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React Strategy Instruction Enriched with Inquiry-Based Experiments: Exploring Middle School Students' Understanding of Mixtures

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ABSTRACT This study investigates the effectiveness of using a REACT strategy instruction enriched with guided inquiry-based experiments to improve 7th-grade students' understanding of mixtures compared to conventional teacher-centered instruction. A convergent parallel mixed-method design was used, and 39 middle school students were divided into experimental (N=19) and control (N=20) groups. In the experimental group, REACT strategy instruction, whose experimenting stage was implemented using inquiry-based experiments, was carried out. In the control group, conventional teacher-centered instruction was conducted. Four concept cartoons were used for data collection. In addition to quantitative analyses, individual profile maps were drawn, and students' explanations in the "Because" section of the concept cartoons were analyzed to gain deeper insight into students' conceptual change. According to the results, a REACT strategy instruction enriched with guided inquiry-based experience effectively improves 7th-grade students' understanding of mixtures and rectifies misconceptions compared to conventional teacher-centered instruction. Based on the results of the study, it can be recommended to use the REACT strategy teaching model enriched with inquiry-based experiments for remedying students' misconceptions and to use concept cartoons not only as a learning strategy but also as a tool for data collection, which will enable better evaluation of students' misconceptions.

Keywords Concept cartoons, Context-based learning, Inquiry-based learning, Mixtures, REACT strategy

1. INTRODUCTION

Middle school years provide a foundation for achievement and understanding of new knowledge in the higher levels of schooling (Gibbs & Poskitt 2010). At this level, scientific concepts can be considered starting points for understanding chemistry, biology, and physics in the higher grades. For this reason, using current active learning approaches (such as inquiry- and context-based learning) in science classrooms is critically important for improving the students' fundamental understanding of these concepts.

1.2 Inquiry-Based Learning

People who have a sense of curiosity by their nature inquire about many things without realizing it when trying to interpret their daily life experiences in their minds. The process of inquiry required to make decisions in day-to-day life is a systematic activity applied by scientists to answer the more significant questions of the world (Deboer, 2006)

Inquiry also functions as an essential science learning and teaching strategy (Delgado-Iglesias, Reinoso-Tapia1 & Bobo-Pinilla, 2023), which can be applied to provide an answer to a question based on students' experiences (The National Research Council [NRC], 1996). Several researchers suggested different classifications of the role of student and teacher in inquiry-based learning environments. One of the most widely used classifications is that of Banchi & Bell (2008), who proposed four inquiry levels: confirmatory, structured, guided and open inquiry. The role of the teacher and student, and the activity level of the student in these levels, are summarized and displayed in Figure 1.

The inquiry-based learning approach provides students with the opportunity to work as scientists. This approach supports students to acquire scientific knowledge through their own scientific experiments (Jerrim, Oliver & Sims, 2022), and to produce a science culture (Kim, 2020). For this reason, teachers should encourage students' inquiry activities (Tuan, Yu & Chin, 2017). In learning

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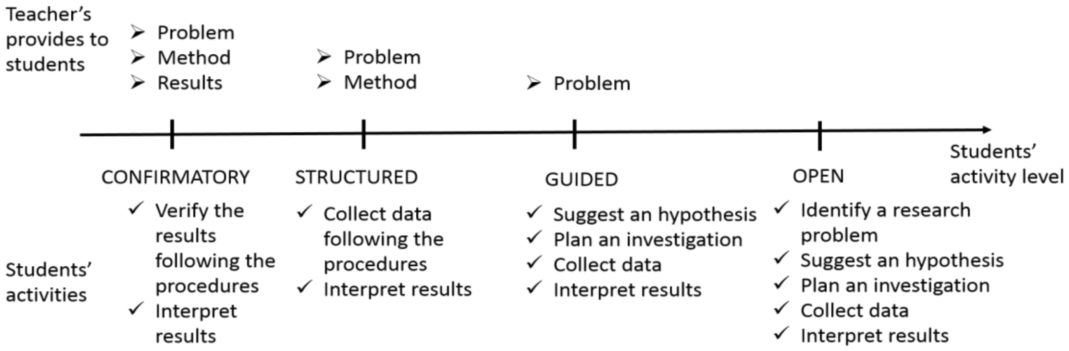


Figure 1 Levels of the inquiry-based learning model

environments, students can generate a research question, design the investigation process concerning important variables, collect and interpret data, and reach a conclusion. By using inquiry-based learning, students gain the skills to express their research questions and methods, present the evidence they obtain from data collection, and justify their conclusions based on this evidence (Contant, Tweed, Bass, & Carin, 2018). Inquiry-based learning expands students' learning horizons and enables them to take a more active role in the learning process (Blessinger & Carfora, 2014). In addition to improving students' understanding of basic science concepts, laws, theories, and principles, inquiry-based learning has a vital role in acquiring knowledge, encouraging students to understand natural phenomena, and seek answers to questions (Chiappetta & Adams, 2004). In inquiry-based learning environments, students follow the scientific method; however, learning activities are not limited to its use, and alternative methods of verifying scientific principles are presented to students through these activities (Deboer, 2006).

1.2 Context-Based Learning and REACT Strategy

Context is a situation that enables students to understand scientific rules, concepts, and laws, and it can be expanded to include opportunities for students to comprehend implementations in the school laboratory (De Jong, 2008). In learning environments, contexts are given to students as case studies to encourage problem-solving (Potter & Overton, 2006). Context-based learning uses realistic contexts to understand scientific concepts and improve students' characteristics efficiently. In context-based learning environments, students work to solve well-planned context-based problems in cooperative groups or individually, using several skills to achieve comprehension of relevant concepts. According to Schwartz (2006), context-based learning instruction addresses critical social issues and establishes interdisciplinary cooperation for learning issues. It also provides a student-centered approach and motivates students to utilize problem-solving skills.

