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THE EFFECT OF SEVEN PRINCIPLES AND MODEL-SUPPORTED COOPERATIVE LEARNING ON THE CONCEPTUAL UNDERSTANDING AND ELIMINATING MISCONCEPTIONS OF THE PARTICULATE NATURE OF MATTER

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ABSTRACT

This study investigated the effect of the seven principles for good practice (SPGP) and model-supported cooperative learning on the conceptual understanding of the particulate nature of matter (PNM) and aimed to eliminate the misconceptions of students related to it. A quasi-experimental method was used. The study was conducted with 73 sixth-grade students divided into three experimental groups and a control group. The reading writing application (RWA) method of cooperative learning was used in all experimental groups, namely the first experimental group [SPGP - RWA - model group (SRMG)], the second experimental group [SPGP - RWA group (SRG)], the third experiment group [RWA group (RG)], and the control group [(CG)]. A concept test containing 16 two-stage questions was used to collect data and one-way ANOVA and ANCOVA were used in the analysis of the data. According to the results, the SPGP and model-supported cooperative learning applications facilitated conceptual understanding of the PNM. Accordingly, it was observed that the SRG and the SRMG further improved their conceptual understanding of the PNM. However, it was found that some misconceptions continued to prevail in all groups in the post-test. It is recommended that different active learning methods be applied together with cooperative learning and models to help conceptual understanding and eliminate misconceptions. In addition, it is suggested to apply different methods to increase the effect of the seven principles.

Keywords: *Conceptual understanding, Cooperative learning, Model, Particulate nature of matter, Seven principles*

INTRODUCTION

The particulate nature of matter (PNM) is a basic science topic, abstract in nature. In order to learn many subjects in science correctly, the PNM should be understood at a basic level. The PNM is very important in this regard and there are many studies concerning the PNM (e.g., Jaber & Boujaoude, 2012, Smith & Villareal, 2015) that focus on academic achievement and conceptual understanding. Accordingly, it has been reported that various methods have a positive effect on the understanding of the PNM, and students' understanding of comprehension has increased. Others have revealed and eliminated misconceptions about the subject (e.g., Krell, Reinisch & Krüger, 2015; Okumuş & Doymuş, 2017). The methods applied are generally effective in eliminating misconceptions and encouraging academic achievement. However, according to the literature, existing misconceptions about the PNM have not been completely eliminated (Adadan, 2014; Çavdar & Doymuş, 2018; Özmen, 2011). Novick and Nussbaum (1981) claim that definitions at both macro and micro levels are necessary in order to learn the concepts correctly. The underlying reason for misconceptions is that students cannot relate micro and macro levels correctly (Sarıtaş, Özcan & Adúriz-Bravo, 2021; Talanquer, 2011); while they are often able to explain events or situations at the macro level, they are unable to explore further at the micro level (Stavridou & Solomonidou, 1998). For this reason, it is predicted that applying methods and techniques that ensure the correct association of micro and macro levels will contribute to the conceptual understanding of the PNM. In this context, the present study aimed to eliminate the misconceptions of students related to the PNM via model-supported cooperative learning and seven principles for good practice (SPGP).

Cooperative Learning

Cooperative learning is a teaching model in which students work together on an academic subject with shared responsibility for reaching a common goal (Bayrakçeken, Doymuş & Doğan, 2013; Karaçöp & Doymuş, 2013). Cooperation, an essential skill in the 21st century, can be learnt most effectively through the cooperative learning process, in which the student shares tasks with friends, thereby developing both a sense of responsibility and effective communication skills (Winschel, Everett, Coppola & Shultz, 2015). Cooperative learning has been found to increase academic achievement and conceptual understanding (Acar & Tarhan,2008; Okumuş & Doymuş, 2020; Raviv, Cohen & Aflalo, 2019; Wang, Cheng, Chen, Mercer & Kirschner, 2017; Warfa, Nyachwaya & Roehrig, 2018; Zorlu & Sezek, 2020). The fact that cooperative learning requires students to work together facilitates peer learning. In this way, students who have difficulty understanding concepts or have misconceptions can find the opportunity to learn from their friends. Therefore, cooperative learning is thought to be an effective way to overcome students' misconceptions about the PNM. Another reason why the cooperative learning model was used in the present research was that cooperative learning includes face-to-face interaction and increases positive commitment by enabling students to work together during the process. In this way, it is thought that students' conceptual understanding will increase and their misconceptions will decrease.

Cooperative learning encompasses a number of methods and techniques, including co-learning (CL), student teams academic divisions (STAD), jigsaw, and reading writing application (RWA). In the present research, the least studied method of cooperative learning was used, RWA, implemented in three stages – reading, writing, and application. It is stated that collaborative writing is important for an effective teaching process (Nykopp, Marttunen & Erkens, 2018). In this context, the fact that RWA includes the writing process after the reading process increases the students' understanding of the subject better. Finally, by conducting an application on the subject, students are enabled to learn by applying what they read and write. The RWA was found to increase academic achievement and conceptual understanding (Okumuş & Doymuş, 2018; Öztürk, 2017). The fact that the RWA includes reading, writing, and application steps in the cooperative learning process allows students to repeat the subject in three stages. Thus, it makes it easier for them to spend more time on the subject and therefore understand it better (Okumuş & Doymuş, 2020). It was decided to use the RWA, which is a method that has been determined to increase conceptual understanding in previous studies and which has not been studied much in the literature, in the present study to eliminate misconceptions about the PNM.

