EXAMINING THE EFFECTIVENESS OF ARGUMENTATION INSTRUCTION ON STUDENTS' MISCONCEPTIONS ABOUT THE PARTICULATE NATURE OF MATTER AND DISSOLUTION ON THE BASIS OF ONTOLOGY

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ABSTRACT

EXAMINING THE EFFECTIVENESS OF ARGUMENTATION INSTRUCTION ON STUDENTS' MISCONCEPTIONS ABOUT THE PARTICULATE NATURE OF MATTER AND DISSOLUTION ON THE BASIS OF ONTOLOGY

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The study aims to identify the misconceptions of 7th-grade students regarding the particulate nature of matter and dissolution and to examine the effect of argumentation instruction on these misconceptions. Furthermore, it seeks to determine the ontological reasons behind these misconceptions and investigate how argumentation instruction impacts eliminating misconceptions incorrectly assigned to ontological categories. The study uses a static group pre-test–post-test design with 35 participants: 16 received curriculum-based instruction, and 19 received argumentation instruction. Data were collected using the "Particulate Nature of Matter Concept Test," a two-tier diagnostic test consisting of 17 questions. The analysis of the content-reason combinations from the concept test revealed that students held various misconceptions about the topic. Non-parametric test results of the quantitative data indicated a significant increase in understanding the concepts among students who received argumentation instruction compared to those who received curriculum-based instruction. In addition, ontological evaluation of the misconceptions revealed that they resulted from incorrect assignment of concepts to lateral and superordinate categories. Analysis of the students' content-reason combination response before and after the instruction on the particulate nature of matter and dissolution concept test indicated that argumentation instruction was more effective than curriculum-based instruction in eliminating these misconceptions caused by incorrect assignment to the lateral and superordinate ontological categories. The study's results provide several implications for researchers, teachers, curriculum developers, textbook writers, and the Ministry of National Education.

Keywords: Misconception, Ontology, Ontological Categories, Argumentation Instruction, Conceptual Understanding, Particulate Nature of Matter and Dissolution

ÖZ

ÖĞRENCİLERİN MADDENİN TANECİKLİ YAPISI VE ÇÖZÜNME KONULARINDAKİ KAVRAM YANILGILARINA YÖNELİK ARGÜMANTASYON ÖĞRETİMİNİN ETKİLİLİĞİNİN ONTOLOJİ TEMELİNDE İNCELENMESİ

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Bu çalışmanın amacı, 7. sınıf öğrencilerinin maddenin tanecikli yapısı ve çözünme konularına yönelik kavram yanılgılarını belirlemek ve argümantasyon öğretiminin tespit edilen kavram yanılgıları üzerindeki etkisini incelemektir. Ayrıca çalışma, belirlenen kavram yanılgılarını ontoloji temelinde nedenlerini tespit ederek, argümantasyon öğretiminin ontolojik kategorilere yanlış atanan kavram yanılgıları üzerindeki etkisini de incelemeyi amaçlamıştır. Araştırma müfredata dayalı öğretim alan 16 öğrenci ve argümantasyon öğretimi alan 19 öğrenci olmak üzere, toplam 35 öğrenci ile nicel araştırma metodolojilerinden biri olan statik grup ön test-son test desen kullanılarak yürütülmüştür. Çalışmanın verileri 17 sorudan oluşan, iki-aşamalı teşhis testi olan “Maddenin Tanecikli Yapısı Kavram Testi" kullanılarak toplanmıştır. Kavram testinin içerik-neden kombinasyonlarının analizi, 7. sınıf öğrencilerinin maddenin tanecikli yapısı ve çözünme konularına ilişkin çeşitli kavram yanılgılarına sahip olduklarını göstermiştir. Nicel verilerin non- parametrik test analiz sonuçları, argümantasyon öğretimi alan öğrencilerin müfredata dayalı öğretim alan öğrencilere göre maddenin tanecikli yapısı ve çözünmeye ilişkin kavramları anlamada anlamlı bir artış olduğunu göstermiştir. Ayrıca, ontolojik kategoriler üzerinden değerlendirilen kavram yanılgılarının, kavramın yanal ve üst kategorilere yanlış atanmasından kaynaklı olduğu belirlenmiştir. Öğretim öncesi ve sonrası, öğrencilerin maddenin tanecikli yapısı ve çözünme kavram testine yönelik içerik-neden kombinasyon yanıtlarının değerlendirilmesi sonucunda, argümantasyon öğretiminin yanal ve üst ontolojik kategorilere yanlış atanmaktan kaynaklı kavram yanılgılarının ortadan kaldırılmasında, müfredata dayalı öğretime oranla daha etkili olduğu sonucuna ulaşılmıştır. Çalışmanın sonuçları, araştırmacılar, öğretmenler, müfredat geliştiricileri, ders kitabı yazarlarına ve Millî Eğitim Bakanlığına yönelik çeşitli öneriler sunmaktadır.

Anahtar Kelimeler: Kavram Yanılgısı, Ontoloji, Ontolojik Kategoriler, Argümantasyon Öğretimi, Kavramsal Anlama, Maddenin Tanecikli Yapısı ve Çözünme

To my beloved family

To my lovely daughter Sütlaç

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TABLE OF CONTENTS

ABSTRACT v

ÖZ vii

ACKNOWLEDGMENTS x

TABLE OF CONTENTS xi

LIST OF TABLES xv

LIST OF FIGURES xxi

LIST OF ABBREVIATIONS xxv

CHAPTERS

1 INTRODUCTION 1

1.1 Scientific Literacy 1

1.2 Conceptual Change Based on Ontology 2

1.3 Argumentation 3

1.4 Purpose of the Study 6

1.5 Research Questions 6

1.6 Definition of Important Terms 7

1.7 Significance of the Study 9

2 LITERATURE REVIEW 15

2.1 Constructivism 15

2.1.1 Misconceptions About Particulate Nature of Matter 19

2.1.2 Conceptual Change 24

2.2 Ontology and Ontological Categories 26

2.2.1 Matter Category 29

2.2.2 Process Category 29

2.2.3 Mental States Category 30

2.3 The Interaction Among Ontological Categories "Lateral and Hierarchical Categories" 31

2.3.1 The Importance Role of Categorization in Learning 33

2.4 Conceptual Change Based on Ontology 34

2.4.1 Studies in Science on Ontological Shift Theory of Misconception 38

2.5 Argumentation 48

2.5.1 Toulmin Argumentation Pattern 49

2.5.2 Argumentation Frameworks for Science Class 52

2.6 Studies on the Effects of Argumentation on Conceptual Understanding of Science Concepts 54

3 METHODOLOGY 65

3.1 Design of the Study 65

3.2 Participants of the Study 69

3.3 Data Collection 72

3.3.1 Instrument 72

3.3.2 Treatment 82

3.4 Data Analysis 115

3.5 Treatment Validity and Verification 116

3.6 Validity 117

3.7 Internal Validity 118

3.8 Limitations 120

3.9 Assumptions 121

4 RESULTS 123

4.1 Results for the Identifying Misconceptions on Particulate Nature of Matter and Dissolution 123

4.2 Results of the Descriptive Statistics for the Particulate Nature of Matter Concept Test 173

4.3 Results of the Inferential Statistics for the Particulate Nature of Matter Concept Test 174

4.4 Results of Ontological Categorizations of Misconceptions 179

4.4.1 Ontological Analysis for Question 1st of PNMCT 179

4.4.2 Ontological Analysis for Question 2nd of PNMCT 183

4.4.3 Ontological Analysis for Question 3rd of PNMCT 186

4.4.4 Ontological Analysis for Question 4th of PNMCT 190

4.4.5 Ontological Analysis for Question 5th of PNMCT 193

4.4.6 Ontological Analysis for Question 6th of PNMCT 196

4.4.7 Ontological Analysis for Question 7th of PNMCT 200

4.4.8 Ontological Analysis for Question 8th of PNMCT 204

4.4.9 Ontological Analysis for Question 9th of PNMCT 207

4.4.10 Ontological Analysis for Question 10th of PNMCT 211

4.4.11 Ontological Analysis for Question 11th of PNMCT 215

4.4.12 Ontological Analysis for Question 12th of PNMCT 219

4.4.13 Ontological Analysis for Question 13th of PNMCT 222

4.4.14 Ontological Analysis for Question 14th of PNMCT 226

4.4.15 Ontological Analysis for Question 15th of PNMCT 229

4.4.16 Ontological Analysis for Question 16th of PNMCT 233

4.4.17 Ontological Analysis for Question 17th of PNMCT 237

4.4.18 Distribution of Misconceptions According to the Upper and Superordinate Categories 241
4.5 Summary of the Study Results 246
5 CONCLUSION 249
5.1 Discussion 249
5.1.1 Discussion of Misconceptions Identified Regarding the Particulate Nature of Matter and Dissolution 249
5.1.2 Discussion on the Effect of Argumentation Instruction in Conceptual Understanding 253
5.2 Discussion on the Effect of Argumentation Instruction on Eliminating Misconceptions in the Context of Ontology 261
5.3 Implications and Recommendations for Practitioners and Researchers 264
REFERENCES 271
APPENDICES
A. MINISTRY OF NATIONAL EDUCATION ETHICAL COMMITTEE APPROVAL 303
B. METU ETHICAL COMMITTEE APPROVAL 304
C. EXAMPLE of ARGUMENTATION-BASED ACTIVITIES 305
D. EXAMPLE of LESSON PLAN 313
E. TEACHER INFORMATION FORM 322
F. LESSON OBSERVATION FORM 327
G. PARENT PERMISSON FORM 328
H. CURRICULUM BASED LESSON PLAN 330
İ. PARTICULATE NATURE OF MATTER CONCEPT TEST 331
J. ETHICAL PERMISSIONS 339

LIST OF TABLES

TABLES

Table 2. 1 Distinctions Between Traditional Class and Constructivist Class 17
Table 3. 1 Symbolic Notation of Weak-experimental Design of the Study: The Static-Group Pretest-Posttest Design 67
Table 3. 2 Weak-experimental Design of the Study: The Static-Group Pretest-Posttest Design 68
Table 3. 3 Frequencies Distribution of the Study Sample into Research Groups .. 70
Table 3. 4 Propositional Knowledge Statements Necessary for Understanding the Particulate Nature of Matter and Dissolution 75
Table 3. 5 Specification Grid Showing the Topic Areas and Propositional Knowledge Statements Addressed by the Questions in the Particulate Nature of Matter Concept Test 78
Table 3. 6 Item Difficulty and Item Discrimination Index of Particulate Nature of Matter Concept Test 80
Table 3. 7 Summary of the Particulate Nature of Matter Concept Test Characteristics 81
Table 3. 8 The Details of Lesson Plans and Instructional Materials Used in Argumentation Instruction 90
Table 3. 9 Application Program of "Particulate Nature of Matter" Unit to Study Groups 108
Table 4. 1 Item 1 of the Particulate Nature of Matter Concept Test 125
Table 4. 2 The percentage of the comparison group and experimental group answer combination for Item 1 of the Particulate Nature of Matter Concept Pre-Test 126
Table 4. 3 The percentage of the comparison group and experimental group answer combination for Item 1 of the Particulate Nature of Matter Concept Post-Test 126
Table 4. 4 Item 2 of the Particulate Nature of Matter Concept Test 128

Table 4. 5 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 2 of the Particulate Nature of Matter Concept Pre-Test 129
Table 4. 6 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 2 of the Particulate Nature of Matter Concept Post-Test 129
Table 4. 7 Item 3 of the Particulate Nature of Matter Concept Test 130
Table 4. 8 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 3 of the Particulate Nature of Matter Concept Pre-Test 131
Table 4. 9 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 3 of the Particulate Nature of Matter Concept Post-Test 131
Table 4. 10 Item 4 of the Particulate Nature of Matter Concept Test 132
Table 4. 11 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 4 of the Particulate Nature of Matter Concept Pre-Test 133
Table 4. 12 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 4 of the Particulate Nature of Matter Concept Post-Test 133
Table 4. 13 Item 5 of the Particulate Nature of Matter Concept Test 134
Table 4. 14 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 5 Of the Particulate Nature of Matter Concept Pre-Test 135
Table 4. 15 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 5 Of the Particulate Nature of Matter Concept Post-Test 135
Table 4. 16 Item 6 of the Particulate Nature of Matter Concept Test 136

Table 4. 17 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 6 of the Particulate Nature of Matter Concept Pre-Test 137
Table 4. 18 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 6 of the Particulate Nature of Matter Concept Post-Test 137
Table 4. 19 Item 7 of the Particulate Nature of Matter Concept Test 139
Table 4. 20 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 7 of the Particulate Nature of Matter Concept Pre-Test 140
Table 4. 21 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 7 of the Particulate Nature of Matter Concept Post-Test 140
Table 4. 22 Item 8 of the Particulate Nature of Matter Concept Test 141
Table 4. 23 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 8 of the Particulate Nature of Matter Concept Pre-Test 141
Table 4. 24 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 8 of the Particulate Nature of Matter Concept Post-Test 142
Table 4. 25 Item 9 of the Particulate Nature of Matter Concept Test 143
Table 4. 26 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 9 of the Particulate Nature of Matter Concept Pre-Test 144
Table 4. 27 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 9 of the Particulate Nature of Matter Concept Post-Test 144
Table 4. 28 Item 10 of the Particulate Nature of Matter Concept Test 146