Context-based learning can be implemented using multiple approaches, including the REACT strategy instruction. The REACT strategy is based on student's prior knowledge to establish a relationship between concepts and context, provide students with varied experiences and opportunities to apply their knowledge, and encourage correcting misconceptions (Navarra, 2006). The REACT strategy consists of five stages (the first letters of which form its acronym): relating, experiencing, applying, cooperating, and transferring. These stages have several requirements, described as follows (Crawford, 2001; Navarra, 2006). In the relating stage, context is presented to the students to provide an association between their existing knowledge and the new information. In the experiencing stage, students explore the new knowledge by conducting an experiment, a project, or other activities. In the applying stage, examples related to the context are presented, and new activities based on the concept are undertaken to overlearn. In the cooperating stage, students work together to solve a problem or accomplish an activity. In the transferring stage, students use their knowledge to interpret and comprehend new case studies. In this way, each stage is related to the context and students' activities by associating learning issues with daily life experiences.

1.3 Significance and Aim of the Study

Mixtures are important in middle school science teaching, as its scope extends throughout high school to undergraduate levels. Meaningful learning of this topic in middle school provides the basis for further study of higher-level mixtures. It improves understanding of other science subjects in middle school. Furthermore, this subject is highly relevant to daily life, as many routine activities require the preparation of mixtures and an understanding of their properties. Using contexts in the teaching process encourages students to consider the subject of mixtures from different perspectives.

The inability of students to associate what they learn with their experiences in daily life and the failure of science programs to encourage this association are two of the most fundamental problems in learning environments. (Gilbert, 2006). Therefore, a tested instruction programme that encourages this association is essential to middle school science teaching. Multiple studies have been conducted in the science classroom, with and without a comparison group, to investigate the impact of instruction based on a context-based learning approach and REACT strategy on students' understanding and conceptual change. Current studies at the elementary level have demonstrated that a context-based learning approach combined with REACT teaching can promote students' understanding and conceptual change of topics such as nutrients, umbra, and eclipses in fifth grade (Karsli & Patan, 2016; Karsli & Saka, 2017); conductors, insulators and the particulate nature, structure, and characteristics of matter, propagation and hearing the sound differently in different environments in sixth grade (Ayvacı, Er-Nas & Dilber, 2016; Karslı-Baydere & Kır, 2021; Kirma-Bilgin, Demircioglu-Yurukel & Yigit, 2017; Kirman-Bilgin & Yigit, 2019); as well as eyes and mixtures, mirrors and absorption of light, force and energy in seventh grade (Akın-Yanmaz, 2021; Karsli-Baydere & Aydin, 2019; Keleş, 2019; Tatlı, 2020).

Compared to conventional teacher-centered instruction, this study investigates the effect of a REACT strategy instruction enriched with guided inquiry-based experiments on 7th grade students' understanding of mixtures. This study differs from previous REACT studies (some of which were referred to above) in several significant ways: Firstly, inquiry-based experiments were embedded in the experiencing stage of the REACT strategy teaching model. This combination allowed students to conduct better-planned, systematic, and cooperative activities in the experiencing stage. As students engaged with the experiment physically and mentally instead of simply observing, they participated much more actively in the activity. Inquiry-based experiments, therefore, serve to enrich REACT instruction further. Secondly, concept cartoons were used for data collection in this study. Most earlier studies collected data using multiple choice or diagnostic tests, open-ended questions, or similar tools. Concept cartoons were mainly used as a learning strategy, and previous studies using this data collection method were limited (Ozdemir, Coramik & Urek, 2020). Concept cartoons enable students to express their ideas more comfortably and without feeling examined. They are, therefore, an effective tool for observing students' conceptual change from different aspects. Thirdly, individual profile maps were drawn for each student, showing their conceptual change following the completion of teaching. Students can correct their previous misconceptions after learning a scientific concept. However, some students may exchange their previous misconception for another misconception or may defend the same misconception despite the instruction. The traditional quantitative comparison methods could not show these changes and could only present an improvement in the scores. Individual profile maps allowed the researchers to investigate all changes for each student. Thus, the aspects of this study discussed above have the potential to fill a gap in the literature on the REACT strategy teaching model. This study aimed to investigate the changes in 7th-grade students' understanding of mixtures following the completion of REACT strategy instruction enriched with guided inquiry-based experiments, compared to conventional teacher-centered instruction.

2. METHOD

A convergent parallel mixed-method research design was used to compare the effects of two instructions on students' understanding of the scientific concept of mixtures. In this mixed-method design, qualitative and qualitative data are collected, analyzed, compared, related, and interpreted (Creswell & Clark, 2011). This research collected and interpreted qualitative and qualitative data about each other.

2.1 Participants

Participants of the study were 39 middle school students (aged 12–13 years) enrolled in two different 7th-grade classes (referred to as 7A (N = 19) and 7B (N = 20)) in a public school. In Türkiye, middle schools provide eight years of education. Students were trained based on the science curriculum provided by the Ministry of National Education, which includes the topic of mixtures for 7th grade. Science courses took place over four 40-minute sessions each week.

Before the study commenced, a semi-structured interview was conducted with each participant to explore their educational background. These interviews determined that the students had similar educational backgrounds, with science lessons taught according to a conventional teacher-centered approach. In addition, they carried out conventional cookbook design laboratory activities in their science lessons until the study started. The mean scores of classes 7A and 7B in the last-semester science course were 74 and 79, respectively. Before this study, the students had been learning about the particulate nature of matter, which included basic concepts such as atoms, elements, compounds, and pure substances.