Model

Another way to overcome misconceptions about the PNM is to use models. Harrison (2001) defines a model as "a simplified representation of a complex object or process", and it is an effective tool for eliminating misconceptions (Abd-El-Khalick, 2012; Krell, et al., 2015) as it gives the abstract situation or events a physical form and, thus, facilitates greater understanding on the part of students. Models offer students the opportunity to learn through doing and living; they are reported to increase conceptual understanding (Adadan, 2014; Cheng, 2018; Durak & Topçu, 2021; Ryoo & Bedell, 2017; Warfa, Roehring, Schneider & Nyacwaya, 2014) and students retain knowledge for longer when the models appeal to more than one sense (Develaki, 2017; Oliva, Aragon & Cuesta, 2015).

During the lesson, the model is not usually used alone, but applied in conjunction with a student-centred teaching method or technique. Since cooperative learning enables students to work together in the learning process and facilitates peer learning, it was thought that it would be more effective to apply with models, because students usually work together in the model design process or in understanding the models offered by the teacher. In this process, it is hoped that achieving positive commitment and face-to-face interaction will contribute to the conceptual understanding of the PNM. It is also stated in the literature that the application of cooperative learning with models increases students' conceptual understanding (Karaçöp, 2016; Özdilek, Okumuş & Doymuş, 2018). While other studies have examined the application of models alongside cooperative learning, the present study differs in that it investigates the effects of RWA-model applications on the conceptual understanding of the PNM in students at secondary school.

Seven Principles for Good Practice (SPGP)

The SPGP framework was introduced by Chickering and Gamson (1987) to improve the quality of undergraduate education. The seven principles are defined as encouraging student–faculty interaction (student–school interaction for K-12), ensuring cooperation among students, encouraging active learning, giving prompt feedback, emphasizing time on tasks, communicating to high-level expectations, and being tolerant of students with different learning styles by Chickering & Gamson (1987). The seven principles place more emphasis on the concept of "education". It advocates that education also be taken into consideration in the teaching process and handles education and training together. It can be said that in an effective education process teachers actually apply the seven principles with or without awareness. However, it is important to apply the seven principles consciously in order to professionally guide the education and training process (Okumuş & Doymuş, 2020). If each principle of the seven principles is applied correctly, it will be ensured that students feel more comfortable and express themselves (first principle), work collaboratively in or out of the classroom (second principle), and increase their academic achievement and conceptual understanding (third principle) (Bishoff, 2010; Deed & Edwards, 2011; Kitazono, 2010; Shoval, 2011; Tanis, 2020). In addition, students will be able to evaluate themselves during the lesson and eliminate their question marks on the subject (fourth principle) (Duijnhouwer, Prins & Stokking, 2012 Taylor, Knorra, Ogrodnika, & Sinclair, 2020). In addition, it will be easier to build the teaching process on mutual trust and develop a sense of responsibility in students (fifth principle) (Bishoff, 2010). With the seven principles, students will be guided by their teachers to realize their expectations (sixth principle) and it will be easier for each student to understand the lesson according to their own learning style (seventh principle) (Legg, Ellis & Hall, 2020; McCabe & Meuter, 2011; Tavani & Losh, 2003).

Although surveys have been conducted on the SPGP (Bishoff, 2010; Fredrickson, 2015), there are few practical studies (Crews, Wilkinson & Neill, 2015; Okumuş & Doymuş, 2018). Furthermore, applications of the SPGP are almost non-existent except at undergraduate level (Okumuş & Doymuş, 2018). The present study is, therefore, important because it is application-oriented research on the SPGP at secondary level. The SPGP is not a teaching model, method, or technique; it simply explains how the teaching process can be made more effective and should, therefore, be applied with at least one model, method, or technique in application-oriented research. In the present study, since the seven principles are directly related to student–school interaction (1st principle), cooperation among students (2nd principle), encouraging active learning (3rd principle), and tolerance to different learning styles (7th principle), and indirectly with other principles, cooperative learning was integrated with the seven principles. For this reason, the effect of using the RWA method with the SPGP and models on the conceptual understanding of the PNM will be investigated herein. The aim of the present study was to investigate the effect of the SPGP and model-supported cooperative learning on the conceptual understanding and to eliminate the misconceptions of students related to the PNM. The research question to be answered herein is as follows:
Does model-based cooperative learning and the seven principles affect students' conceptual understanding of the PNM?

The sub-problems for which answers are sought within the framework of the research question are as follows:

1. Is there any significant difference between the research groups' conceptual understanding of the PNM before and after application?
2. Do the research groups have any misconceptions about the PNM after the application?