Table 4. 29 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 10 of the Particulate Nature of Matter Concept Pre-Test 147
Table 4. 30 The percentage of the comparison group and experimental group answer combination for Item 10 of the Particulate Nature of Matter Concept Post-Test 147
Table 4. 31 Item 11 of the Particulate Nature of Matter Concept Test 149
Table 4. 32 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 11 of the Particulate Nature of Matter Concept Pre-Test 150
Table 4. 33 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 11 of the Particulate Nature of Matter Concept Post-Test 150
Table 4. 34 Item 12 of the Particulate Nature of Matter Concept Test 151
Table 4. 35 The Percentage of The Comparison Group and Experimental Group Answer Combination for Item 12 of the Particulate Nature of Matter Concept Pre-Test 152
Table 4. 36 The Percentage of The Comparison Group and Experimental Group Answer Combination for Item 12 of the Particulate Nature of Matter Concept Post-Test 152
Table 4. 37 Item 13 of the Particulate Nature of Matter Concept Test 153
Table 4. 38 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 13 of the Particulate Nature of Matter Concept Pre-Test 154
Table 4. 39 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 13 of the Particulate Nature of Matter Concept Post-Test 154
Table 4. 40 Item 14 of the Particulate Nature of Matter Concept Test 155

Table 4. 41 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 14 of the Particulate Nature of Matter Concept Pre-Test.......... 156
Table 4. 42 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 14 of the Particulate Nature of Matter Concept Post-Test.......... 156
Table 4. 43 Item 15 of the Particulate Nature of Matter Concept Test.......... 158
Table 4. 44 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 15 of the Particulate Nature of Matter Concept Pre-Test.......... 158
Table 4. 45 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 15 of the Particulate Nature of Matter Concept Post-Test.......... 159
Table 4. 46 Item 16 of the Particulate Nature of Matter Concept Test.......... 159
Table 4. 47 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 16 of the Particulate Nature of Matter Concept Pre-Test.......... 160
Table 4. 48 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 16 of the Particulate Nature of Matter Concept Post-Test.......... 160
Table 4. 49 Item 17 of the Particulate Nature of Matter Concept Test.......... 162
Table 4. 50 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 17 of the Particulate Nature of Matter Concept Pre-Test.......... 162
Table 4. 51 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 17 of the Particulate Nature of Matter Concept Post-Test.......... 163
Table 4. 52 The Percentages of Correct Content and Correct Content-Reason Combinations Chosen by The Comparison and Experimental Group Students in The Particulate Nature of Matter Concept Test Before and After Instruction...... 164

Table 4. 53 Percentages of Comparison and Experimental Group Students with Misconceptions Identified in Particulate Nature of Matter Concept Pre-Test and Post-Test 169
Table 4. 54 Results of the Shapiro-Wilk Normality Test of Particulate Nature of Matter Concept Pre-Test Scores of the Experimental and Comparison Group 173
Table 4. 55 Results of the Shapiro-Wilk Normality Test of Particulate Nature of Matter Concept Post-Test Scores of the Experimental and Comparison Group ... 174
Table 4. 56 Results of the Mann- Whitney U Test of Particulate Nature of Matter Concept Pre-Test Scores of the Experimental and Comparison Group 175
Table 4. 57 Results of the Particulate Nature of Matter Concept Pre-Test Median Values for Experimental and Comparison Groups 175
Table 4. 58 Results of the Wilcoxon Signed Rank Test of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Comparison Group 176
Table 4. 59 Results of the Descriptive Statistics of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Comparison Group 176
Table 4. 60 Results of the Wilcoxon Signed Rank Test of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Experimental Group 177
Table 4. 61 Results of the Descriptive Statistics of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Experimental Group 177
Table 4. 62 Results of the Mann- Whitney U Test of Particulate Nature of Matter Concept Post-Test Scores of the Experimental and Comparison Group 178
Table 4. 63 Results of the Particulate Nature of Matter Concept Post-Test Median Values for Experimental and Comparison Groups 178

LIST OF FIGURES

FIGURES

Figure 2. 1 A Possible Categorization Scheme and Subcategories of Entities in the World 28
Figure 2. 2 Example of Hierarchical and Lateral Relationships within Tree Categories 32
Figure 2. 3 Schematic Representation Example of the Radical Conceptual Change and Conceptual Change 36
Figure 2. 4 Schematic Representation of Toulmin Argumentation Pattern........... 50
Figure 3. 1 Classroom Seating Plans 71
Figure 4. 1 Distribution of the Percentage of Correct Combination in the Pre-test and Post-test of the Comparison Group 165
Figure 4. 2 Distribution of the Percentage of Correct Combination in the Pre-test and Post-test of the Experimental Group 166
Figure 4. 3 Percentages of Comparison Group Misconceptions in Ontological Analysis of the First Question of the Particulate Nature of Matter Concept Test 181
Figure 4. 4 Percentages of Experimental Group Misconceptions in Ontological Analysis of the First Question of the Particulate Nature of Matter Concept Test 182
Figure 4. 5 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Second Question of the Particulate Nature of Matter Concept Test 184
Figure 4. 6 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Second Question of the Particulate Nature of Matter Concept Test 185
Figure 4. 7 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Third Question of the Particulate Nature of Matter Concept Test188
Figure 4. 8 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Third Question of the Particulate Nature of Matter Concept Test189

Figure 4. 9 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fourth Question of the Particulate Nature of Matter Concept Test 191
Figure 4. 10 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fourth Question of the Particulate Nature of Matter Concept Test 192
Figure 4. 11 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fifth Question of the Particulate Nature of Matter Concept Test 194
Figure 4. 12 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fifth Question of the Particulate Nature of Matter Concept Test 195
Figure 4. 13 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Sixth Question of the Particulate Nature of Matter Concept Test 198
Figure 4. 14 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Sixth Question of the Particulate Nature of Matter Concept Test 199
Figure 4. 15 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Seventh Question of the Particulate Nature of Matter Concept Test 202
Figure 4. 16 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Seventh Question of the Particulate Nature of Matter Concept Test 203
Figure 4. 17 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Eighth Question of the Particulate Nature of Matter Concept Test 205
Figure 4. 18 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Eighth Question of the Particulate Nature of Matter Concept Test 206
Figure 4. 19 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Ninth Question of the Particulate Nature of Matter Concept Test 209

Figure 4. 20 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Ninth Question of the Particulate Nature of Matter Concept Test 210
Figure 4. 21 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Tenth Question of the Particulate Nature of Matter Concept Test 213
Figure 4. 22 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Tenth Question of the Particulate Nature of Matter Concept Test 214
Figure 4. 23 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Eleventh Question of the Particulate Nature of Matter Concept Test 217
Figure 4. 24 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Eleventh Question of the Particulate Nature of Matter Concept Test 218
Figure 4. 25 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Twelfth Question of the Particulate Nature of Matter Concept Test 220
Figure 4. 26 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Twelfth Question of the Particulate Nature of Matter Concept Test 221
Figure 4. 27 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Thirteenth Question of the Particulate Nature of Matter Concept Test.. 224
Figure 4. 28 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Thirteenth Question of the Particulate Nature of Matter Concept Test.. 225
Figure 4. 29 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fourteenth Question of the Particulate Nature of Matter Concept Test.. 227

Figure 4. 30 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fourteenth Question of the Particulate Nature of Matter Concept Test 228
Figure 4. 31 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fifteenth Question of the Particulate Nature of Matter Concept Test 231
Figure 4. 32 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fifteenth Question of the Particulate Nature of Matter Concept Test 232
Figure 4. 33 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Sixteenth Question of the Particulate Nature of Matter Concept Test 235
Figure 4. 34 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Sixteenth Question of the Particulate Nature of Matter Concept Test 236
Figure 4. 35 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Seventeenth Question of the Particulate Nature of Matter Concept Test 239
Figure 4. 36 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Seventeenth Question of the Particulate Nature of Matter Concept Test 240
Figure 4. 37 Total Frequencies of Comparison Group Misconceptions Based on Ontological Categories 242
Figure 4. 38 Total Frequencies of Experimental Group Misconceptions Based on Ontological Categories 243
Figure 4. 39 Distribution Percentages of Elimination Rates of Misconceptions . 245

LIST OF ABBREVIATIONS

ABBREVIATIONS

MoNE: Ministry of National Education

CHAPTER 1

INTRODUCTION

1.1 Scientific Literacy

The discourses about the goals of science education are often expressed in terms of scientific literacy (Norris & Phillips, 2003). Therefore, one of the most important goals of science educators is to raise scientifically literate individuals (Lederman, 1992). Even in the 21st century, international discussions and preparations have become the central theme to achieve the stated purpose of science education (de Boer, 2000). The characteristics expected from scientifically literate individuals are being able to distinguish science from non-science (Mayer, 1997), being able to use scientific process skills to solve problems related to real life, make decisions, and develop their ideas (NRC, 1996), being able to think critically about scientific issues (Shamos, 1995) and being able to understand scientific concepts, principles, laws, and theories correctly (Rubba & Anderson, 1978). Considering the common points of these definitions, concept learning is one of the main themes of scientific literacy (Choi et al., 2011). In other words, scientific literacy is the ability to ask questions and create evidence-based answers to make sense of natural and human events that occur in the world and to find a way to produce knowledge about them (OECD, 1999; de Boer, 2000). These definitions show that scientific literacy has a broad meaning that includes making sense of science and the nature of science. When evaluated from this perspective, scientific literacy is possible if the applied instruction design is shaped within the framework of the perspective of conceptual change (Treagust et al., 2008).

1.2 Conceptual Change Based on Ontology

The conceptual change approach, developed to combat students' misconceptions, has become a focal point for science educators (Chambers & Andre, 1997). The process of conceptual change is eliminating misconceptions and modifying misinformation to adapt to new information, taking into account prior knowledge to ensure meaningful learning (Smith et al., 1993a). Since students' prior knowledge must be considered and emphasized for conceptual change, many researchers have tried to define and understand students' prior knowledge using different terminologies. In line with the different epistemological orientations of researchers, individuals' prior knowledge has been expressed with different terminologies such as misconceptions (Posner et al., 1982; Vosniadou, 1994), alternative conceptions (Hewson & Hewson, 1989; Mungsing, 1993), naive conceptions (Vosniadou, 1994), and children' science (Karpudewan et al., 2017). In the following processes, researchers have tried to understand the nature of misconceptions rather than the definitions (Wittmann, 2002). In one interpretation of misconceptions, Chi and colleagues consider misconceptions in terms of ontological categories (Chi, 1992; Chi & Slatto, 1993; Chi & Roscoe, 2002). According to Chi and Roscoe (2002), a misconception places a concept in the wrong ontological category to which it does not belong. In other words, all entities in the universe fall under three basic ontological categories, each with its unique characteristics: matter, process, and mental states. Suppose there is a discrepancy between the ontological category to which the concept belongs in these categories, indicating a misconception (Chi & Slatto, 1993). In this context, the present study's theoretical framework on conceptual change builds upon Chi and colleagues' (1993; 2002) approach, which emphasizes the ontological nature of entities and the characteristics of scientific concepts.

Science education has increasingly focused on addressing students' misconceptions. A key reason for this focus is the realization that students often come to school with pre-existing ideas and concepts that diverge significantly from scientifically accurate understandings. These misconceptions are often deeply rooted, making them resistant to change (Duit, 2007). This situation causes students not to understand new information and concepts (Osborne & Wittrock, 1983) and to struggle to make sense of a higher concept based on a concept in their wrong category (Ayvacı & Devecioğlu, 2002). Chemistry, in particular, poses a challenge for students, as it includes many abstract concepts that are difficult to grasp (Nakhleh, 1992). For students to succeed, they need to attribute a concept according to the characteristics of the category it belongs to and relate it to other concepts with the correct characteristics it assigns (Treagust et al., 2003). At this point, identifying and eliminating students' misconceptions is essential to success because misconceptions prevent students from learning (Nakhleh, 1992; Ayvacı & Devecioğlu, 2002). Griffiths et al. (1988) emphasize that the first step in overcoming misconceptions is their identification, followed by the design and implementation of appropriate instructional strategies. One practical approach is argumentation, which enhances a deeper conceptual understanding of science (Driver et al., 2000).