Class 7A was randomly assigned as the experimental group and 7B as the control group. While the experimental group received teaching on mixtures according to the REACT strategy instruction enriched with guided inquiry-based experiments, the control group was taught using the conventional learning approach with confirmatory experiments. Before and after the teaching, concept cartoons were used as a data collection tool to investigate students' understanding of mixtures.

2.2 Ethical Statements

Because the study participants were 39 middle school students, the researcher first applied to the ethical committee for approval. (…) Social and Human Sciences Research Ethics Committee approval was obtained for this study […]. All ethical standards were taken into consideration during this study. Before the research, the researcher and the students' teachers gave detailed

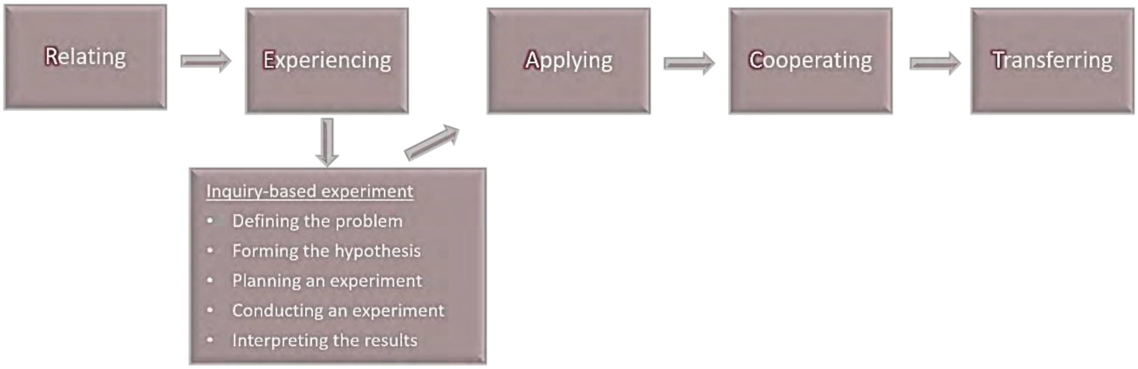


Figure 2 Stages of REACT instruction enriched with the guided inquiry-based experiments

information about the content of the research to the students' parents. They presented an informed consent form to sign to declare their children's voluntary participation in the research.

2.3 Instructions

In this study, the effect of two different instructions on students' understanding was compared using a quasi-experimental research design, shown in Table 1.

While REACT strategy instruction enriched with guided inquiry-based experiments was used in the experimental group, conventional teacher-centered instruction was conducted in the control group. Both instructions had the same educational objectives for learning mixtures and related concepts (see Table 2).

Instructions in both groups were conducted for three weeks (a total of twelve 40-minute lesson sessions), with concept cartoons, which enable students not to feel examined and to express their ideas more comfortably, applied before and after the instruction.

REACT Strategy Instruction Enriched with Guided Inquiry-Based Experiments

A teaching plan based on the REACT strategy instruction enriched with guided inquiry-based experiments was developed and applied in the experimental group. REACT strategy instruction has five stages: relating, experiencing, applying, cooperating, and transferring. Guided inquiry-based experiments were embedded in the experiencing stage. Guided inquiry was preferred, as the students had no prior experience with inquiry-based learning activities and would, therefore, require some guidance to start and conduct the inquiry process.

Guided inquiry-based experiments were developed based on Hofstein, Shore & Kipnis's (2004) steps. In the instruction, the problem situation, including the context presented in the relating stage, begins the inquiry process in the experiencing stage. The stages of REACT instruction enriched with guided inquiry-based experiments are shown in Figure 2.

Worksheets were also prepared for use in classroom teaching. All worksheets and the instruction were reviewed by a chemistry teacher, two science educators, and a science teacher to ensure context validity, and they were piloted with five middle school students.

Two subtopics were determined for the mixture subject, and instruction was designed accordingly. Two contexts were therefore defined, one for each subtopic: 'salt of the sea' and 'vitamins'. The first context was presented in the relating stage. The students then

Table 1 The research design of this study

Group	Pre-test	Treatment	Post-test
Experimental Group	Concept Cartoons	REACT strategy instruction enriched with the guided inquiry-based experiments	Concept Cartoons
Control Group		Conventional teacher-centred instruction	

Table 2 Educational objectives of the instructions

Mixtures' subtopics	Educational Objectives	Related Concepts
Basic concepts of mixtures	1. Students will be able to classify the mixtures as homogenous and heterogeneous. 2. Students will be able to prepare different mixtures.	Dissolution Solute Solvent Mixtures Homogenous mixtures (solutions) Heterogeneous mixtures
Factors affecting the rate of dissolution	3. Students will be able to identify factors affecting the rate of dissolution	Temperature Surface areaStirring

accomplished the other stages of experiencing, applying, cooperating, and transferring. Following the completion of the stages, the second context was presented in the new relating stage, and the other stages subsequently followed. The stages of REACT were therefore conducted two times for each context. Instruction was conducted in four small groups of four or five students, and students were given requirements to accomplish in each stage (Table 3).