METHODOLOGY

Research Design

Since the study aimed to examine the cause–effect relationship between the variables and the intervention in the learning process, a quasi-experimental design was used (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2012), i.e., not all parameters of randomness and a true-experimental design can be applied when creating groups. Since this study was performed in a school affiliated to the Ministry of National Education in Turkey and the classes in this school were already determined, a quasi-experimental method with control group pre- and post-test application was used.

Participants

The sample consisted of 73 students studying in the 6th grade (11-12 years of age) of a secondary school in the city of Erzurum in Turkey. Convenience sampling was used in sample selection. Accordingly, the first experimental group [SPGP - RWA - model group (SRMG) n = 19], the second experimental group [SPGP - RWA group (SRG) n = 18], the third experiment group [RWA group - (RG) n = 19], and the control group [(CG), n = 17] were studied with 73 students.

Data Collection Tool

The data were collected with the concept test (CT). The CT was used to determine students' levels of understanding and misconceptions about the PNM, and consisted of two-stage questions to include existing misconceptions about the PNM. The PNM were considered the steps highlighted by Treagust (1988); misconceptions determined from the literature were added to the second stage of the questions as a distractor. In the first stage, students were asked to identify whether the statement given to them was 'true' or 'false'. In the second stage, they were asked to choose the reason for the answer they gave in the first stage from the options given, with an open option 'D' in which they could write their own explanation if they thought that none of the options was correct. A student who marked any of the distractors was deemed to have the misconception reflected by that distractor. The CT originally consisted of 20 two-stage questions. As a result of the validity and reliability studies, 4 questions were removed from the test. The reliability coefficient of the test was determined as KR-20 = .94. A maximum of 4 points was available for each question in the CT, with a maximum possible score of 64.

Implementation

First, the CT was applied to all groups as a pre-test. Then each experimental group was taught the lesson according to the designated teaching method, and the lesson was taught according to the curriculum in the CG. The RWA method was used in the RG: the students read each sub-subject of the unit as a group at the reading stage, wrote a group report of what they understood from their reading during the writing phase, and told their friends what they understood of the subject during the application phase. In addition to RWA, the seven principles were integrated into the subject handling in the SRG. Project homework was given to the students and each group provided an evaluation of the project created by another group. After the end of classroom work, students evaluated their own work. In addition, the students had a picnic and were given careers information. In the SRMG, in addition to RWA and the application of the seven principles, a model was also applied to consolidate the concepts of the unit in the students' minds.

Data Analyses

In the analysis of the data obtained from the CT, the categories used by Çalık (2006) and Okumuş (2012) were used, as shown with the scores in Table 1.

Table 1
Categories and scores of CT

Categories		Score
TA-TE	True Answer - True Explanation	4
TA-FE	True Answer - False Explanation	3
TA-E	True Answer - Empty	2
FA-TE	False Answer - True Explanation	3
FA-FE	False Answer - False Explanation	2
FA-E	False Answer - Empty	1
E-TE	Empty - True Explanation	2
E-FE	Empty - False Explanation	1
E-E	Empty – Empty	0

The Shapiro–Wilk test was used to determine whether the data were normally distributed. One-way ANOVA and ANCOVA were used for significance analysis. In addition, the effect size (η^2) was calculated. According to Green and Salkind (2005), for η^2, a value of .01 is interpreted as a small effect size, .06 as medium, and .14 as large (Can, 2017). Moreover, each question in the CT was examined in detail.

RESULTS

Results for the First Research Question

The Shapiro–Wilk test was performed for determining the normality of the pre-CT. According to this, the data were normally distributed (p>.05) (SRMG, p=.08; SRG, p=.34; RG, p=.4; CG, p=.07). One-way ANOVA from parametric tests was then applied; the descriptive statistics and one-way ANOVA results of the pre-test are given in Tables 2 and 3.

Table 2
Descriptive statistics of the pre-test

Groups	n	X	SS
SRMG	21	38.33	9.876
SRG	21	49.38	4.577
RG	19	47.32	4.820
CG	16	43.38	6.612

According to Table 2, the highest mean was in the SRG and the lowest was in the SRMG in the pre-test. It is noteworthy that the average of the SRMG is lower than that of the other groups.

Table 3
One-way ANOVA results of the pre-test

Groups	Sum of Squares	df	Mean Square	F	p
Between Groups	1468.837	3	489.612	10.380	.001
Within Groups	3443.474	73	47.171		
Total	4912.312	76			
Significant difference	SRMG - RG*	SRG*- SRMG		SRG*- CG	

* Shows significant difference

There was a significant difference among the groups in Table 3 ($p<.05$). The Games–Howell test, a post hoc test, was used to determine the significant difference. According to the Games–Howell test, this difference was significant in favour of the RG between the SRMG and the RG, in favour of the SRG between the SRG and the SRMG, and in favour of the SRG between the SRG and the CG.