1.3 Argumentation

Argumentation, which has the potential to provide an environment for students to think deeply, make their ideas visible, and refute misconceptions, is seen to have a significant place in terms of conceptual understanding (Baker,1999). Furthermore, according to Vygotsky (1978), it is not easy to learn concepts scientifically without social interactions that create a discussion environment that reveals differences in ideas. Argumentation is the process of evaluating theoretical claims using data obtained through various means (Jiménez-Aleixandre & Pereiro-Munoz, 2002), and students are involved in this argumentation process with the argument structures they create (Simon et al., 2003). Different models have been developed in the literature to analyze the argumentation process, argument formation styles, and process management. The "Informal Argumentation Model" developed by Johnson and Blair (1994), the "Walton Argument Model" developed by Walton (2006), and the Toulmin Argumentation Pattern developed by Toulmin (1958) are the main ones.

Among these, the Toulmin Argumentation Pattern has been recognized as particularly suitable for studies in science education (Aldağ, 2006) and serves as the theoretical foundation for the argumentation framework in the present study. Toulmin (1958) presented a model that defines the elements of argument to support argumentation in science education and to be assessed easily by science educators. According to this model, the structure of an argument consists of the claim, data, warrants, backings, rebuttals, and qualifiers. In a basic sense, the argumentation process involves participants making claims, using data to indicate the source of their claims, supporting their claims with scientific evidence, making their warrants more scientifically acceptable when additional data is presented, or changing their claims entirely (Toulmin, 1958; Driver, Newton, & Osborne, 2000; Simon et al., 2002). In this respect, argumentation allows students to review existing knowledge in their minds and create new knowledge by considering different information (Brown & Campione, 1998). Students frequently encounter different ideas during argumentation, leading them to think more about their ideas and reconsider alternative concepts (Patronis et al., 1999; Duit & Treagust, 2012; Pacaci et al., 2024). Because argumentation is a social phenomenon with no winner or loser, this situation motivates students to exchange ideas freely (Simon et al., 2006). In this way, improvements occur in the conceptual understanding level of students (Jimenez-Aleixandre & Erduran, 2007). However, this is only possible if argumentation is integrated effectively into the classroom. At this point, Osborne et al. (2004b) have put forward some frameworks for effectively integrating argumentation in science classes. The frameworks used in the present study are a table of statements, competing theories with concept cartoons, competing theories with ideas and evidence, structuring the argument, and predict-observe-explain (POE). A table of statements is a framework in which students discuss different ideas regarding given statements on science topics. Competing theories with concept cartoons involves presenting students with concept cartoons depicting two or more theories and asking them to construct arguments supporting the theory they find most convincing. Competing theories using concept cartoons involve with concept cartoons depicting two or more theories and asking them to construct arguments supporting the theory they find most convincing. Different theories about a given event are presented in competing theories with ideas and evidence. Students are asked to argue which theory best represents the event using the evidence cards given to them. In argument structuring, students are presented with a story that includes concepts related to their learning topic. Students are asked to make their arguments using the statements in the story. Finally, in POE, students are asked for preliminary ideas about a science event. Then, the event is conveyed to the students, who are asked to make the necessary notes by observing during this time. Then, they are expected to explain the compatibility between their preliminary ideas and observation notes. The common goal of all preferred frameworks is to ensure that students question and discuss the arguments they create within a scientific framework, thus improving their conceptual understanding (Altun, 2010).

Although there are findings in the relevant literature that argumentation improves conceptual understanding (Driver, 1994; Dawson & Carson, 2020; Pontecorvo, 1987; Sampson & Gleim, 2009; Uzuntiryaki Kondakci et al., 2021), it is seen that argumentation is not included in science classes to a large extent (Simon et al., 2006; Sampson & Blanchard, 2012; Cengiz, 2017). In classes where traditional science education is provided, students are presented with scientific facts to be memorized and are not allowed to make any claims (Wells, 1999). This situation causes the students to have a negative impact on an example of how science is formed and applied and causes the individuals' existing knowledge to be devalued (Norris, 1997). For this reason, meaningful science teaching should not be based on presenting ready-made scientific facts to students; it should be built on an argumentation environment where students can make claims about scientific concepts, support their claims, and evaluate other’s claims (Jiménez-Aleixandre & Erduran, 2007; Cross et al., 2008).

1.4 Purpose of the Study

This research is structured for two primary purposes in line with the information provided above. The first is to determine the students' misconceptions about the particulate nature of matter and dissolution and examine the effect of argumentation instruction in eliminating these misconceptions. Another is to evaluate the misconceptions determined about the particulate nature of matter and dissolution based on ontology, identify their ontological causes, and assess the effectiveness of argumentation and curriculum-based instruction in eliminating misconceptions resulting from incorrect ontological categorization.

1.5 Research Questions

The following research questions are focused on in this study.

1. What are the misconceptions of 7th-grade students about the particulate structure of matter and dissolution?
2. What is the effect of argumentation instruction compared to curriculum–based instruction on 7th-grade students' conceptual understanding of the particulate nature of matter and dissolution concepts?

   2. a. Is there a statistically significant difference between the pre-test of the particulate nature of matter and dissolution concepts scores of the comparison group receiving curriculum-based instruction and the experimental group receiving argumentation instruction?

   2. b. Is there any statistically significant difference between the pre-test and post-test scores of the particulate nature of matter and dissolution concepts of the comparison group receiving curriculum-based instruction?

2. c. Is there any statistically significant difference between the pre-test and post-test scores of the particulate nature of matter and dissolution concepts of the experimental group receiving argumentation instruction?

2.d. Is there a statistically significant difference between the post-test of the particulate nature of matter and dissolution concepts scores of the comparison group receiving curriculum-based instruction and the experimental group receiving argumentation instruction?

3. What is the effect of argumentation instruction compared to curriculum-based instruction in eliminating ontologically evaluated misconceptions of 7th-grade students regarding the particulate nature of matter and dissolution concepts?

3.a. How does argumentation instruction impact eliminating 7th-grade students' misconceptions caused by incorrectly placing the concepts of the particulate structure of matter and dissolution into lateral and upper ontological categories?

3. b. How does curriculum-based instruction impact eliminating 7th-grade students' misconceptions caused by incorrectly placing the concepts of the particulate structure of matter and dissolution into lateral and upper ontological categories?

1.6 Definition of Important Terms

This section includes definitions of important terms used in the study.

Ontology: It is defined as the science of existence and expresses the categorical structure of reality, that is, the things that exist (Chi, 1997; Chi & Roscoe, 2002).

Ontological Category: It represents the different categories to which things or beings belong. There are three fundamental ontological categories: matter, processes, and mental states (Chi, 1994).

Ontological Property: It is a quality that an entity or thing has the potential to possess in the context of the ontological category to which it belongs (Chi, 1994).

Misconception: According to Chi and Roscoe (2002), misconceptions are categorizing concepts into categories to which they do not ontologically belong. In other words, misconceptions are incorrect categorizations of concepts laterally rather than hierarchically.

Conceptual Change: Conceptual change is the process of repairing misconceptions. During this process, if the concept does not move away from its primary meaning and gains a more specific meaning with more qualities, changing its place within the same ontological category is called conceptual change, conceptual change in the ontological categories, or non-radical conceptual change. However, if the concept takes on a different meaning in all its aspects and changes its place between different ontological categories, it is defined as radical conceptual change or conceptual change across the ontological categories (Chi, 1992; Chi & Roscoe, 2002).

Argumentation: It is a social discursive process in which claims made are tried to be proven by relying on warrants and backing (Toulmin, 1958)

Argumentation Instruction: The learning of students through activities prepared using frameworks that will provide the argumentation process in the classroom, as described by Osborne et al. (2004b). In this study, it was applied to the experimental group. While students actively learn the relevant subject by participating in group and class discussions, the teacher guides the process.

Curriculum-Based Instruction: This is teacher-centered instruction in which the teacher is the primary source in conveying the relevant subject, and the students are listeners. This instruction includes dialogues based on the question-answer method applied to the comparison group.

1.7 Significance of the Study

Argumentation plays a crucial role in developing students' conceptual understanding in science courses within the framework of constructivist learning theory (Newton et al., 1999; Driver, Newton, & Osborne, 2000). This is because it encompasses linguistic (Binkley, 1995), verbal, social (Bricker & Bell, 2008), and rational (Osborne et al., 2004a) activities that facilitate learning. However, despite the emphasis on the importance of constructivist classes (Brooks & Brooks, 1994; MoNE, 2018; 2024), curriculum-based instruction continues to dominate in most schools (Cengiz& Kabapınar, 2017). As a result, students rarely experience an argumentative environment that promotes practical learning and conceptual understanding (Driver et al., 2000; Sampson & Blanchard, 2012). One key reason for this is that many teachers find it challenging to introduce argumentation processes into their classrooms (Erduran et al., 2004). Therefore, the present study is essential to encourage and support science teachers by providing guidance on structuring lesson plans and teaching processes that integrate argumentation effectively. On the other hand, teachers often lack sufficient pedagogical content knowledge to effectively integrate argumentation into science lessons, which can reduce their self-confidence in implementing argumentation activities in the classroom (Driver et al., 2000). They may also have difficulty finding detailed materials to guide them through this process (Simon et al., 2006). Therefore, this study is essential as it provides examples of argumentation-based materials for the topic "Particulate Nature of Matter and Dissolution" and provides lesson plans to support science in facilitating the argumentation process.

Although argumentation in science education is closely related to students' conceptual understanding in many ways, it has not been studied at a sufficient level, especially in the field of chemistry (Erduran, 2019). As a distinct branch of science, chemistry employs unique inquiry methods that require students to engage with diverse and complex questions. Thus, integrating argumentation into chemistry education is especially valuable (Aydeniz, 2019). In addition, since students can gain various benefits from participating in the argumentation process, there is a significant need for educational studies that include chemistry topics (Erduran, 2019). In this context, the present study is essential in contributing to the limited research that focuses on conceptual understanding of chemistry concepts through argumentation instruction.

Many educators and researchers have frequently emphasized that chemistry is complex for students to understand (Lorenzo, 2005; Nakhleh, 1992). The abstract nature of the concepts included in chemistry (Collette & Chiappetta, 1989), comprehensibility of chemistry concepts depends on representing them at macroscopic, submicroscopic (or microscopic), and symbolic levels (Johnstone, 1982; Treagust et al., 2003), the frequent misuse of chemistry concepts, especially in daily life (such as melting and dissolving), and the inadequacy of individual student work for understanding chemistry concepts (Nakhleh, 1992) are some of the reasons why chemistry concepts are challenging to understand. The way to overcome these difficulties depends on effectively teaching students the particulate nature of matter and dissolution, which is the main topic of chemistry (Adbo & Taber, 2009). Because teaching the basis of chemistry concepts that students would encounter throughout their academic lives, including physical and chemical change (Adbo & Taber, 2009), gas laws, chemical and physical reactions, and solution chemistry (Gabel et al., 1987), acids and bases, the heat of reaction, enthalpy, thermodynamics, polymerization, hydrocarbons and stoichiometry (Nicoll, 2001), and builds the foundation for adequate conceptual understanding against complex chemistry concepts (Harrison & Treagust, 2000; Treagust et al., 2003). At this point, priority should be given to argumentation instruction, which provides an in-class discussion environment to develop students' conceptual understanding and encourages students to produce arguments during this process because the argumentation environment shows students that their ideas are valuable and allows them to express their thoughts freely in a social discussion environment, just like a scientist. In this way, concepts consisting of particles such as atoms and ions become more understandable (Driver et al., 2000). However, there is a lack of studies in the relevant literature that show the effects of science course activities developed with frameworks providing an argumentation environment in the classroom (Osborne et al., 2004b), particularly those targeting the particulate nature of matter and dissolution concepts (Hasançebi & Günel, 2013). Therefore, this study has the potential to show whether such activities improve students' conceptual understanding of challenging and fundamental topics, like the particulate nature of matter and dissolution, and whether argumentation can be a preferable instructional model for teaching this topic, especially to middle school students. In addition, this study contributes to the limited studies in the literature on the effect of using argumentation frameworks in science classes on students' conceptual understanding of the related topic.

Another point that adds importance to the study is about identifying misconceptions. In national and international studies, various misconceptions of students regarding the particulate nature of matter and dissolution have been identified (Abraham et al., 1994; Canpolat et al., 2004, p.380; Ergün & Sarıkaya, 2014; Griffiths & Preston, 1992; Harrison & Treagust, 2000; Kayalı & Tarhan, 2004, p.150; Lee et al., 1993; Stepans, 1996). These misconceptions among students hinder their understanding of fundamental chemistry concepts (Hewson & Hewson, 1984). Osborne and Freyberg (1985) noted that the designed instructional method would lead to misunderstandings unless we know what students think and why they think that way. At this point, this study is vital in determining students' misconceptions about the particulate nature of matter and dissolution and understanding the underlying reasons for these misconceptions. In addition, identifying these misconceptions provides valuable insights for researchers conducting future conceptual change studies about the misconceptions they need to focus on. Additionally, this study contributes by highlighting key misconceptions that should be integrated into the curriculum, offering educators and researchers guidance on how to design instructional methods that promote satisfactory conceptual understanding. Moreover, this study offers a unique interpretation of the nature of the detected misconceptions by using the conceptual change strategy of ontological category reassignment, as introduced by Chi and Slotta (1993). This strategy, which relates the existence of misconceptions to the ontological nature of entities and scientific concepts, forms the foundation of the conceptual change approach adopted in this study.