For example, under the teacher's guidance, the ‘salt of the sea’ context was used to teach principles of dissolution, mixtures, solutes, solvents and, homogenous (solutions) and heterogeneous mixtures. Correcting misconceptions about these concepts was also a focus of every activity stage. A reading passage related to the salt in the sea (context) was presented in the relating stage. After reading, the students were asked two questions, and they were required to discuss the amount of salt and water in the sea and the source of the salt in the sea. In the experiencing stage, students were given a research problem and carried out a guided inquiry-based experiment. This research problem was “If we want, we can prepare some seawater using water and salt. What would happen if we use oil instead of water in this mixture?”. Students were required to form a hypothesis to solve this problem and then plan and conduct an experiment to test their hypothesis. In the experiment, students prepared two mixtures: water with salt and oil with salt. In the data collection process, students were directed to use tables for effective organization and comparison of data. In the last step of the guided inquiry-based experiment, students discussed and shared their findings with other groups. In the applying stage, students prepared different mixtures and classified them as homogenous (solutions) or heterogeneous mixtures based on the knowledge obtained from the experiencing stage. They also assigned solutes and solvents in these mixtures. In the cooperating stage, students prepared posters by drawing the particulates of the two mixtures, sugar-water, and sand-water, with their group mates. In the transferring stage, a question was posed for the students to investigate and answer using their new knowledge. For this, some information on serums (including salt or dextrose) was provided, and students were required to discuss and investigate what would happen if oil was used in the serum instead of water.

Conventional Teacher-Centred Instruction

Conventional teacher-centered instruction was conducted in the control group. The learning topic was taught using the traditional teacher-centered methods the teacher regularly employed, mainly lecturing. In addition to the presentation and explanation of the subject, brainstorming, and question-answer techniques were also used in the lessons. After teaching the subject, confirmatory experiments were conducted to minimize threats to internal validity. These experiments were the same as those carried out by the experimental group in the experiencing stage. However, while the experimental group carried out these experiments based on guided inquiry-based learning, the control group conducted them based on the conventional confirmatory approach. Two subtopics (Table 2) were assigned for the subject of mixtures, and the following experiments were conducted in four small groups after teaching the corresponding subtopic (Table 4).

2.4 Instrument

This study used a booklet with four concept cartoons for data collection. A literature review for common misconceptions about mixtures at the middle school level was conducted. To increase the reliability and validity of the concept cartoons, misconceptions used in their creation were chosen from previous studies in the literature (Akgün & Aydın, 2009; Arıkıl & Kalın, 2010; Barke, Hazari & Yitbarek, 2009; Durmuş & Bayraktar, 2010; Ebenezer & Erickson, 1996; Gökulu, 2017; Karaer, 2007; Kuşakçıekim, 2007; Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Özalp, 2008; Say, 2011; Say & Özmen, 2018; Tezcan

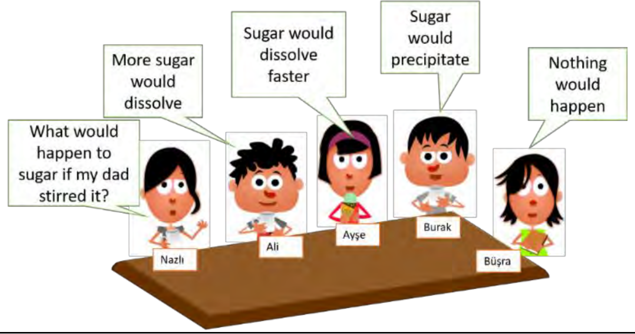
Table 3 Students’ requirements in the activities

Stage	Students’ requirements in each step
Relating	• Reading and discussing the text. • Identifying the context and relating it to their prior knowledge and experiences. • Discussing the problem situation related to the context.
Experiencing	• Carrying out the inquiry-based experiment in light of the problem situation. • Exploring the learning issue by conducting the inquiry-based experiment.
Applying	• Applying the concepts by carrying out new experiments.
Cooperating	• Working together with their teammates to solve a problem and conducting an experiment. • Sharing their new knowledge with their teammates using effective communication skills.
Transferring	• Using their new knowledge for a new and different situation or solving a different problem related to learning issues.

Table 4 Conventional confirmatory experiments and related subtopics

Subtopics for mixtures	Conventional confirmatory experiments
Basic concepts of mixtures	Preparing and examining oil-salt and water-salt mixtures
Factors affecting the rate of dissolution	Investigating the rate of dissolution under different conditions using vitamin tablets

Nazlı had breakfast with her family. Her father added a cube of sugar to his tea and started to stir it with a teaspoon. Nazlı wondered why her father did this, but she couldn't ask him because she had to go to school. When she drank something with her friends in the school cafeteria, she told them about the event that morning, and asked them:



Whose opinion do you agree with?

a) Ali
b) Ayşe
c) Burak
d) Büşra

Because….

Figure 3 A concept cartoon related to factors affecting the rate of dissolving

& Bilgin, 2004; Uzuntiryaki & Geban, 2005; Valanides, 2000). Based on their similarities, these misconceptions were then classified into themes about mixtures. From these results, four concept cartoons were developed.

The four concept cartoons for data collection were prepared as a booklet and given to all students. They began with a short text describing a daily life event experienced by Nazlı and her friends. That was intended to help the students associate the learning topic with their daily lives. One of the characters was designated as the character to begin the discussion. Nazlı asked her friends about the event explained in the text, and her friends gave their opinions. One of these opinions was scientifically accurate, while the others included misconceptions. The number of characters included varied according to the number of answers to the question. The opinions presented by the characters were of similar credibility levels and were expressed in short and legible sentences. Each character was given a name of similar interest level to facilitate students' answers. The characters were of appropriate size and color and had similar facial expressions so as not to distract the concentration of the students. Speech bubbles were plain, colorless, and positioned not to obscure the text. Characters and concept cartoons were designed using mobile phone applications and computer programs. The concept cartoons were reviewed by a chemistry educator and two science educators. Corrections were then made according to their suggestions, and the booklet was piloted with the participation of five middle school students who had previously learned a mixture of topics (aged 12–13 years). The final version of the booklet, including concept cartoons, was subsequently prepared based on all revisions.