The Shapiro–Wilk test was performed for determining the normality of the post-CT. According to this, the data were normally distributed ($p>.05$) (SRMG, $p=.21$; SRG, $p=.66$; RG, $p=.64$; CG, $p=.78$). Since the data were normally distributed and there was a significant difference among the groups in the pre-CT, the ANCOVA test was performed on the data obtained from the post-test. Descriptive statistics of the post-test and the ANCOVA results are given in Tables 4 and 5.

Table 4
Descriptive statistics of the post-test

Groups	N	X*	SS
SRMG	19	53.46	6.657
SRG	18	53.79	4.663
RG	19	52.09	3.902
CG	17	47.90	4.025

* Shows the corrected mean

According to Table 4, the highest mean was in the SRG and the lowest was in the CG in the post-test. It is noteworthy that the averages of the experimental groups are close to each other.

Table 5
ANCOVA results of the post-test

Source	Sum of Squares	df	Mean Square	F	p
Pre-CT	29.083	1	29.083	1.177	.280
Groups	364.294	3	121.431	4.915	.001
Error	1655.423	67	24.708		
Total	2083.778	71			
Significant difference	SRMG*- CG		SRG*- CG		

* Shows significant difference

When the data obtained from the pre-test were statistically analysed, a significant difference was determined between these results and the groups post-test, $F(3.67)=4.915$; $p<.05$. According to the Bonferroni test, a significant difference was found between the SRMG and the CG in favour of the SRMG and between the SRG and the CG in favour of the SRG. The effect size was determined as $\eta^2 = .17$, which signified a high level of effect.

Results for the Second Research Question

For conceptual analysis, students' answers to the post-test were analysed according to the categories above, and the analysis is shown in Tables 6–21. The choice of explanations for each statement is given at the foot of each table, with the correct option marked by an asterisk.

Table 6
Descriptive statistics for Question 1

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-A*	73.7	83.3	89.5	58.8
TA-FE	F-B	-	-	5.3	-
	F-C	5.3	-	-	-
FA-TE	T-A	10.5	16.7	5.3	11.8
FA-FE	T-B	-	-	-	5.9
	T-C	5.3	-	-	23.5
	T-D	5.3	-	-	-

A*: Gases can compress since the distance between the gas particles is large.
B: Gases cannot compress since the distance between the gas particles is small.
C: Gases cannot compress because there is air between the gas particles.

In Question 1, the majority of students marked the statement *'Gases cannot be compressed'* as false and chose explanation A. The proportion of TA-TE responses was highest in the RG and lowest in the CG. Errors most commonly fell within the FA-TE category.

Table 7
Descriptive statistics of Question 2

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-B*	73.7	44.4	63.2	17.6
TA-FE	F-A	-	11.1	-	5.9
	F-C	-	-	10.5	-
FA-TE	T-B	-	11.1	-	23.5
FA-FE	T-A	26.3	11.1	-	29.4
	T-C	-	22.2	10.5	23.5
	T-D	-	-	10.5	-
E-E	-	-	-	5.3	-

A: There is no gap between particles in solids.
B*: In solids, particles vibrate.
C: Since solids are hard and immobile, their particles are also immobile.

In Question 2, the majority of students marked the statement *'Particles of substances are immobile in the solid state'* as false and chose explanation B. The proportion of TA-TE responses was highest in the SRMG and lowest in the CG. Errors were most commonly in the FA-FE category.

Table 8
Descriptive statistics of Question 3

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-C*	52.6	22.2	26.3	41.2
TA-FE	T-A	36.8	66.7	52.6	29.4
	T-B	5.3	-	15.8	17.6
	T-D	-	-	-	11.8
FA-TE	F-C	5.3	-	-	-
FA-FE	F-B	-	5.6	-	-
E-FE	- A	-	5.6	-	-

A: Particles of reactants in a chemical reaction turn into other particles.
B: When a chemical reaction occurs, particles disappear.
C*: New and different substances are formed from one or more substances in a chemical reaction.

In Question 3, the majority of students marked the statement *'In chemical changes, the identity of the substance changes'* as true and chose explanation C. The proportion of TA-TE responses was highest in the SRMG and lowest in the SRG. Errors most commonly fell in the TA-FE category.

Table 9
Descriptive statistics of Question 4

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-C*	89.4	88.9	89.4	47.1
TA-FE	T-A	-	5.6	5.3	11.8
	T-B	-	5.6	5.3	11.8
FA-FE	F-A	-	-	-	5.9
	F-B	-	-	-	17.6
E-FE	- B	5.3	-	-	-
E-E	-	5.3	-	-	-

A: The properties of the substance are not preserved during the change in state.
B: The substance disappears when it becomes gaseous.
C*: Only the appearance of the substance changes when changing state.

In Question 4, the majority of students marked the *statement 'A change in state is a physical change'* as 'true' and chose explanation C. The proportion of TA-TE responses was highest in the SRMG and the RG and lowest in the CG. Errors most commonly fell in the TA-FE category.