Although many researchers have emphasized it as an effective strategy for conceptual change (Chiu & Lin, 2005; Slotta & Chi, 2006), very few studies in the relevant literature have interpreted the nature of misconceptions through ontological categories. Studies on science topics such as basic physics concepts (Slatto et al., 1995; Johnson & Southern, 2000), electromagnetic induction (Acar, 2010), electricity (Lee & Law, 2001), force and motion (Topalsan, 2015; Diyarbekir, 2020), genetics (Tsui & Treagust, 2004), natural selection (McLure et al., 2020), particulate nature of matter (Özalp, 2008), matter and mixtures (Sarı, 2014; Sarı & Bayram, 2018; Kabapınar, 2013), speed in chemical reactions (Çetin, 2022), melting and dissolution (Şen & Yılmaz, 2012) are both relevant and limited in number. There are no studies in the literature that evaluate middle school students' conceptual changes regarding the particulate nature of matter and dissolution within the theoretical framework of "ontological category reassignment," nor do any present the effectiveness of argumentation instruction through ontological categories. In this context, this study is important for filling this gap in the literature, enriching the relevant field, expanding the scope of ontology as a theoretical framework for understanding the nature of misconceptions, and demonstrating the effect of argumentation instruction on the conceptual change process through ontological categories.

Last but not least, ontological categorization of misconceptions also has a crucial place in learning scientific concepts (Bransford et al., 1999). Based on ontology, a concept carries the characteristics of the category it is assigned to and has some common characteristics with all categories to which it has a hierarchical connection. This situation shows that even if students do not know a concept, they will make inferences about the new concept by assigning it to the closest category. Therefore, if students assign a concept to an incorrect category, they may have misconceptions about the concepts they will learn later, harming learning (Chi, 2008). At this point, ensuring that the student assigns the concept to the correct ontological category improves the student's learning process (Chi & Roscoe, 2002). Another advantage of categorization is that it allows individuals to assign the same label to a new category member and to form deductive or inductive inferences about a new category member (Chi et al., 1989). In other words, the student uses category knowledge to refer to a new concept (Medin & Rips, 2005). Therefore, this study is important because it has the potential to enhance student's ability to make more scientific inferences about the concepts they learn. We can improve their conceptual understanding by identifying the ontological categories to which students' misconceptions about the particulate structure of matter and dissolution belong and by implementing necessary category adjustments through appropriate instructional methods.

In summary, the present study is critical for several reasons. It encourages educators to prefer argumentation instruction by providing sample course materials and lesson plans related to the argumentation process. It demonstrates the effectiveness of argumentation instruction in enhancing students' conceptual understanding of the particulate nature of matter and dissolution. By identifying misconceptions, it creates content for further conceptual change activities. Additionally, it addresses a gap in the literature by introducing the effectiveness of argumentation instruction in conceptual change from an ontology perspective, focusing on the ontological nature of misconceptions. By determining the ontological reasons of misconceptions behind these misconceptions, the study enables students to make more consistent inferences when encountering new scientific information, facilitating successful reassignment through correct categorization and accurate knowledge.

CHAPTER 2

LITERATURE REVIEW

This part of the study mainly presents a literature review on the learning theory of constructivism, misconceptions, conceptual change, and the ontological approach of conceptual change perspective.

2.1 Constructivism

A learning theory of constructivism has impacted science education programs and education in the last twenty-two years (Matthews, 2002). The constructivist learning approach represents an understanding in which the student is at the center of learning and structuring knowledge, and in this context, the student is given responsibility, which emphasizes the impact of individual experiences and the social environment and that individuals' prior knowledge is essential in structuring knowledge (Airasian & Walsh, 1997; Ausubel, 1968; Brooks & Brooks, 1999). The basis of this idea is that knowledge is not an element transferred from one person to another. However, it is a phenomenon constructed only by the one who receives the knowledge, that is, the learner (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

The focal point of constructivist learning theory is social interaction (student-student, student-teacher, student-social environment, or situation). In this context, learning is a social activity in constructivist learning theory and Vygotsky's idea that high-level mental processes develop through social interactions (Brooks & Brooks, 1999). According to Vygotsky (1978), the pioneer of social constructivism, learning is not independent of the social environment and is built on social interactions. However, the common denominator of all types of constructivism, which are cognitive constructivism, pioneered by Piaget, social constructivism, and radical constructivism, pioneered by von Glasersfeld, is that the process of learning knowledge, that is, new concepts, is constructed by the individuals throughout the process, based on their own experiences and existing concepts, instead of obtaining them from external sources (Driscoll, 1994; McLeod, 2003). In a constructivist teaching environment, learners are thinkers, teachers have the task of determining students' existing perspectives, the products produced by students are evaluated during the learning process, and group work in which students engage in social interaction is prevalent (Brooks & Brooks, 1999).

Brooks and Brooks (1999, pp.35–85) stated the principles adopted by the constructivist learning theory as follows: Learning involves structuring concepts and knowledge in an active collaboration. Students should be allowed to produce ideas and solutions for problems and see their applicability. Learning represents a process structured around the knowledge that students already possess and the experiences they gain from the social environment. The role of the teacher is to be a guide who facilitates the learning process. The teaching design should consider the student's prior knowledge, and evaluation should occur during the teaching process.

Constructivist views have been quite effective in education, especially on how the curriculum should be designed (Jones & Brader-Araje, 2002). From the perspective of constructivist teaching theory, since students come to classes with already existing prior knowledge before teaching, learning depends not only on the classroom environment but also on the student's prior knowledge (Driver & Bell, 1986). Knowledge is reconstructed by the student in line with the student's experiences and prior knowledge. Therefore, the person responsible for learning is the individual himself. However, it is necessary to provide a teaching environment that will give students this opportunity and cause them to share their ideas in a social environment (Driver et al., 1994). In this context, constructivist classes are quite different from traditional classes. These differences are indicated in Table 2.1. by Brooks and Brooks (1999, p.17)

Table 2. 1 Distinctions Between Traditional Class and Constructivist Class

Traditional Class	Constructivist Class
The curriculum focuses on basic skills and builds knowledge from part to whole.	Knowledge of structure from the whole to part by focusing on essential concepts in the curriculum.
Compliance with the program and curriculum is required.	Students' interests and questions are the focus.
Classroom activities are limited to the textbook.	Various sources of information shape classroom activities.
Teachers have didactic behavior; information is transferred through them.	Teachers are guides, providing classroom interaction and organize the classroom order.
The sign of learning is to provide the correct answer.	Different perspectives for students revealed when planning other lessons.
Measurement and evaluation are limited to written exams.	Measurement and evaluation occur throughout the learning process and include evaluating students' work and all the products they produce.
There is no in-group or inter-group work among students.	In-group, and intergroup work is typical.
Students' minds are seen as blank blank pages to be memorized.	Students are seen as thinkers.

According to Savery and Duffy (1995), the principles of constructivist learning theory are that classroom activities should have clear and understandable purposes for students, as students' goals influence what they learn, and the subject to be learned should be adopted as a task by the students, and students should be actively encouraged to construct their own understanding. The teacher plays a key role in revealing students' alternative views, encouraging them to express these views, and facilitating the discussion of different ideas. Maintaining classroom order is also one of the teacher's responsibilities.

In summary, the role of prior concepts and knowledge structures in the learning process of science (Anderson, 1992; Bodner, 1986); the role of active learning and flexible or changeable, different thoughts in the construction of knowledge with the mental and physical participation of students (Ausubel et al., 1978; Mitchell & Lawson, 1988) are emphasized in constructivist theory. In this context, constructivist learning theory offers a general framework for learning and teaching science. A subset of this general framework includes a view that focuses on how an individual processes and transforms information during learning, which is "conceptual change" (Anderson, 1992), and especially conceptual change has become a focal point for science educators (Ebenezer & Gaskell, 1995; Hewson & Hewson, 1984). The process of conceptual change begins when the meanings of concepts in students' minds do not match scientific accuracy (Chi & Roscoe, 2002). Therefore, identifying misconceptions in students' minds is a critical first step toward achieving conceptual change.

In science education literature, it is widely accepted that students' minds are different from blank pages containing no concepts (Shuell, 1987). Before students even start their education, many of the concepts that already exist in their minds contradict generally accepted scientific knowledge (Posner et al., 1982). These concepts are expressed with different terminologies in the relevant literature as *misconception, naive conceptions* (Vosniadou, 1994), *children's science* (Osborne et al., 1983), *alternative conceptions* (Hewson & Hewson, 1984), *incorrect ideas* (Nussbaum & Novick, 1982) and *misunderstanding* (Shepherd & Renner, 1982).

This study will use the term "*misconceptions*" to refer to students' contradictory prior knowledge, as it is a commonly used term in research on the effectiveness of teaching practices in conceptual change. According to Nakhleh (1992), misconceptions represent any concept far from the widely accepted scientific understanding. Misconceptions mostly contradict the views of the experts in the field they belong to and are connected with the past. Similarly, some misconceptions held by students include information that is outdated today. While these misconceptions may seem meaningless to others, they are considered correct by the individual within their context and can even lead to solutions (Driver et al. 1985). Considering these characteristics, misconceptions are broad in scope due to their ability to represent beliefs, expectations, and a concept, and many of them are very difficult to change significantly or eliminate with traditional teaching (Driver & Easley, 1978). However, they should be eliminated (Osborne & Freyberg, 1985) because, they cause learning difficulties and can interfere with the understanding of scientific ideas (Chinn & Brewer, 1993). There are various sources of why misconceptions exist. Teaching practices in schools (Fisher, 1985), social environment and daily experiences within it (Novick & Nussbaum, 1981), daily language, and even textbooks can all contribute to the formation of misconceptions (Gilbert & Watts, 1983). For example, Gibson (1996) found that textbooks with straightforward explanations caused various misconceptions among students. Learning concepts accurately is central to meaningful learning and holds significant value (Griffitts, 1998). From this perspective, overcoming misconceptions that hinder understanding of scientific terms should be a primary objective in education (Smith et al., 1993a).

2.1.1 Misconceptions About Particulate Nature of Matter

As Gabel (1999) stated, chemistry is a field in which students often develop misconceptions at every level of education, from primary school to university, because of the highly abstract nature of concepts and the need to understand them across three basic levels- microscopic, macroscopic, and symbolic. The macroscopic level, which is the first level in the triple way of understanding and representing matter, includes concepts referred to as chemical representation, diagrams, pictures, and observable facts. On the other hand, the microscopic level includes concepts referring to particles and the movement of particles to explain the particulate structure of matter and generate ideas in chemistry. The symbolic level refers to chemical symbols and formulas representing atoms, molecules, and compounds. In other words, the macro dimension includes matter's observable and measurable dimensions, while the micro dimension includes the world of particles.

In addition to the association of the three primary levels of understanding chemistry, teaching errors during the transmission of concepts can lead to persistent misconceptions (Griffiths & Preston, 1989). For example, the moments when students encounter concepts related to atoms, elements, compounds, melting, dissolution, and chemical and physical changes, they are often presented with explanations only at the macroscopic level in textbooks. Students who read these texts may develop the misconception that salt "disappears" when dissolved in water. In short, the basis of the misconceptions is students' failure to correctly place basic chemistry concepts in their minds starting from primary school and ignoring the particulate structure of chemistry (Nakhleh, 1992). This situation has caused students to have misconceptions about the particulate structure of matter even during their university education (Novick & Nussbaum, 1981). In a study with undergraduate chemistry students, Bodner (1991) asked: "Let us say a pot of water is boiling on the stove. After a certain period, you can see bubbles coming up from the water. What do you think these bubbles are, and what do they consist of?". He found that only 20% of the participants made evaluations at the microscopic level and used the terms oxygen and hydrogen gases to describe the bubbles. The remaining students responded at the macroscopic level, focusing on the shapes of the bubbles. Developing students' conceptual understanding is an inevitable necessity to ensure that they associate chemistry, that is, matter, at three levels of representation, which are microscopic, macroscopic, and symbolic (Gabel, 1999). Achieving this requires identifying misconceptions and implementing effective teaching strategies (Griffitts, 1998).

A synthesis of the literature reveals that misconceptions about the particulate structure of matter and dissolution are concentrated around specific key concepts. These are particles' animism, structure, shape, size, energy, phase change, and attributing macroscopic properties to particles. The misconceptions in the literature are presented below.