The four concept cartoons were on the subjects of dissolution, solvent-solute in the mixtures, factors affecting the dissolution rate, and homogeneous/heterogeneous mixtures. For example, a concept cartoon discussing factors affecting the rate of dissolution is presented in Figure 3. Other concept cartoons are presented in the Appendix section as dialogue-only to simplify the interpretation of results for readers. The concept cartoons were initially written in Turkish and were translated into English by the author. A native English speaker checked the translation to ensure quality and accuracy.

2.5 Data Analysis

For comparative research, the concept cartoons were applied to the experimental and control groups before and after the instruction, and extensive analysis was performed. Firstly, the total scores obtained by the students for each concept cartoon were calculated. In this analysis, one point was given for the correct answer and zero for the wrong answer. In comparing the groups' post-test scores, ANCOVA was used to control for the effect of pre-test scores on post-test scores (Pallant, 2007). After the assumptions of ANCOVA were tested, the pre-test was treated as a covariate. Wilcoxon signed-rank tests were also used to determine the improvement in groups' scores.

The data were subsequently analyzed according to the method described by Karakırık & Kabapınar (2019). In this analysis, individual profile maps were drawn for each concept cartoon to investigate students' conceptual changes thoroughly. Each student was assigned an ID number, and their answer was listed for each concept cartoon in the pre-and post-test. Concept cartoons had options that included a scientifically valid opinion/concept (ST) and misconceptions (M). The maps showed these options, and the frequency of students who chose them was presented there. In addition, links are created between the answers given by the students in the pre-test and post-

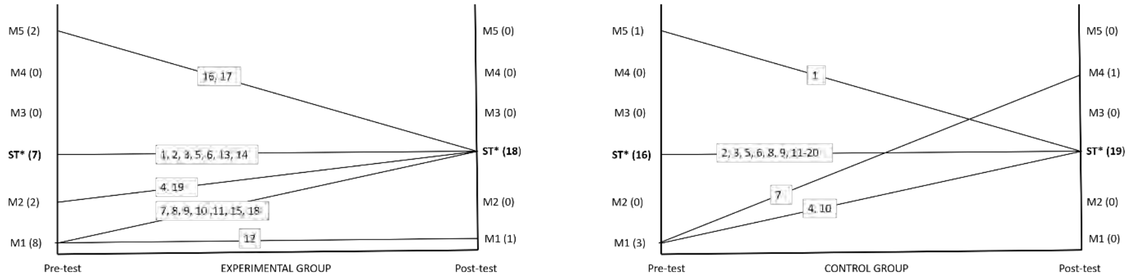


Figure 4 Individual profile maps for concept cartoon-1

test. ID numbers of the students are written on the link. In this way, the answers of the students in the pre-test and post-test and how these answers differed could be seen simultaneously.

Lastly, the "Because" part of the concept cartoons was analyzed. When selecting their answer in the concept cartoons, students were asked to justify their choice and write it in the "Because" section. This section was analyzed using content analysis. To do this, students' pre- and post-test answers were read to identify justifications that could be listed for evaluation. Students' misconceptions were also identified, and their frequencies were calculated.

3. RESULT AND DISCUSSION

3.1 Students' Scores Obtained from Concept Cartoons

In this study, scores for concept cartoons obtained from the pre and post-tests were calculated and compared to identify students' conceptual changes. The results of the ANCOVA analysis are shown in Table 5.

The ANCOVA results showed a significant difference between the groups' post-test scores (F (1, 36) = 12.112, $p < 0.05$)—the corrected mean scores of the experimental and control groups post-test were 3.329 and 2.238, respectively. There was a significant difference between the groups' post-test scores, with the experimental group performing better than the control group.

The Wilcoxon signed-rank test was used to identify whether there was an improvement in the groups' conceptual understanding after the instruction (Table 6). From the results in Table 6, it can be seen that, while there was a significant improvement in the scores of the experimental group between the pre-and post-test ($z = -3.663$, $p < 0.05$), there was no significant difference in the scores of the control group ($z = -1.485$, $p > 0.05$).

3.2 Students' Individual Profile Maps

Individual profile maps were drawn to investigate how students' conceptions changed following the teaching. Misconceptions (M) in the concept cartoons are presented in the Appendix section as character dialogue. Changes in misconceptions about teaching were observed in the individual profile maps for both groups. The first concept map was related to the topic of dissolution, and the maps for the experimental and control groups are given in Figure 4.

In the experimental group, seven students chose the scientifically accurate option before teaching, while 12 students had misconceptions about the concept of dissolution. After the instruction, the original seven students still defended their scientifically accurate concepts and were joined by 11 students who previously held misconceptions. One resisted conceptual change and defended the same misconception despite the instruction. In the control group, most students (16) chose the scientifically accurate option before teaching. After teaching, they maintained these concepts. In addition, one student who chose M5 and two who chose M1 changed

Table 5 ANCOVA results

Source	Sum of squares	df	Mean square	F	P	Partial Eta Squared
Pre-Test	0.026	1	0.026	0.034	0.855	0.001
Group	9.363	1	9.363	12.112	0.001	0.252
Error	27.829	36	0.773			
Corrected Total	38.923	38				

Table 6 Wilcoxon signed-rank test results

Group	Post-test-Pre test	N	Mean Ranks	Sum of Ranks	Z	p
Experimental	Negative Rank	0	0.00	0.00	-3.663	0.000
	Positive Rank	17	9.00	153.00		
	Ties	2				
Control	Negative Rank	3	7.00	21.00	-1.485	0.138
	Positive Rank	9	6.33	57.00		
	Ties	8				