Table 10
Descriptive statistics of Question 5

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-D*	15.8	16.7	31.6	5.9
TA-FE	T-A	63.2	50	26.3	23.5
	T-B	10.5	11.1	15.8	23.5
	T- C	-	5.6	10.5	5.9
	T-D	-	-	5.3	29.4
TA-E	T-	5.3	-	-	-
FA-FE	F-A	-	5.6	10.5	5.9
	F-B	-	5.6	-	-
	F-C	-	-	-	5.9
	F-D	5.3	-	-	-
FA-E	F-	-	5.6	-	-

A: Water particles are most regular when in solid form.
B: Water particles are the same, whether solid, liquid, or gaseous.
C: The distance between particles does not change during the process of changing state.
D*: The distance between particles in solids is almost negligible; the distance between particles in liquids is a little greater than in solids; there are large gaps between particles in gases

In Question 5, students marked the statement *'Water is solid in state A, liquid in state B, and gaseous in state C'* as true and wrote their own explanation under Option D to the effect that *'The distance between particles in solids is almost negligible; the distance between particles in liquids is a little greater than in solids; there are large gaps between particles in gases.'* The proportion of TA-TE responses was highest in the RG and lowest in the CG, but the correct response rate was very low across all groups. Errors most commonly fell within the TA-FE category.

Table 11
Descriptive statistics of Question 6

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-A*	21.1	44.4	26.3	5.9
TA-FE	F-B	-	-	5.3	-
FA-TE	T-A	5.3	22.2	5.3	23.5
FA-FE	T-B	-	5.6	-	11.8
	T-C	68.4	11.1	63.2	58.8
	T-D	-	11.1	-	-
E-FE	- B	5.3	-	-	-

A*: Regardless of the shape of the container, the shape of the particles does not change.
B: Water particles are in the form of drops of water.
C: Liquids take the shape of the container in which they are placed.

In Question 6, students marked the statement *'The shape of water particles depends on the container they are in'* as false and chose explanation A. The proportion of TA-TE responses was highest in the SRG and lowest in the CG. The correct response rate was very low in all groups and the majority of errors were in the FA-FE category.

Table 12
Descriptive statistics of Question 7

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-B*	31.6	50	26.3	-
TA-FE	F-A	-	-	-	5.9
	F-C	15.8	-	-	-
	F-D	-	5.6	5.3	-
TA-E	F-	5.3	-	-	-
FA-TE	T-B	-	5.6	-	5.9
FA-FE	T-A	26.3	38.9	52.6	70.6
	T-C	-	-	10.5	17.6
	T-D	-	-	5.3	-
FA-E	T-	5.3	-	-	-
E-FE	- A	5.3	-	-	-
	-C	5.3	-	-	-
E	-	5.3	-	-	-

A: Since ice is solid, its particles are solid, and since water is liquid, its particles are liquid.
B*: Particles do not exist in liquid or solid form.
C: Particles are always in solid form.

In Question 7, students marked the statement *'Ice particles are solid; water particles are liquid'* as false and chose explanation B. The proportion of TA-TE responses was highest in the SRG and lowest in the CG. The correct response rate was very low in all groups, and the majority of errors were in the FA-FE category.

Table 13
Descriptive statistics of Question 8

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-D*	15.8	11.1	5.3	-
TA-FE	T-A	52.6	50	63.2	23.5
	T-B	-	5.6	-	-
	T- C	-	5.6	5.3	11.8
	T-D	-	5.6	5.3	-
FA-FE	F-A	5.3	16.7	15.8	29.4
	F-B	-	5.6	-	23.5
	F-C	-	-	5.3	5.9
E-FE	-A	10.5	-	-	-
	-C	10.5	-	-	5.9
E	-	5.3	-	-	-

A: Gases have no specific shape.
B: Gases have a specific mass.
C: Gases have a specific volume.
D*: Gases do not have a specific shape or volume and they expand through translational motion.

In Question 8, students marked the expression *'Gases fill the container they are in'* as true and wrote their own explanation in Option D to the effect that *'Gases do not have a specific shape or volume, and they expand through translational motion.'* The proportion of TA-TE responses was highest in the SRMG and lowest in the CG. The correct response rate was very low in all groups, and the majority of errors fell within the TA-FE category.

Table 14
Descriptive statistics of Question 9

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-B*	73.7	66.7	31.6	76.5
TA-FE	T-A	5.3	11.1	21.1	11.8
	T-C	10.5	5.6	42.1	11.8
	T-D	-	-	5.3	-
TA-E	T-	-	5.6	-	-
FA-TE	F-B	-	5.6	-	-
FA-FE	F-A	-	5.6	-	-
E-TE	-B	5.3	-	-	-
E	-	5.3	-	-	-

A: Since dissolution is a chemical change, the structures of the water and the sugar have changed.
B*: Dissolution is a physical change and sugar particles enter the gaps between the water particles.
C: Dissolution is a chemical change and sugar particles are in the water particles.

In Question 9, students marked the statement *'During the dissolution of the sugar in the water, the sugar particles are distributed among the water particles'* as true and chose explanation B. The proportion of TA-TE responses was highest in the CG and lowest in the RG. Errors most commonly fell within the TA-FE category.