Animism about Particles:

- All atoms have the features of life.
- Atoms that make living beings have the features of life, while atoms that make up inanimate beings do not.
- Inorganic atoms are nonliving.
- The fact that atoms can move shows that they are alive.
- The fact that atoms can come together to form matter shows that they are alive (Griffiths & Preston, 1992; Griffitts, 1998; Harrison & Treagust, 1996).

Structure, Energy, and Interparticle Space about Particles:

- Solid state atoms do not move because they do not have or have limited space to move.
- Table Salt is in molecular form.
- Sodium ion comes together with a chloride ion to form table salt.
- In the formation of NaCl, a structure like a physical hook or rope is formed between Sodium and Chlorine ions.
- Although NaCI is an example of a molecule, it is formed by combining ions.
- There is air, not space, between the particles of matter.
- Substance has its state between the particles of matter. The space between water molecules is filled with water, and the space between stone molecules is filled with stone.

- While solids have bonds in their structure, liquids do not have bonds in their structure.
- Elements form molecules.
- Atoms can be flat, circular, or dotted.
- Stone molecules cannot move because stone is tough.
- Ice molecules cannot move, but if melted, molecules can move (Boz, 2006; Griffiths & Preston, 1992; Griffitts, 1998; Othman et al.,2008; Harrison & Treagust, 1996).

Phase Changes about Particles:

- If heat is added to ice cubes, the particles of the ice cubes freeze.
- If heat is added to ice cubes, the particles of the ice cubes melt.
- In the phase change of water, freezing, heating, and condensation are seen in its molecules.
- The atoms of solid substances are in solid form, and the atoms of liquid substances are in liquid form.
- The molecules of liquid substances such as water and alcohol are in liquid form (Andersson, 1992; Boz,2006; Brook et al., 1984; Griffiths, 1998; Koulaidis & Hatzinikita, 1966; Lee et al., 1993).

Size About Particles:

- The particles are of a size that can be seen under a microscope.
- The size of water molecules' volumes decreases when water changes from liquid to solid and increases from liquid to gas.
- The size of the particles is about the size of a dot.
- The volume of water molecules is the smallest in the gaseous state.
- The size of an atom is the size of a cell. (Griffiths & Preston, 1992; Pereira & Pestana, 1991; Lee et al., 1993).

Shape About Particles:

- The shape of water particles is similar to water drops.
- All particles are the same shape.
- Temperature changes the shape of water molecules because it also changes their volume.
- All particles are round.
- Water molecules are flat.
- Particles of liquid substances take the shape of the container in which the liquid is located.
- Pressure and heat cause the molecules to change shape.
- The shape and size of a particle of a substance is the most minor form of the substance it is composed of. For example, a particle of water is the shape and size of a water drop (Boz, 2006; Griffiths & Preston, 1992; Preston, 1988; Lee et al., 1993; Nakhleh et al., 2005).

Dissolution:

- When the solute is thrown into the solvent, it melts and disappears.
- When the solute forms a solution in the solvent, the particles of the solute fill the air spaces between the solvent.
- If no external intervention (such as mixing) exists, dissolution does not occur.
- Dissolution is a non-physical or chemical event.
- The terminological equivalents of dissolution are melting and disappearing.
- After a while in the solution, the solute turns into the solvent.
- Dissolution is breaking down into smaller pieces (Driver et al., 1994; Krnel et al., 1998; Nakhleh et al., 2005; Othman et al., 2008).

Research indicates that students across all educational levels hold various misconceptions about the particulate nature of matter and its dissolution. Teaching efforts should focus on eliminating these misconceptions, as they hinder students' understanding and create difficulties for students in the learning process (Smith et al., 1993). However, misconceptions are often resistant to curriculum-based instruction (Driver& Easley, 1978; Duit & Treagust, 2012). The role and impact of students' pre-instruction conceptions on learning are evaluated within the theoretical framework of conceptual change (Duit & Treagust, 2012).

2.1.2 Conceptual Change

In learning and teaching based on constructivist learning theory, conceptual change involves changing or organizing individuals' basic concepts (Hynd et al., 1997). In other words, the conceptual change approach evaluates existing information and modifies incorrect information to ensure that it is compatible with new information to eliminate misconceptions and promote meaningful learning (Smith et al., 1993). Conceptual change, which represents an approach that encourages students to eliminate misconceptions by raising awareness in order to make a transition from misconceptions, that is, information that contradicts scientific accuracy, to scientifically accepted information, is based on Piaget's (1964) theoretical framework of assimilation, accommodation, and equilibration on the evolution of proposed knowledge in young people’s cognitive development (Von Glasersfeld, 1995). When individuals encounter a new concept, they prefer to associate it with their existing concepts or to add new concepts to their existing concepts. This process is defined as "assimilation". When individuals encounter a new concept, if their old knowledge is insufficient to make sense of it, reorganizing their existing concepts is defined as "accommodation" (Chambers & Andre, 1997). In other words, accommodation covers the process of changing the internal structure of unconventional knowledge in order for the knowledge to be compatible with external validity (Yang, 2010, p. 203). Posner et al. (1982) considered this accommodation process as "conceptual change" and foresaw some requirements for conceptual change to occur. These are the conditions for conceptual change are "*dissatisfaction,*" which includes students seeing that their existing concepts are inadequate in making sense of the events they encounter; "*intelligibility,*" which includes students not having difficulty in understanding the concepts they encounter and the comprehensibility of new concepts; "*plausibility,*" which includes new concepts being logical, reasonable and consistent; and "*fruitfulness,*" which includes the new concept providing the student with a different solution and a different perspective (Posner et al., 1982).

The model of conceptual change introduced to the literature by Posner et al. (1982) is based on the idea that dissatisfaction or conflict must exist for an individual to begin learning new scientific concepts. In the following years, different approaches to the requirements for conceptual change and the nature of conceptual change have come to the fore. One of these belongs to diSessa (2002, 2008), who states that the necessity of dissatisfaction as one of how conceptual change occurs is incompatible with the essential elements of constructivism. According to diSessa (2008), instead of creating dissatisfaction in students, the diversity of external sources should be shown to students so they can use them effectively. According to diSessa (1998), misconceptions are parts of a more considerable knowledge that enables individuals to produce ideas at a higher level. In this context, conceptual change involves the process of gradually adding new information to the information that already exists in the mind, which is quite productive.

An entirely different interpretation of the definition of misconception and the nature of the conceptual change process was brought to the science education literature by Chi and others (1993; 2002). Chi and Slotta (1993) based the misconceptions in students on the ontological nature of the entities that exist in the world and the nature of scientific concepts. According to Chi and Slotta (2002), if there is a mismatch between the ontological categorization of the concept in students' minds and the ontological category to which the concept belongs in scientific reality, this indicates the existence of misconception. In order to successfully eliminate these misconceptions that result from the incorrect categorization of concepts, the concept must be assigned to or shifted to the ontological category to which it belongs. This process is conceptual change. In the literature, studies have shown that shifting the concept to the category it should belong to, in other words, ontological category change, is a practical perspective for eliminating misconceptions in students, that is, for conceptual change (Chiu & Lin, 2005; Diyarbekir, 2020; Erdmann, 2001; Slotta & Chi, 2006; Sarı, 2014; Topalsan, 2015). The ontological categorization perspective, which offers simple comprehensibility regarding the definition of misconception and the conceptual change process, is strongly comprehensible (Chi & Roscoe,2002). The present study examines the conceptual change process from the ontological categorization perspective, presenting a distinct viewpoint within science education.

2.2 Ontology and Ontological Categories

Ontology covers the categorical structure of reality, that is, of existing things. Since the time of Aristotle, it has long been accepted that "things" have a categorical structure; the part open to discussion here is the structure of categories. In the categorical structure, "being" is the beginning and encompassing of everything; therefore, "being" is at the top of all concepts. The expression "concept" here represents, terminologically, an example of a category. For example, butterflies represent a concept in the category of animals. Concepts are divided into categories according to their ontological attributes, or they can be examples or members of a category (Chi & Hausmann, 2003). According to Chi et al. (1994), all entities worldwide are divided into three basic ontological categories. These are "matter (entities)," "process," and "mental states." These three major ontological categories can also be expressed as "trees." Each of these main trees contains different categories that are hierarchically linked to each other. For example, the "Matter" category can be divided into "Natural Kind" and "Artifacts"; the "Processes" category can be divided into "Procedure," "Event," and "Constraint-based

Interaction"; and the "Mental States" tree can be divided into different categories as "Emotional" and "Intentional." These categories can even be divided into other categories. The categories can change as long as the three main trees remain constant since the other categories may vary according to the relevant field (Chi, 1992). Figure 2.1. presents the three main ontological categories and their subcategories (Chi, 1992; Chi et al., 1994).

Each primary tree is entirely different from another in terms of ontological aspects. For example, a concept in the matter category is ontologically different from a concept in the process category. What makes the difference here is the concepts' different ontological attributes. The ontological attribute has a terminological meaning that differs from descriptive and characteristic features. In other words, the ontological attribute is a property that an entity has the potential to have, that is, a property that the entity is not obliged to have but has the potential to be (Sommers, 1971). For example, squirrels are not usually green; however, squirrels can be colored; in this case, squirrels have an ontological attribute (green), such as being colored (Chi & Hausmann, 2003). For example, a "water glass," a member of the artifact category, a subcategory of the substance category (see Figure 2.1.), must have a mouthpiece as a descriptive feature. It is usually made of glass but not necessarily glass (characteristic feature). However, it can be "broken" after a hard blow as a potential feature, and this feature is the ontological attribute of a water glass is “fragility.” Each main tree has specific ontological attributes (Chi, 1992; Chi et al., 1994). If an attribute of a category does not wholly cover the instances of another category, these two categories are considered ontologically different. However, distinctions can be between trees and in different branches of the same tree. For example, the concept of an elephant is a member of the category of animals, which is a subcategory of the matter tree and has the attribute of "being heavy." However, the concept of "elephant" cannot have the attribute of being "one hour long," which is the ontological attribute of the process tree. This example shows that each category of the tree is ontologically different. The example in different branches of the same tree, as indicated in Figure 2.1, shows that animals and plants are subcategories of the living category. Both categories are in the same tree, "matter." Both animals and plants have the potential to be colorful; however, both categories have their characteristics that do not cover each other. These characteristics represent two ontologically different categories (Chi & Hausmann, 2003).

In summary, ontology divides what we know into different categories in a conceptual context that is not easy to understand. The restrictions that occur depending on the unique ontological attributes determine the boundaries of each ontological category, causing the formation of different categories (Chi, 1992). Three main categories are expected to be understood in essence: *matter, processes, and mental states* (Chi et al., 1994). Although Chi (1992) considered the main categories stated in his source as *matter, events, and abstractions*, in his later studies, these concepts were expressed as stated in this study.

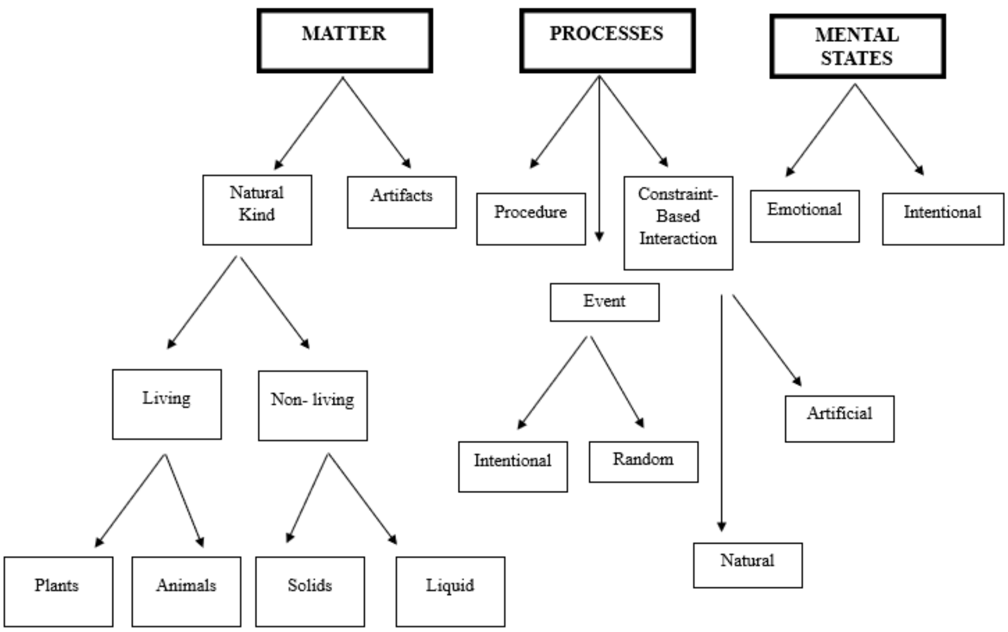

Figure 2. 1 A Possible Categorization Scheme and Subcategories of Entities in the World (Chi et al.,1994, p.29)

2.2.1 Matter Category

The concepts in the matter category, one of the fundamental ontological categories, have their ontological attributes, such as being colorful, being consumable, being able to move, having mass and volume, being able to be stored, and being able to be accumulated. These attributes distinguish them from the other main trees (process and stress-based instruction) (Chi, 1997). Since matter can be seen and touched, it contains concepts more easily understood by students (Johnston & Southerland, 2000). For example, plants, sand, and crayons are members of the matter category. As indicated in Figure 2.1, the matter category is divided into two subcategories. These are natural kinds (birds, roses, water ...etc.) and artifacts (dining tables, spoons...etc.). Although both are in the same main category, members of the natural kind category do not include artifact members. For example, we can say that the dining table broke, but the expression water broke does not make sense, and a category mistake occurs. The ontological attribute of "breaking" has separated both categories and in this context, it can be said that these categories are ontologically different (Chi & Hausmann, 2003).