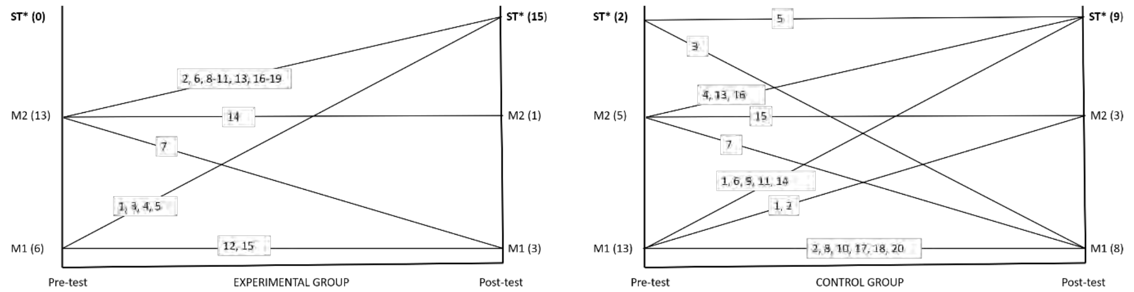


Figure 5 Individual profile maps for concept cartoon-2

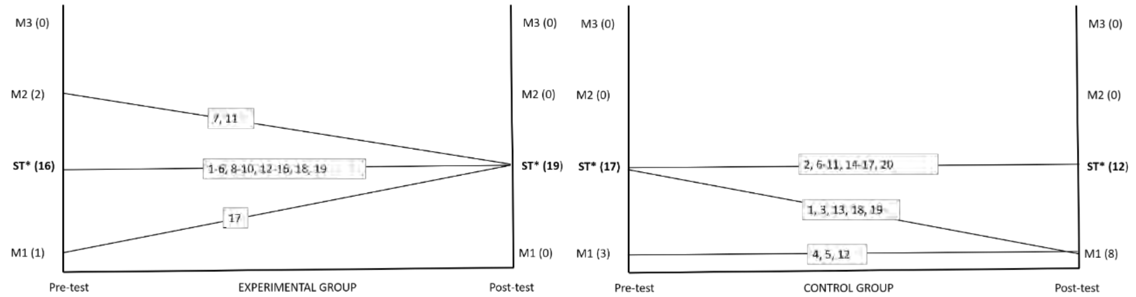


Figure 6 Individual profile maps for concept cartoon-3

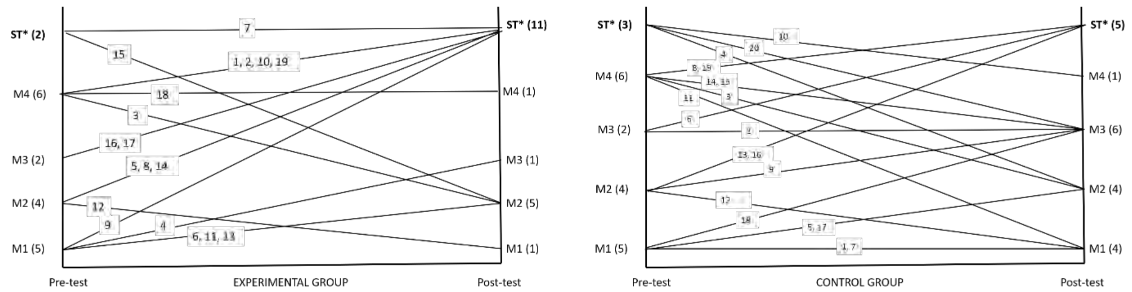


Figure 7 Individual profile maps for concept cartoon-4

their misconceptions to scientifically accurate concepts. Unfortunately, one student who initially chose M1 changed their misconception to another misconception (M4).

The second concept cartoon assessed conceptual change in solute and solvent interactions. Individual profile maps based on concept cartoon two are shown in Figure 5. As seen in Figure 5, no student in the experimental group held a scientifically accurate opinion about solvent and solute interactions before teaching. After teaching, while 15 students changed their misconceptions to accurate opinions, three students did not change their minds. In the control group, the number of students who held scientifically accurate opinions increased from two before teaching to nine following teaching. However, four students (one initially held an accurate opinion) chose a different misconception post-test from their choice in the pre-test, and seven defended the same misconception in the post-test.

The third concept cartoon evaluated students' conceptual changes on factors affecting the dissolution rate. The students' maps are presented in Figure 6.

As seen in Figure 6, the instruction received by the experimental group was more effective in inducing conceptual change in students, and all students held scientifically accurate opinions post-test. In the control group, while seventeen students had scientifically accurate opinions in the pre-test, five had misconceptions (M1) in the post-test. Three students had the same misconception (M1) in both pre-and post-tests.

The last concept map was related to homogeneous and heterogeneous mixtures. Individual maps for this concept cartoon are presented in Figure 7.

The results of the maps indicate that students in the experimental group demonstrated better conceptual change than the control group. While the number of students in the experimental group who held a scientifically accurate opinion increased in the post-test, M2 was a strong distracter for students both pre- and post-test. Conversely, students in the control group had some confusion about this subject. Students who had a scientifically accurate opinion in the pre-test changed their opinion to different misconceptions (M2, M3, and M4) in the post-test. Although five students converted to a scientifically accurate opinion following teaching, the rest of the group (15) merely switched to a different misconception.

3.3 Results of the Analysis of the "Because" Section of the Concept Cartoons

Students' responses in the "Because" section of the concept cartoons were also analyzed. According to analyses of this section in the pre-test, it was noted that some students merely repeated the option they chose originally. For example, in the first concept cartoon, one student chose the opinion of the "Ali" character (sugar melted) and wrote "Because sugar melted" as their reason. Similarly, some students wrote justifications that could not be evaluated, including "Because Ayşe ate sugar", "Because I felt like that," and "Because I guessed so". Such explanations did not justify choice and were therefore excluded from the analysis.