Table 15
Descriptive statistics of Question 10

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-A*	73.7	55.6	68.4	17.6
TA-FE	F-B	-	-	-	5.9
	F-C	10.5	-	-	-
	F-D	-	-	-	5.9
TA-E	F-	-	5.6	-	23.5
FA-TE	T-A	5.3	16.7	10.5	5.9
FA-FE	T-B	5.3	11.1	10.5	11.8
	T-C	-	11.1	10.5	29.4
	T-D	-	-	5.3	-
E	-	5.3	-	-	-

A*: With the melting of the candle, only its appearance changed.
B: With the melting of the candle, its internal structure changed.
C: With the melting of the candle, its mass decreased.

In Question 10, students marked the statement *'The melting of a candle is a chemical change'* as false and chose explanation A. The proportion of TA-TE responses was highest in the SRMG and lowest in the CG. The majority of errors were in the FA-FE category.

Table 16
Descriptive statistics of Question 11

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-A*	84.2	88.9	73.7	64.7
TA-FE	T-B	5.3	-	21.1	17.6
	T-C	5.3	-	-	5.9
	T-D	-	-	-	5.9
TA-E	T-	-	5.6	-	-
FA-TE	F-A	-	-	5.3	-
FA-FE	F-B	-	5.6	-	-
	F-D	-	-	-	5.9
E	-	5.3	-	-	-

A*: There are gaps between particles in liquids, which have fluid properties due to translational motion.
B: There are no gaps between particles in liquids.
C: Liquids have the ability to flow because their particles only move through vibration.

In Question 11, students marked the statement *'Liquids have the ability to flow'* as true and chose explanation A. The proportion of TA-TE responses was highest in the SRG and lowest in the CG. The majority of errors fell within the TA-FE category.

Table 17
Descriptive statistics of Question 12

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-B*	78.9	88.9	84.2	76.5
TA-FE	T-A	-	5.6	-	23.5
	T-C	5.3	5.6	5.3	-
TA-E	T-	5.3	-	5.3	-
FA-TE	F-B	5.3	-	-	-
FA-FE	F-A	5.3	-	5.3	-
E	-	5.3	-	-	-

A: Since the lake will freeze in winter, fish cannot survive in the lake.

B*: Since the density of ice is lower than that of water, ice forms on the surface of the water, but the bottom of the lake remains liquid.
C: Lakes begin to freeze from above and, as time goes by, the entire lake freezes.

In Question 12, students marked the statement *'Fish can live in a frozen lake'* as true and chose explanation B. The proportion of TA-TE responses was highest in the SRG and lowest in the CG. The majority of errors fell into the TA-FE category.

Table 18
Descriptive statistics of Question 13

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-C*	52.6	88.9	47.4	35.3
TA-FE	F-A	5.3	-	5.3	17.6
	F-B	5.3	-	5.3	-
FA-TE	T-C	5.3	-	5.3	5.9
FA-FE	T-A	10.5	5.6	31.6	35.3
	T-B	10.5	-	5.3	5.9
FA-E	T-	-	5.6	-	-
E-FE	- A	5.3	-	-	-
E	-	5.3	-	-	-

A: As the temperature decreases during freezing, the particles freeze as well.
B: Since the volume of water increases as it freezes, the volume of the particles increases.
C*: Whether the substance is solid or liquid is related to the interactions between the particles; the particles themselves are not affected by the freezing event.

In Question 13, students marked the statement *'If the water is turned into ice, its particles will also freeze'* as false and chose explanation C. The proportion of TA-TE responses was highest in the SRG and lowest in the CG. The majority of errors fell within the FA-FE category.

Table 19
Descriptive statistics of Question 14

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-B*	73.7	66.7	68.4	29.4
TA-FE	F-A	-	-	10.5	5.9
	F-C	5.3	-	-	5.9
TA-E	F-	-	11.1	-	-
FA-TE	T-B	-	5.6	5.3	29.4
FA-FE	T-A	-	-	5.3	23.5
	T-C	5.3	16.7	10.5	-
	T-D	-	-	-	5.9
FA-E	T-	5.3	-	-	-
E-FE	-C	5.3	-	-	-
E	-	5.3	-	-	-

A: As the ice turns into water, its volume decreases, so the size of the particles decreases.
B*: Physical changes do not affect the structure of the particles.
C: Since the distance among particles in the solid state is very small, particle size increases when the substance becomes liquid.

In Question 14, students marked the statement *'If a piece of ice is heated and turned into water, its particles will increase in size'* as false and chose explanation B. The proportion of TA-TE responses was highest in the SRMG and lowest in the CG. The majority of errors fell within the FA-FE category.

Table 20
Descriptive statistics of Question 15

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	F-C*	42.1	50	26.3	11.8
TA-FE	F-A	15.8	22.2	21.1	5.9
	F-B	10.5	5.6	5.3	5.9
	F-D	-	5.6	-	-
FA-TE	T-C	5.3	-	15.8	11.8
FA-FE	T-A	-	11.1	5.3	23.5
	T-B	10.5	5.6	21.1	41.2
FA-E	T-	5.3	-	-	-
E-FE	- A	5.3	-	5.3	-
E	-	5.3	-	-	-

A: When the substance turns into gas, it becomes invisible but its amount does not decrease.
B: Since the substance disappears when it becomes a gas, its amount decreases.
C*: Change in state is a physical event and the amount of substance is preserved.