Additionally, "macroscopic matter" and "microscopic particle," which are subcategories of the matter category, are two different lateral categories that need to be understood due to the nature of chemistry. The macroscopic category includes expressions that include observable, tangible, measurable, and sensory phenomena, while the microscopic category includes expressions on microparticles such as atoms, ions, and molecules (Johnstone, 2000).

2.2.2 Process Category

Concepts in the process category, one of the fundamental ontological categories, have qualitative features such as "occurring in a period" and "being able to result." Concepts in the processes category are "action moments"; in other words, they involve physical interaction and situations spread over a period of time. For example, writing, working, thinking, rain, strong wind, and cooking are concepts in this category. However, these concepts do not include a physical definition. For example, we can say that the car's color is pink; here, the car is in the matter category; however, "driving is pink" is an illogical explanation. Driving is a concept belonging to the process category and does not include a physical definition (Chi et al., 1994; Johnston & Southerland, 2000). The process category has three primary subcategories: “Procedure,” “Event,” and “Constraint-Based Instruction.”

The attributes of the basic concepts in the *event category* are that they have some ontological attributes for example, they have a beginning and an end, the subcomponents are based on a sequence, they may contain a purpose, and they may stop when the movement or action ends. For example, a volleyball match falls into the event category: it involves action, has a clear beginning and end, contains a purpose, and ends when the movement ends (Chi et al., 1994, p.448).

The ontological attributes of the concepts in the *constraint-based interaction* category are that they do not contain a cause, have a beginning or an end, can occur simultaneously everywhere, are in balance, are static or continuous, and do not include progress. For instance, concepts such as light, electric current, natural selection, force, and heat are in this category. Many concepts in the branches of physics and biology are in this category (Chi et al., 1994; Chi & Slatto, 1993, p. 253).

The ontological attributes of the concepts in the *procedure category* include concepts done in a certain order for a purpose. At the end of the process, a product is created, such as cooking (Chi et al., 1994; Chi & Slatto, 1993, p. 253).

2.2.3 Mental States Category

The ontological attributes of the concepts in the *mental state category*, which is one of the fundamental ontological categories, are related to abstract things such as dreams and imagination. They are divided into two categories: *emotional* and *intentional*. While concepts such as fear, happiness, and hatred are in the emotional category, desire and wish are in the intentional category (Chi & Slatto, 1993, p. 253).

2.3 The Interaction Among Ontological Categories "Lateral and Hierarchical Categories"

Concepts can be defined, understood, and taught in the context of the properties of the category to which they belong. This shows that a concept inherits the properties of its assigned category and can transfer some of its properties to other related concepts. At this point, the cause of misconceptions is not due to the "hierarchical relationship" but the "lateral relationship." In other words, misconceptions may arise from the lateral assignment of a concept to the wrong ontological category (Chi & Roscoe, 2002, pp. 13-14).

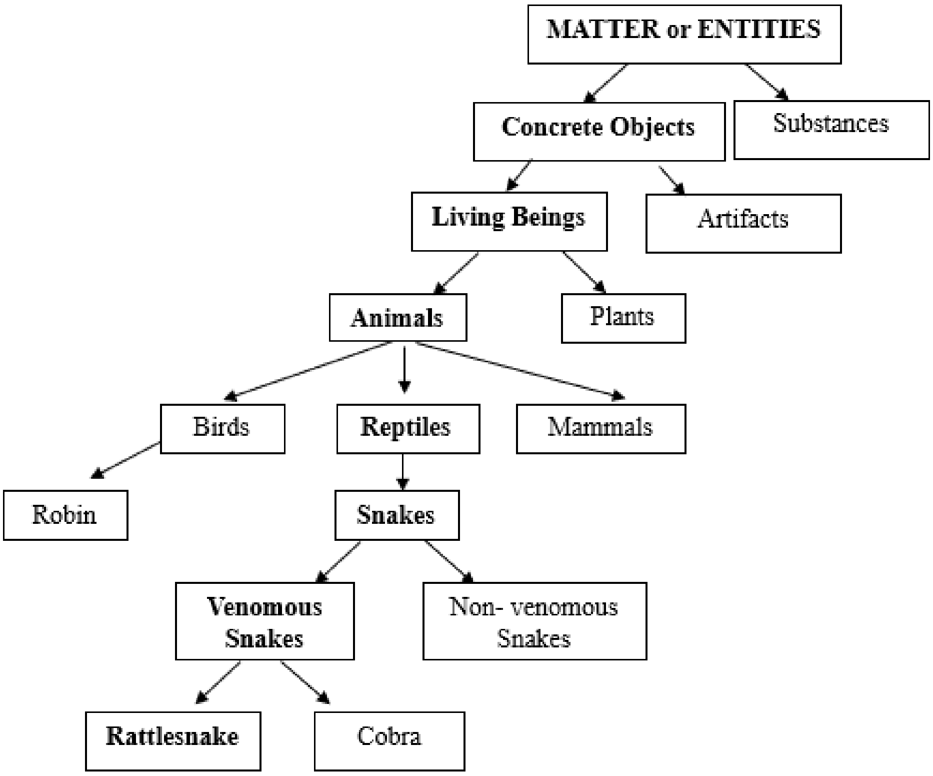

Figure 2. 2 Example of Hierarchical and Lateral Relationships within Tree Categories (Chi & Roscoe, 2002; Chi, 2008)

As shown in Figure 2.2, a rattlesnake is a member of the venomous snake category, which includes a concept such as cobra. A superordinate category of "rattlesnake" is "venomous snakes," a superordinate category of "venomous snakes" is "snakes," a superordinate category of the category "snakes" is "reptiles," then "animals" and then "concrete Object." Therefore, the categories "rattlesnake," "venomous snake," "snake," "reptiles," "animals," and "living beings" are *hierarchically* related; they are shown in **bold in Figure 2.2.** Assigning a concept to a hierarchically related category does not mean that it is assigned to the wrong ontological category; it neither leads to incorrect conceptual understanding nor hinders the learning process. Also, fundamental ontological categories such as matter and processes are lateral because none of their members and qualifications contain one another. In addition, lateral categories are called "*parallel*" categories if they are at almost the same level within the same tree. In Figure 2.2, "Living Beings" and "Artifacts" are laterally related and two separate branches at nearly the same level within the matter tree. In this case, they are parallel (Chi, 1997; Chi & Roscoe, 2002; Chi, 2008).

Apart from the hierarchical relationship, there is also a *lateral* connection between ontological concepts. In its most basic sense, lateral categories are categories that are not hierarchically related to each other. In other words, one of the two categories with a lateral connection between them is not the "parent" or "grandparent" of the other. However, some lateral categories are "*siblings*" because they share the same parent. For example, in Figure 2.2, cobra and rattlesnake are "sibling lateral categories" because they share the parent "poisonous snake." It is also possible for lateral categories to share a higher superordinate category or a standard "grandparent." These lateral categories are referred to as "*cousin lateral categories*." However, it should be noted that they do not share a parent category. To give an example from Figure 2.2, the members of the artifacts category, which includes the concepts table, chair, etc., and snakes, which are members of the natural kind, are cousins. They are only associated with a common category at a higher superordinate level, such as concrete objects (Chi, 1997; Chi & Roscoe, 2002).

2.3.1 The Importance Role of Categorization in Learning

Categorization is the definition or assignment of a concept to the category it should belong to, and its effect on the individual's conceptual understanding is relatively high (Bransford et al., 1999). First, the individual's ability to categorize a concept correctly enables them to put forward correct ideas on new concepts from which they will make inferences. For example, as shown in Figure 2.2, as long as it is known that a robin is a bird and that birds are creatures that can lay eggs, it is pretty easy to make the following inference: Robins reproduce by laying eggs. This inference is a result of a category member inheriting some characteristics from other category members with whom it is in a hierarchical relationship (Gobbo & Chi, 1986; Chi, 2008, pp. 62-65). Secondly, if the student has a deficiency in category knowledge regarding the new concept they have learned, they assign the new concept to the superordinate category that they deem most appropriate. As long as they have mastered the characteristics of the category they will assign, they will make a correct assumption regarding the new concept; however, if the category that the student will assign to their mind is wrong, they will place the new concept in their mind with wrong assumptions (Chi, 2008, pp. 62-65). In short, knowing a category's ontological attributes well and correctly placing the category members are essential for accurately attributing meaning to a concept. If students miscategorize a concept, it can subsequently lead to misunderstandings of all related concepts they learn (Johnston & Southerland, 2000).

2.4 Conceptual Change Based on Ontology

The practical learning of concepts in science courses depends on three preconditions. First, it is a situation where the student has no prior knowledge about the new concept they will learn. In this case, the student's understanding is incomplete, and learning occurs when new information is added to the student's mind. Second, it is a situation where the student has some information about the new concept they will learn, even if it is insufficient. In this case, learning occurs when the student fills the gap in their conceptual knowledge (Carey, 1991). Finally, it is a situation where the student has information that does not entirely overlap or contradict the concept they will learn (Vosniadou, 2004). In this case, learning includes *conceptual change*. In this case, learning is not about completing the missing information or transferring the new information to the student; it is about preventing the conflict with the correct information to be learned by changing the existing incorrect prior knowledge (Chi, 2008).

According to Chi (1992), the term “*conceptual change*” is misleading because it refers to either the outcome of a change or the processes that bring about such changes. In its simplest form, "*conceptual change*," "*conceptual change within* *ontological category or tree*," is defined as a concept gaining more attributes and being *reassigned* to its appropriate category, not hierarchically but laterally. In this reassignment, some features of the concept become more apparent. In this type of conceptual change, changes occur in the tree's nodes, and the tree is rearranged.

Radical conceptual change refers to the result of a change in which the original assignment of a concept to a category is shifted to a *new assignment*. In cases of radical conceptual change, the entire tree may be different. In Figure 2.3, conceptual change and non-radical conceptual change are represented on sample ontological trees (Chi, 1992).

The common definition of *conceptual* and *radical conceptual change* is the shifting or assignment of a concept to the category to which it should belong. However, there is no apparent reason as to whether a conceptual change in the ontological tree is a lesser degree than radical conceptual change (Chi et al., 1994). Furthermore, Henderson et al. (2018) defined the terminology of the ontology-based approach to misconceptions as "*Ontological Shift or Reassignment Theory of Conceptual Change*."

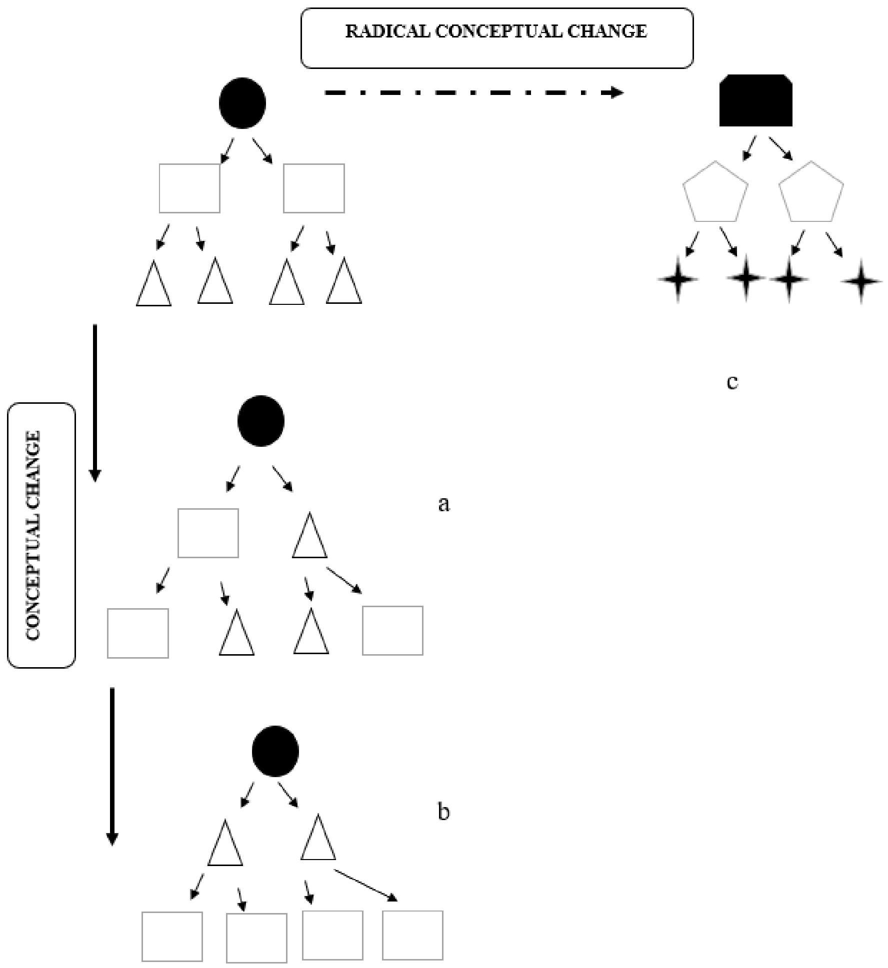

Figure 2. 3 Schematic Representation Example of the Radical Conceptual Change and Conceptual Change (Chi, 1992, p.135)

In the a and b tree diagrams shown in Figure 2.3, while the basic meanings of the concepts do not change, they have acquired some specific features, and the concept has been reassigned to another category in the tree. In the c diagram, the tree has evolved with the complete change of the concept's meaning. For example, while the concept was initially in a diagram, it has been newly assigned to the c diagram due to conceptual change. The point to be noted here is a gradual change in the a and b diagrams in Figure 2.3. However, conceptual change can be gradual or sudden (Chi, 1992, pp.134-135).