In the post-test assessment, some students repeated the option they chose in the pre-test, but the number of these students was lower. In addition, some students in the experimental group explained their reasoning in detail and provided examples of the experiments performed during the instruction to support their claims. Some misconceptions were identified in the students' explanations in the pre-and post-test. The frequency of these misconceptions was calculated, and the results showed that it decreased post-test. These results are presented in Table 7.

This study developed an instruction using the REACT strategy enriched with guided inquiry-based experiments. It investigated its effectiveness in improving 7th-grade students' understanding of mixtures compared to conventional teacher-centered instruction. Quantitative and qualitative methods were used to analyze students' understanding of this subject thoroughly. The evidence obtained from ANCOVA and the Wilcoxon signed-rank test indicated that REACT strategy instruction enriched with guided inquiry-based experiments improved students' understanding of the topic of mixtures more than conventional teacher-centered instruction. Responses of students in the "Because" part of the concept cartoons also indicated that the frequency of misconceptions decreased from the pre-test to the post-test, and this decrease was more substantial in the experimental group than the control group. The effectiveness of the REACT strategy on students' understanding has been established by earlier research, and their findings are consistent with the results of this study (Akın-Yanmaz, 2021; Ayvacı, Er-Nas & Dilber, 2016; Karslı & Patan, 2016; Karslı & Saka, 2017;

Table 7 Students' misconceptions in pre- and post-test

Concept cartoons and related concepts	**Misconceptions**	**Pre-test**		**Post-test**	
		EG (f)	**CG (f)**	**EG (f)**	**CG (f)**
CC1 – Dissolution	Particulates of sugar distribute into the water by becoming wet.	1	1	-	-
	Sugar dissolves because it is a solid.	1	-	-	-
	Sugar melts with the heating of the water.	3	-	1	-
	Water liquifies sugar.	2	1		-
	Sugar dissolves because water is hot.	1	1	-	-
	Sugar turns into a different matter because it is invisible after dissolving.	1	1	-	-
	All matter that is particulate dissolves.	-	1	-	-
	Sugar dissolves because water has a higher density than sugar.	-	-	-	1
CC2 – Solute and solvent	Sugar is not liquid, so it is not a solute.	1	-	-	-
	If sugar is liquid, we could not identify which matter is the solute.	1	-	-	-
	Sugar melts because the water boiled.	1	-	-	-
	When sugar melts, there will be only water in the mixture.	1	-	-	-
	Water has a higher density than sugar.	1	-	-	-
	A solute is always solid because liquids do not melt.	1	-	-	-
	A solute disappears when the mixture is stirred.	1	1	-	-
	Liquids do not dissolve.	-	2	-	1
	Sugar dissolves into the water by melting.	-	-	-	1
CC3 – Effective factors on dissolution rate	When the mixture is stirred, the sugar turns into water.	1	-	-	-
	When the mixture is stirred, sugar drops to the bottom of the mixture and disappears.	1	-	-	-
	When the mixture is stirred, sugar melts with heating of the water.	1	-	-	-
	Solids melt faster than liquids.	-	1	-	-
	Sugar melts more easily due to contraction.	-	1	-	-
CC4 – Homogeneous and heterogeneous mixtures	Salt disappears into the water and turns into a new matter.	1	-	-	-
	Particulates of the matter melt in mixtures.	3	2	-	-
	Particulates of matter melt in the solution	2	2	-	1
	Salt melts more easily because it is homogeneous.	1	-	-	-
	Mixtures prepared with different matters are not homogeneous.	1	1	-	-
	Matters that melt in the mixture form a homogeneous solution.	-	1	-	-

Karslı-Baydere & Aydın, 2019; Keleş, 2019; Kır, 2021; Kirman-Bilgin, Demircioğlu-Yürükel & Yiğit, 2017; Kirman-Bilgin & Yiğit, 2019; Tatlı, 2020). However, this study differed to previous ones by embedding inquiry-based experiments in the experiencing stage of the REACT teaching. Context is inherent to inquiry (Herranen, Kousa, Fooladi & Aksela, 2019), and inquiry is a key component of context-based learning (Glynn & Winter, 2004). In this study, students in the experimental group had some opportunities to conduct more systematic and well-planned activities. Each stage of the REACT activities focused on misconceptions about mixture and included several applications for remedying them. The teacher especially underlined scientifically correct concepts in each activity, and he immediately corrected if students used a misconception. In addition, the activity stages were designed so that students would reencounter the same misconception. Thus, if the students did not replace their misconceptions with scientific concepts, intervention could be made, and they were offered the chance to have scientific concepts. Based on the results of the present study, it was confirmed that REACT instruction enriched with inquiry-based experiments would be effective for improving students' understanding of the subject of mixtures.

Students' profile maps were drawn for each concept of the concept cartoons. These concepts were discussed under the context provided by the teaching. Contexts from daily life allow students to transfer knowledge into and out of the science classroom (Gilbert, Bulte & Pilot, 2011), and two contexts were therefore derived from the students' daily lives for use in the contexts. The first context was 'salt of the sea', and it was expected that students would learn the basic mixture concepts of dissolution, solutes, solvents, homogenous (solutions), and heterogeneous mixtures. According to the individual profile maps, most students in the control group (16) and less than half of the students in the experimental group (7) were already familiar with dissolution before teaching. A common misconception that students in the experimental group had before teaching was that "Sugar melts in the water". This misconception also occurs due to the daily language used by students, and this has been identified by previous studies (Durmuş & Bayraktar, 2010; Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Özalp, 2008; Say, 2011; Say & Özmen, 2018). As seen in the maps, REACT instruction enriched with inquiry-based experiments effectively remedied this misconception. Solutes and solvents were other concepts included in the first context. While no student in the experimental group chose the correct option in the concept cartoon before teaching, only two students in the control group grasped the scientifically accurate concept. After teaching, the experimental group showed considerable improvement, and 15 students held scientifically accurate opinions following the completion of the instruction. Homogenous (solutions) and heterogeneous mixtures were also concepts investigated in the first context. According to the individual maps, despite the instructions, students in both groups were confused about these concepts. However, the number of students with scientifically accurate concepts in the experimental group increased from 2 to 11 following teaching, while the increase in the control group was less pronounced (from 3 to 5). A meaningful understanding of homogenous and heterogeneous mixtures is possible by comprehending their particulate nature. However, these abstract concepts are not observed in the laboratory environment, and studies have shown that students have some difficulty understanding the submicroscopic level (Akaygün & Adadan, 2019; Akaygün & Jones, 2013, 2014; Taskin & Bernholt, 2014) like homogenous and heterogeneous mixtures concepts. In the REACT instruction, the teacher explained the distribution of solute and solvent particulates using two-dimensional models. When learning this concept, students may benefit from visualization tools such as animation, simulation, or augmented reality applications.