In Question 15, students marked the statement *'Amount decreases when the substance becomes gaseous'* as false and chose explanation C. The proportion of TA-TE responses was highest in the SRG and lowest in the CG, but the correct response rate was very low across all groups. The majority of errors were in the TA-FE category.

Table 21
Descriptive statistics of Question 16

Answers	Choice/Explanation	SRMG (%)	SRG (%)	RG (%)	CG (%)
TA-TE	T-A*	78.9	50	47.4	47.1
TA-FE	T-B	5.3	-	5.3	5.9
	T-C	5.3	16.7	10.5	23.5
TA-E	T-	-	5.6	-	-
FA-TE	F-A	5.3	16.7	-	11.8
FA-FE	F-B	-	-	-	11.8
	F-C	-	11.1	36.8	-

A*: If the amount of substance in a unit volume increases, the density of the substance increases.
B: If the amount of substance in a unit volume increases, the density of the substance decreases.
C: Changing the amount of substance in a unit volume does not change the density.

In Question 16, students marked the statement *'If two objects are of the same volume, the density of the larger mass is greater'* as true and chose explanation A. The proportion of TA-TE was highest in the SRMG and lowest in the CG. The majority of errors fell within the TA-FE category.

DISCUSSION AND CONCLUSION

Discussion on the First Research Question

A significant difference was found in the pre-test between the SRG and the other groups in favour of the SRG. Accordingly, the SRG apparently had a higher conceptual understanding than the other groups related to the PNM before the implementation. In the post-test, a significant difference was found between both the SRMG and the SRG and the CG in favour of the SRMG and the SRG. Accordingly, it appears that the conceptual understanding of the SRMG and the SRG improved after the application and made a significant difference with the CG. From this, it can be concluded that model-based cooperative learning increases the conceptual understanding of the PNM. In addition, it has been observed that the application of model-based cooperative learning with the seven principles is also effective in increasing conceptual understanding. It seems that RWA alone is not effective enough in increasing conceptual understanding. There was no significant difference between the SRMG and the

SRG. It can, therefore, be concluded that using cooperative learning with the seven principles increases conceptual understanding. Cooperative learning has previously been reported to increase conceptual understanding (Avcı, Kırbaşlar & Acar Şeşen, 2019; Karaçöp & Doymuş, 2013). The size of the effect was significant. Accordingly, the application performed apparently reached the desired level in increasing the conceptual understanding. The SRMG had the lowest average in the pre-test, but differed significantly from the CG in the post-test. It can, therefore, be concluded that using models as well as cooperative learning increases conceptual understanding, a finding reported previously by Çavdar, Okumuş, Alyar & Doymuş (2019); Ergün & Sarıkaya (2019); Okumuş, Koç & Doymuş (2019); and Prins, Bulte & Pilot (2016). The most successful group in the post-test was the SRG, showing that the application of the seven principles had a positive effect on conceptual understanding.

Discussion on the Second Research Question

In this section, first of all, the misconceptions detected in the study about the PNM are presented and those given in the literature are shown in parentheses with the related studies. Then the reasons for these misconceptions are discussed. In addition, after the application was completed, it was discussed in which groups there were more misconceptions.

The most important misconceptions of students regarding the PNM, as shown in the present study, are as follows:

- Gases cannot compress because there is air between their particles (Kirman Bilgin & Yiğit, 2019).
- There is air between the gas particles (Adadan & Ataman, 2021).
- There are no gaps between the particles of solids (Griffiths & Preston, 1992; Nakleh & Samarapungavan, 1999).
- Particles are immobile in solids (Kirman Bilgin & Yiğit, 2019; Nuić & Glažar, 2020).
- The shape of water particles varies according to the container in which the water is located.
- Water particles are in the form of water drops (Griffiths & Preston, 1992).
- Since ice is solid, its particles are solid, and since water is liquid, its particles are liquid.
- When a substance freezes, its particles also freeze (Griffiths & Preston, 1992).
- As ice turns into water, its volume decreases, so the size of the particles decreases.
- Since the distance between particles in a solid state is very small, the size of the particles increases when the substance becomes liquid (Kirman Bilgin & Yiğit, 2019).