According to Chi (2008), achieving successful conceptual change in individuals depends on awareness, which means that during the conceptual change process, students do not realize that they need to shift the assignment of the science concept to a different category. For a successful conceptual change in individuals or the start of conceptual change, it is necessary to make them aware of the area in which they have misconceptions. However, this is not easy because, in our daily lives, assigning concepts between categories is not preferred. Individuals tend to rely on the category in which they initially learned it (Keil, 1989). For example, a child who sees a whale in the ocean is likely to think it is a fish due to its perceptual features (fins, swimming in water, etc.). This incorrect categorization causes the child to think and believe that the whale will breathe with gills, similar to other fish, through osmosis (ontological attribute). At this point, for the conceptual change to occur, making the child aware of the existence of blowholes on whales will cause a refutation at the level of the person's belief. Although it does not provide a straightforward solution for conceptual change, it improves the process. The most apparent solution is to directly present them with the correct category of information, like telling them that whales are not fish (Chi, 2008).

The other factor in successful conceptual change is constructing a new lateral concept; the fact that individuals do not have a new category for conceptual change also makes the process difficult. This is more valid for radical conceptual change (Chi, 2008). For example, students believe that "electric current" is fluid like water and can be stored in a battery like the storable feature of water. The fact that the ontological attributes of storability, fluidity, and exhaustion are loaded to electric current shows that they assign "electric current" to the liquids category from the subcategories of matter. The assignment of "electric current" to the matter category, which should be in the process category, indicates the existence of a misconception (Chi & Roscoe, 2002). The student should be taught the process category's ontological attributes for a conceptual change between trees. In short, fostering students' awareness requires an effective instructional method to initiate conceptual change. Argumentation-based environments are particularly effective, where students discuss and reveal their knowledge in a social setting. This approach enables students to understand concepts more deeply (Andriessen et al., 2003, p. 83) and serves as a suitable method for achieving successful conceptual change.

At this point, argumentation-based environments, where students discuss and reveal their knowledge in a social environment, are particularly effective. Thus, an in-depth understanding of the concept is gained (Andriessen et al., 2003, p. 83), which serves as a suitable instructional method for successful conceptual change.

2.4.1 Studies in Science on Ontological Shift Theory of Misconception

Ferrari and Chi (1998) analyzed the concept and understanding of natural selection in terms of ontological categories. They tested their hypothesis that students were successful in understanding Darwinian principles but unsuccessful in understanding the ontological attributes of the concept of natural selection. Researchers have stated that natural selection should be placed in the "Equilibration" (later called the Constraint-Based Category) category due to qualities such as being uniform, continuous, simultaneous, containing a certain degree of randomness, that is, not creating random and causal sub-events, and not containing an end. The qualitative study sample consisted of 40 university students who had not taken an evolution course before. The study's data were collected using a scale developed on five predictions-explanations related to Darwinian principles, developed by Mayr (1982) and Larreamendy-Joerns (1996). The content of the test directed to the participants was about intraspecific variability, heredity, different survival rates, different reproduction rates, and accumulation of changes during generations. The codes of the obtained qualitative data were determined as Darwinism-Neo-Darwinism -Event Category- Equilibration Category. The study results revealed that the participants primarily assigned natural selection to the event category (only 8.3% of the participants assigned it to the ontological category of equilibration) and did not understand Darwinian principles, especially the equilibrium feature.

In a similar vein, McLure, Won, and Treagust (2020) studied the effectiveness of the *TFA* lesson plans they designed on students' ontological conceptual changes on natural selection. *TFA* lesson plans consisted of 4 stages: the "*Visualization stage*," where students' misconceptions (the researchers used alternative conceptual terminology) and ontological models were identified; the "*Thinking stage,"* where students put forward their thoughts on natural selection; the "*Paragraph creation stage"* where students noted their comments in line with their ideas on an event related to natural selection, and finally, the "*Evaluation*" process, that is, students shared and discussed their inferences on the subject with their classmates in line with their prior knowledge, the teacher encouraged the students to question their mistakes based on their existing ontological model, and the students evaluated their paragraphs. The study sample consisted of 59 10th-grade students. The design of the research is a quasi-experimental design with a pre-test-post-test group. The quantitative data of the study were obtained from the "*Concept Inventory of Natural Selection Concept Test"* (Anderson et al., 2002), which includes 20 multiple-choice questions, and the qualitative data were obtained from the "*Open Response Instrument*." The qualitative data and test results showed that *TFA* lesson plans positively affected students' conceptual changes regarding the subject and that many ontological model categories were adopted. In other words, it was concluded that small group discussions and teacher feedback improved students' conceptual understanding of natural selection and caused them to evaluate it in the correct ontological category, equilibration rather than event.

Furthermore, Tsui and Treagust (2004) conducted a case study examining 10th-grade students' conceptual understanding of genetics from an ontological perspective. The study involved 33 students from a public high school. Qualitative data on the students' ontological categories were collected through online open-ended questions, with 23 students participating in this phase. The students engaged with the topic using the BioLogica software model, a hypermodel designed to teach basic genetic concepts through graphs, objects, and text. BioLogica adapts to the student's flow in the activity by switching from one view to another in response to the student's actions. In addition, this software model presents the graph and its explanation on a screen and then directs the students to multiple-choice questions to test their conceptual understanding. Before the study, the participants gained experience by completing three practice sessions. Students were asked questions like, "*What do you know about genes?* (Pre-Study), "*What do you know about genes?* "*How did your knowledge change after the study? (Post-Study),"* and the qualitative data were coded and analyzed. The findings of the analysis were as follows. The most notable conceptual change observed among students was a shift from viewing a gene as "an active particle" to "an inactive particle." However, this conceptual change is non-radical; it occurred within different branches of the "*Matter*" ontological category. Only a limited number of students demonstrated a radical conceptual change, shifting the concept of a gene from the "*Matter*" category to the "*Process category*." These students mentioned that the *gene interacts with the cell* and *the gene has the feature of carrying information*. In summary, the research indicated that the students' ontological conceptual changes regarding genes were generally non-radical. Therefore, BioLogica software did not promote radical conceptual change about genes in 10th-grade students.

On another topic, Sanmarti, Izquierdo, and Watson (1995) investigated students' understanding of some chemistry concepts based on ontology. The study sample consisted of 54 8th-grade students (13-14 years old) studying in two public schools. The study data were obtained from a test of five questions, two of which were multiple choice and three were open-ended. The questions were about defining elements, compounds, mixtures, and solutions. It was designed to determine how the participants could distinguish the specified concepts. The questions in the data collection tool include: *What is a mixture? Why? How do you define a compound? Why? What is the reason for the taste in water and milk when sugar is added? What happens to sugar when we mix it with water and milk? Why?* Data were collected after the sample group had completed their primary chemistry education. After the qualitative analysis of the data, it was determined that the students in the 13-year-old group could not correctly categorize the concepts of element, compound, mixture, solution, and melting.

In a different study on chemistry topics, Özalp (2008) conducted a study to determine the reasons for the misconceptions of primary and secondary school students about the particulate nature of matter on an ontology basis. The study sample consisted of 696 students from the 6th and 11th grades selected randomly (382 students from the 6th, 7th, and 8th grades and 314 students from the 9th, 10th, and 11th grades). The quantitative data were obtained from a concept test consisting of 25 questions, 15 of which were two-tier and 10 of which were multiple choice, and lasted 4 weeks. A pilot study of the concept test was carried out, and after the item analysis, Cronbach's Alpha value for the test was found to be 0.78. The content-reason response combinations given by the students to the test stages of the answers were examined. The students' misconceptions were determined by their reasons; then, the ontological category reasons were investigated. In the significant findings of the study, the misconceptions detected are generally due to the lateral incorrect placement of the categories of "*macroscopic matter-microscopic particle,*" "*chemical event-physical event,*" "*melting-dissolution,*" "*living beings-nonliving beings*." The most common misconception detected in the study is the belief that "the physical state of matter would determine the physical state of particles," with 38.6%. In other words, most misconceptions are due to incorrect placement in the sub-branches of the matter category. Another critical emphasis obtained is that while the percentage of correct content answers of 6th, 7th, and 8th-grade students was 30% on average, the percentage of correct content responses was 10%. These rates were 50% and 30% for 9th, 10th, and 11th grades. The research results showed that students hold misconceptions based on the "matter category" regarding the particulate nature of matter. They have difficulty in achieving meaningful learning and remain at a superficial level of understanding.

Furthermore, Sarı (2014) conducted a study on the effectiveness of computer-aided and concept map-supported teaching in determining the ontological reasons for 7th-grade students' misconceptions on the subject of "structure and properties of matter" and in eliminating misconceptions originating from which type of incorrect categorization. The sample consisted of 55 7th-grade students studying in three different classes in a private school. The research design was a pre-test-post-test control group quasi-experimental design. The data collection tool was a two-tiered diagnostic test prepared by the researcher within the scope of the 2008 Science Curriculum and consisting of 20 questions. The test was piloted and rearranged after expert recommendations. After the item analysis of the final version of the test, the Cronbach alpha value was found to be 0.81. In the experimental group, I received computer-supported instruction, including animations, virtual experiments, digital stories, and presentations focused on the subjects of microscopic matter, microscopic particles, elements, compounds, mixtures, dissolutions, and chemical bonds. Experimental group II learned the same topics with instruction supported by concept maps, while the control group students received curriculum-based instruction, engaging with the lessons through a question-answer format. The misconceptions identified in the study are often due to incorrect assignment to the categories of "physical and chemical event," "melting-dissolution," "macroscopic matter-microscopic particle," "atom-molecule-ion," “living-nonliving,” and “ionic bond-covalent bond." The research findings indicated that ontological reasons for misconceptions related to the subject of matter are due to placing the concept in the lateral category or superordinate category (non-hierarchical). The most effective instruction in eliminating these misconceptions caused by incorrect placement in the lateral category was computer-supported instruction, followed by instruction supported by concept maps and finally, curriculum-based instruction. The most successful instruction in eliminating misconceptions caused by incorrect placement in the superordinate category was computer-supported instruction, followed by curriculum-based instruction, and finally, instruction supported by concept maps. A notable finding of the study is that curriculum-based instruction is more effective than instruction supported by concept maps in eliminating misconceptions arising from incorrect placement in the superordinate category.

In another alternative study, Şen and Yılmaz (2012) examined university students' misconceptions about melting and dissolution on an ontological basis. The study sample consisted of 25 university students in the biology department taking basic chemistry courses. The qualitative data were obtained from 5 open-ended questions prepared by the researchers. The results of the study emphasized that the ontological reasons for university students' misconceptions about melting and dissolution were concentrated among the categories of "*physical and chemical event*," "*melting-dissolution*," "*macroscopic matter-microscopic particle*," and "*atom-molecule-ion*," which is a subcategory of the microscopic particle category.

Similarly, Somon (2000) studied the ontological classification of concepts at educational levels. The sample comprised 24 first- and second-year university students, graduates, and professors. Questions about basic chemistry concepts were directed to the participants, and the ontological categories to which they assigned the concepts were determined. The questions posed to participants included basic chemistry concepts such as water, evaporation, chemical equilibrium, chemical reaction, mole concept, chemical bonds, kilogram, titration, and electron exchange. After the interviews conducted at the end of the research, most of the participants assigned the concepts of water, mole, and electron to the matter category, reasoning that these concepts have mass and volume. Most participants assigned chemical reaction and titration concepts to the process category. However, it was determined that some of the first- and second-year university students assigned the concept of chemical bonds, which should be in the constraint-based category, which is one of the subcategories of the process category, to the matter or mental states category. As a result of the study, the researcher emphasized the importance of educators' instruction based on ontology to develop better conceptual understanding among educators and learners.

