clearly understand the process from the formation of activated complex to the formation of products (Task 3), 3) Students understand that ice at -20 °C does not evaporate (Task 4). Some drawings from students' responses are given in Figure 4, 5 and 6 in order to exemplify the case.

CONCLUSIONS

In most prior studies, group investigation cooperative teaching was found to be no more effective in terms of academic achievement than the jigsaw cooperative teaching and comparison treatments [18]. In our study, group investigation had a significant positive effect on the thermochemistry learning experience of undergraduate chemistry students.

By including in these discussions the importance of temperature and its influence on structure and properties, students can gain an appreciation of the concept of thermochemistry even before it is formally addressed in thermochemistry, solution and solid, liquid and gas equilibria [17,40]. When provided with thermochemistry, the product of fundamental theoretical and experimental research and a discussion of its physical and chemical relevance, students could begin to make the connection between the chemistry of atoms and molecules on the one hand and the natural world around them on the other. This is indeed one of the most important aims of the general chemistry course.

The students appreciated how the group investigation technique turned their science classrooms into more cooperative learning environments. They also reported in their drawings that group investigation technique group experiences resulted in several positive learning outcomes, including more positive for particulate nature of matter and science learning, gaining new information, improved learning capabilities and greater self-esteem. Thus, there are good reasons for using a group learning process such as group investigation technique in order to create an "inquiring community" [18] in which students participate actively and continuously in practices of scientific inquiry. Teachers of science should remember, however, that students at times have difficulty and may experience trouble when cooperative methods are employed in classrooms. In such cases, it would not be a solution to just place students in an inquiry-oriented environment and expect them to work effectively. Rather, the teacher must attend to the students' current state of knowledge, abilities, attitudes, or other learning-related factors, provide help accordingly and guide them gradually to take on autonomy for their own learning of science. The results of the study suggest important implications for future research on jigsaw technique and group investigation technique for learning science. Although several possible learning outcomes were indicated by students, the present study lacks direct evidence for these positive results beyond the reflections provided by the learners in their written responses to a question about the jigsaw technique and group investigation technique experiences. Therefore, further studies are needed to examine the relationship between jigsaw technique and group investigation technique from cooperative science learning methods and different kinds of science learning outcomes.

In this study, from the results of PNMET with drawings and a two-tier format, which was devised to test misunderstandings concerning the particulate nature of matter, it was clear that students perceived the gas as a continuous medium, rather than as an aggregation of particles. This could be the reason for students' misunderstanding the particulate nature of matter. In other words, even though they had learned it in school, the particulate theory was not useful for most students. This is the reason why students cannot correctly learn the related science concepts. In view of those findings, it was shown that the existence and persistence of students' misunderstandings about the particulate nature of matter is an important factor to be considered in the teaching of the principles or theories of the particulate conceptions related to the general chemistry course. It indicated that to teach the term knowledge was not enough in school. The relationships and links in the new knowledge and the preconceptions or misconceptions held by the students should be emphasized. In this research, after the instruction with a group investigation and jigsaw teaching curriculum that was developed to stimulate learners to generate modifications of their own pre-existing concept concerning the particulate nature of matter, the students did demonstrate significant improvements on the PNMET concerning particulate concepts.

In university, chemistry instruction is challenging for both the students and the teacher. There is a wide range of skills and abilities required for students to comprehend the course material; for example, students need spatial ability to comprehend kinetic motion of matter particles, atomic structure, or molecular configuration. One challenge for the teachers is in the use of teaching technology they require for the wide variation of students' abilities and skills.

Future research should also be designed to find appropriate strategies for enhancing student participation in and contribution to group inquiry. While many strategies have been suggested, there are still research questions that need to be examined to determine how these actually affect interactions among classroom participants in different learning situations.

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