These misconceptions may cause students not to be able to fully understand the sub-micro level and to have problems in associating it with the macro level. It is stated in the literature that students have difficulty in associating micro and macro levels (Stavridou & Solomonidou, 1998; Sarıtaş et al., 2021; Talanquer, 2011). Students may think that there are no gaps between particles in solids because solid items are frequently stacked and therefore solids cannot be compressed. They may be thinking of particles at the macro level. Similar to the results of the present study, it is stated in the literature that some students have difficulty understanding the granular nature of gases and solids (Adadan & Ataman, 2021; Kirman Bilgin & Yiğit, 2019). However, it was stated in the studies by Adadan and Ataman (2021) that the students understood the particulate nature of solids and gases more easily, but had difficulty in understanding the granular structure of liquids. In addition, some students found it hard to understand that only the distance between particles changes during the process of state change. According to these findings, as stated in the literature, it can be concluded that some students have difficulty in comprehending PNM even after the application is completed, they cannot associate micro and macro dimensions, and they tend to understand the substance at the macrocontinuous or macroparticulate level (Adadan & Ataman, 2021; Boz, 2006; Samarapungavan, Bryan & Wills, 2017).
The most important misconceptions students have regarding physical/chemical changes, as shown in the present study, are as follows:

- Reactant particles in a chemical reaction turn into other particles (Adadan, 2013; Chang, Quintana & Krajcik, 2014).
- The substance is not protected during chemical change; the substance disappears when it becomes gaseous (Aragon, Olive & Navarrete, 2014; Kirman Bilgin & Yiğit, 2019).
- Changing state involves a chemical change (Kıngır & Geban, 2014; Oliva et al., 2015).
- When the substance turns into gas, it becomes invisible, but its amount does not decrease (Aragon et al., 2014; Papageorgiou, Stamovlasis & Johnson, 2010).
- Since the substance disappears when it becomes a gas, its amount decreases (Bar & Galili, 1994; Papageorgiou et al., 2010).
- Dissolution is a chemical change and sugar particles are in the water particles (Abraham, Williamson & Westbrook, 1994).

Some students confuse the concepts of physical and chemical change, and think that substances disappear due to the invisibility of the gases formed in the chemical reaction. The fact that the substance that turns into gas during chemical changes is generally invisible to the eye may be the reason for this thought. Students also found it hard to comprehend that the process of state change was related to the distance between particles. It is thought that the perception of the process as a chemical change is due to an inability to understand that the distance between particles has changed. In the questions related to the physical and chemical changes sub-topic in the CT, it was determined that the highest average was in the SRMG and SRG, and generally the lowest averages were in the CG. From this, it can be inferred that model-supported cooperative/seven principle applications and cooperative/seven principle applications are more effective for learning physical and chemical changes. Especially for the 3rd and 5th questions, the rate of correct answers of all groups was low in general. Accordingly, it was observed that some students knew that the property of the substance changed as a result of the chemical change, but they did not understand that this change was due to the reordering of the particles. In this event, the idea that particles of matter transform into other particles and form new substances may cause this error.

The most important misconceptions students have regarding density in the present study are as follows:

- A lake begins to freeze from above; therefore, as time goes by, the entire lake freezes.
- Since lakes freeze, fish cannot survive in the winter.
- Changing the amount of substance in a unit volume does not change the density.

Studies producing results similar to these were not encountered in the literature. However, in line with the results of the present study, it was determined in the study that Mete (2020) conducted with preservice classroom teachers that they could not fully grasp the concept of density and could not understand the decrease in density during the state change of water. Some students did not fully understand the difference in density between the solid and liquid states of water. The reason for the students' not understanding that water freezes from the surface may be their inability to grasp that water expands when it freezes. The students' inability to fully grasp the concept of density may be due to their inability to perceive the meaning of the concepts of mass and volume. In the questions about density, the means of the SRG and SRMG were better than those of the other groups, and the lowest average was in the CG. However, the averages of all groups were high for the 12th question, and the means of the groups except the SRMG for the 16th question were medium. Accordingly, it can be inferred that students in groups other than the SRMG have problems in internalizing the concept of density. From these results, it can be surmised that besides the cooperative/seven principle applications, model applications also help students better understand the concept of density, because it is striking that the part that makes the difference in this question is the models.

The results obtained from the CT indicate that some students had some misconceptions about the PNM, physical/chemical changes, and density, and some of these misconceptions continued after the implementation. According to Piaget, concepts are learnt with the help of diagrams created in the mind. Schemas form the mental models of the person related to that concept. Misconceptions occur if there are errors in the schemas. Misconceptions are resistant to change (Adadan, 2014; Çavdar et al., 2018; Okumuş & Doymuş, 2017; Özmen, 2011; Papageorgiou et al., 2010; Tsai, 1999). For this reason, learning a concept for the first time is easier than correcting something learnt wrong. Therefore, it can be surmised that misconceptions are related to mental models that exist in students' minds. However, students' conceptual understanding was better in the experimental groups, from which it can be concluded that the applied methods increase conceptual understanding. It is thought that a cause of basic misconceptions is that students are unable to visualise sub-micro level events and concepts in their minds as they have not yet developed an understanding of abstract operations.

RECOMMENDATIONS

According to this research, the effects of different cooperative learning methods on conceptual understanding of the PNM can be examined. The effects of different types of models such as simulation, concept–process models, and pedagogical–analogical models on the conceptual understanding of the PNM can be investigated. In addition, it is recommended that different active learning methods be applied together with cooperative learning and models to help conceptual understanding and eliminate misconceptions.

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