The second context was 'vitamins', which was related to factors affecting the dissolution rate in a solution. As seen in the individual profile maps for the experimental and control groups, the best results for this context were observed in the experimental group. Before teaching, 16 students in the experimental group had a scientifically accurate understanding of factors affecting the dissolution rate. After undergoing REACT strategy instruction enriched with inquiry-based experiments, the misconceptions of three students were remedied, and all students in the experimental group had an accurate understanding of this subject. The students performed two experiments using vitamin tablets (in the experiencing stage) and sugar (in the applying stage). They were thus able to not only observe these experiments but also to inquire. In the cooperating stage, they proposed the fastest way to dissolve sugar.

In contrast, students in the control group performed experiments using vitamin tablets only to confirm expected results without inquiring. After receiving conventional teacher-centered instruction, three students in the control group resisted changing their misconceptions from the beginning of the study, and five students changed their previously accurate understanding of the concept to the common misconception "If mixtures were stirred, more sugar would dissolve". These results confirm that the traditional approach to teaching is insufficient for meaningful learning.

4. CONCLUSION

The relationship between student achievement and the conducting of instructional approaches in the classroom is a significant indicator of teaching effectiveness

(Teig, Scherer & Nilsen, 2018). This study provides notable results on the effectiveness of classroom teaching techniques. The findings may encourage teachers to conduct science lessons using the REACT strategy teaching model enriched with inquiry-based experiments. They could be a useful guide on how to do so. In this way, the laboratory experiments performed in the experiencing stage of the REACT strategy will become minds-on activities. In addition, the results of this study demonstrate that concept cartoons may be used by both teachers and researchers not only as a learning strategy but also as a tool for data collection, which will enable better evaluation of students' misconceptions. Furthermore, teachers and researchers can analyze these misconceptions using individual profile maps rather than traditional quantitative comparison methods. In this way, tangible improvements in students' conceptual understanding can be made.

It should be noted that this study had some limitations (described in this paragraph), which could be addressed by future research in this field. The teaching in this study was limited to the subject of mixtures and their subtopics, which are basic concepts about mixtures and factors affecting the dissolution rate. The teaching lasted three weeks and was administered as twelve 40-minute lesson sessions. Data collection was limited to results obtained from four concept cartoons. This study was also limited by the involvement of only two science classes. Future studies should, therefore, seek to investigate the teaching of multiple science topics in different grades for more extended periods. They should aim to use larger study populations to achieve more generalizable and extensive results.

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Appendix

Misconceptions in the Concept Cartoons

1. "Nazlı made some sherbet with her friends. To do this, she added some sugar to the water in the cooker. After a while, she could not see sugar in the water. She was surprised, and asked them:
Nazlı: What happened to sugar?
Ali (Misconception-1, M1): It melted.
Ayşe (Misconception-2, M2): It disappeared.
Burak (Scientifically true, ST): It dissolved.
Büşra (Misconception-3, M3). It transformed into water.
Can (Misconception-4, M4): It evaporated.
Ceyda (Misconception-5, M5): It transformed into a different matter."

2. "Nazlı made sherbet with her friends on a different day. She added a half-cup glass of sugar to 1L of water on the cooker. Suddenly, she wondered and asked her friends:
Nazlı: Sugar is the solute in this solution, I know this, but why is the solute sugar?
Ali (Misconception-1, M1): The solute is always solid.
Ayşe (Misconception-2, M2): Water melts the sugar.
Burak (Scientifically true, ST): There is a larger amount of water than sugar."

3. "Nazlı had breakfast with her family. Her father added a cube of sugar to his tea and started to stir it with a teaspoon. Nazlı wondered why her father did this, but she couldn't ask him because she had to go to school. When she drank something with her friends in the school cafeteria, she told them about the event that morning, and asked them:
Nazlı: What would happen to sugar if my dad stirred it?
Ali (Misconception-1, M1): More sugar would dissolve.
Ayşe (Scientifically true, ST): Sugar would dissolve faster.
Burak (Misconception-2, M2): Sugar would precipitate.
Büşra (Misconception-3, M3): Nothing would happen."

4. "Nazlı's nose was stuffy because of illness, and the doctor gave her a nasal spray for it. Her friends visited her and they investigated the content of the nasal spray. They were surprised to find this spray included water and ocean salt. Nazlı asked her friends:
Nazlı: Why is this solution homogeneous?
Ali (Misconception-1, M1): Because the particulates of the solution have
melted.
Ayşe (Misconception-2, M2): Because all mixtures are the solutions.
Burak (Misconception-3, M3): Because the particulates of the solution did not distribute equally.
Büşra (Misconception-4, M4): Because the salt disappeared.
Can (Scientifically true, ST): Because it has the same proportions of its components throughout any given sample.