In another study, Lee and Law (2001) aimed to determine the ontological reasons for students' misconceptions about electrical circuits and to reveal the role of Chi et al.'s (1994) conceptual change theory in developing an effective teaching strategy. The study sample consisted of a total of 6 secondary school students (17 years of age) with high (two people), medium (two people), and low (two people) academic achievement levels in science courses. The qualitative data were obtained from oral interviews and written test questions. Written test questions were applied to the same sample group before and after the instruction. In the first part of the study, data collection tools were applied to the participants as a pre-test. The findings determined that the students had various misconceptions. It was determined that the general ontological reason for the obtained misconceptions was the assignment of concepts related to electricity, which should be in the process (constraint-based instruction) category, to the substance category. For example, most students defined current as a substance that can be consumed and flows. In the second part of the study, a POE (Predict-Observe-Explain) instruction was implemented for the participants. The instructional design focused on the ontological categories associated with students' misconceptions, aiming to raise their awareness of these categories. In the third part of the study, the same data collection tools were presented to the same sample group. After the qualitative data analysis, an improvement was recorded in the test performance of all participants. The research concluded that the instruction method designed by considering ontological categories raised students' awareness and improved their conceptual understanding. Another finding obtained from the study was that teachers often had difficulty distinguishing between matter and process categories. For example, the science teacher frequently used expressions such as "the current comes out of the battery and goes" and "the total current wants to go to the intersection."

Diyarbekir (2020) conducted a similar study, examining the reasons for the misconceptions of 7th-grade students about force and motion based on ontology and evaluating the effectiveness of animation-supported instruction in eliminating these misconceptions from an ontological perspective. The sample consisted of 7th graders (52 students) studying in a public school. The study design is a semi-experimental model with a pre-test and post-test control group. The qualitative data were obtained from the "Force and Motion Subject Concept Test," a two-tier diagnostic test with 25 questions prepared by the researcher. A pilot study of the test was carried out, and the KR-20 value was determined to be 0.81 after item analysis. The study was designed on the concepts of force, friction force, work, conservation of energy, kinetic energy, potential energy, mechanical energy, and energy stored in springs and lasted six weeks. While the students in the experimental group learned the relevant concepts with activities developed with animations, the students in the control group received curriculum-based instruction. The qualitative data analysis of the study showed that the participant groups frequently had misconceptions resulting from incorrect placement of the "artifacts-natural kind" subcategories of the substance category and the "event-procedure-constraint based interaction" subcategories of the process category in the lateral and superordinate categories (not in a hierarchical relationship). It was concluded that animation-supported instruction was more effective in eliminating misconceptions resulting from incorrect assignments to the lateral and superordinate categories after the instruction. This instruction also developed the students' conceptual understanding.

In addition, Slotta and Chi (2006) investigated the effect of a training module (simulation) structured on ontological categories in assigning concepts related to electrical units (current, lamp brightness, etc.) to the processes category. The sample consisted of a total of 24 university students who did not have any electrical knowledge at the undergraduate level. The design of the study is a pre-test, post-test control group quasi-experimental design. In the control and experimental groups, where the participants were randomly formed into groups of 12, the electrical unit was conveyed to the students in the control group within the scope of traditional instruction by using physics texts on electricity. In contrast, the lessons in the experimental group were processed using a simulation model specially designed by the researchers and containing clues that would allow the electrical concepts to be evaluated in the process category. Quantitative and qualitative data were obtained through a written exam consisting of 8 questions, including four options and one explanation section related to the electrical circuit, which was applied to the participants as a pre-test and post-test. After the analysis of the quantitative data, no significant difference was found between the pre-test scores of the groups; however, a significant difference was found in favor of the experimental group students who received an education with the simulation module on the constraint-based interaction category after the study. The qualitative data was collected by coding the reasons for the participants' answers. The researchers coded the attributes of providing, being consumed, stopping, being absorbed, moving, and having quantity as "matter predicates"; the attributes of the moving process, not being dependent, uniformity, not being able to be broken down into subcomponents, balance, and synchronicity as "process predicates." After the study, it was determined that the participants in the experimental group used process predicates more in explaining the topics related to electricity, while the participants in the control group used matter predicates more. The result of the study was that education based on ontology in teaching electricity-related concepts facilitates the learning of concepts. Researchers have also emphasized that instruction designed on ontological categories can positively affect conceptual change.

Additionally, Topalsan (2015) conducted a study to determine the ontological reasons for classroom teachers' misconceptions about force and motion and the effect of argumentation teaching on conceptual understanding. The research design is a quasi-experimental model with a pre-test-post-test control group. The study sample consisted of 70 classroom teacher candidates, distributed into two equal groups based on certain equivalences (gender, academic achievement, etc.). The quantitative data were obtained through the "Force and Motion Concept Test," a two-tier diagnostic test consisting of 17 questions and prepared by the researcher with a KR-20 value of 0.73. In the experimental group, concepts of force and motion were taught through activities designed using frameworks that fostered an in-class argumentation environment, as suggested by Osborne et al. (2004b). In the control group, the subjects were taught based on curriculum-based instruction. The control group also completed activities from the 7th-grade science textbook. After analyzing the quantitative data, it was determined that the misconceptions of the groups regarding the subject of force and motion were mostly in the subcategories of the process category. It was determined that argumentation instruction was more effective than curriculum-based instruction in eliminating the misconceptions caused by assigning the concepts to incorrect lateral and superordinate (not in a hierarchical relationship) categories. This instruction also positively impacted the students' conceptual understanding.

In another study, Slotta, Chi, and Joram (1995) conducted a study on what ontological category-level experts and students in physics address fundamental physics concepts related to light, heat, and electricity. The sample of the study consisted of 13 people in total: nine students who do not have expertise in physics education (novice protocol), two experts who have completed their master's degree in physics education, and two experts who have completed their undergraduate education in physics education (expert protocol). The qualitative and quantitative data of the study were obtained from a total of 36 problems, including multiple choice and one open-ended option, related to the subjects of heat, light, and electricity. The quantitative analysis of the data revealed that experts and students selected more correct answers on tests involving concepts within the matter category. The coding and analysis of the qualitative data revealed that experts could explain the specified physics problems using the attributes of the "process" category, while they could answer material matter problems using the attributes of the "matter" category. Students answered almost all the issues using expressions, including "matter" category attributes. For example, novices stated that heat is lost more quickly from a styrofoam cup than from a ceramic cup because it is a substance that can flow through the gaps in the styrofoam. They expressed heat with attributes of the matter category instead of the process category (fluidity). On the other hand, experts explained the transfer of heat in the styrofoam cup and the ceramic cup based on the difference between the glass temperature and the liquid temperature. The study results showed that those who received specialized training in their field had higher skills in explaining concepts at the level of the category they belonged to.

2.5 Argumentation

According to Toulmin (1976, p. 220; Toulmin et al., 1984, pp. 127-128), argumentation is a dynamic process encompassing the entire interaction process between individuals in which claims are put forward and expressed. These claims are substantiated using data, warranted, supported with backings, or criticized using rebuttals. In other words, while argument corresponds to the definitions of data, warrant, claim, and backing, argumentation covers a process in which these components are collected and evaluated (Simon et al., 2003). Also, Van Eemeren et al. (1996) define argumentation as a social and verbal activity in which the acceptability of a controversial statement is increased or decreased.

The features that draw the general argumentation framework are as follows: It is a process of reaching a consensus in which the claimant conveys someone's ideas and thoughts to the other party, although reaching a consensus is not mandatory. Argumentation is a linguistic and verbal activity. In addition, the interest in and necessity for argumentation increases when there are differing or opposing discourses on a specific subject (Van Eemeren et al., 1996).

In the relevant literature, based on the works of Aristotle, there are three accepted argument forms: analytical, rhetorical, and dialectical arguments (Van Eemeren et al., 1996). While "*Analytical Arguments*" based on logic theory conclude inductive and deductive processes, "*Dialectical Arguments*" include the conclusion of unaccepted assumptions with correct evidence. "Rhetorical Arguments" are verbal discussions to convince the other party or the listener. Since the main goal in this argument form is to convince the other party by presenting evidence, the argument forms in classes where curriculum-based instruction is based are mostly rhetorical (Jiménez-Aleixandre et al., 2000). There is no mutual communication in “Rhetorical Arguments,” and the other party's thoughts are generally not considered. The only goal is to get the other party's acceptance of the claim. An example of this in science classes is when a teacher uses one-sided persuasion while explaining a scientific explanation to students. On the other hand, dialectical arguments involve a mutual discussion of the acceptability of the claims (Driver, Newton, & Osborne, 2000). In science teaching, the way to ensure an effective argumentation process is the presence of dialectical arguments in classroom argumentation (Ritchie & Tobin, 2001).

In short, argumentation is a social, rational, and verbal activity where one party seeks to convince another of the acceptability of a viewpoint through justified or refuted statements (Van Eemeren & Grootendorst, 2004). The literature presents various argumentation patterns that define this process's standards and essential elements, one of which is the *Toulmin Argumentation Pattern*.

2.5.1 Toulmin Argumentation Pattern

According to Toulmin (2003a), there are common elements that arguments used in different fields (scientific, law, politics, medicine, etc.) share formally. From Toulmin's perspective, a qualified argument consists of a claim, data supporting the claim, warrants providing the connection between the data and the argument, supporting evidence that strengthens the truth of the warrants, and rebuttals showing that the claim is not valid (Simon, 2008). The relationship between them is presented in Figure 2.4.

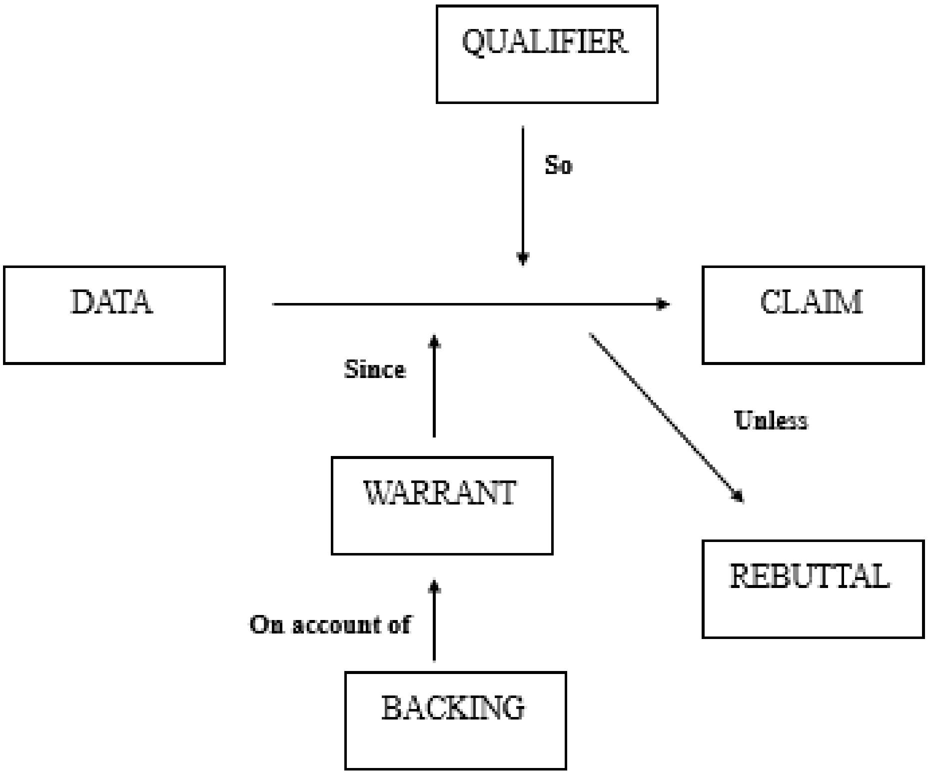

Figure 2. 4 Schematic Representation of Toulmin Argumentation Pattern (1958)

The elements of the argument are defined as follows;

Claim: In the argumentation process, the statement that the person defends and supports (Driver et al., 2020). In other words, the claim is the starting point of the argumentation discussed, rejected, or opposed. The claim is the basis of the argumentation, and the argument's beginning depends on the existence of this statement. Question patterns such as *"What are these people discussing?", "What do you think is intended to be explained in this text?" "What do you think about …?"* facilitates the finding or creation of the claim (Toulmin et al., 1984, pp. 25 – 26).

Data: Data constitute the basis and foundation of claims. Data are information, examples, observational statements, individual testimonies (persons' statements, opinions, or thoughts), statistical data, factual information, and facts used to support the claim. Question patterns such as *"Why do you make such a claim?", "What is the* *basis of the claim?" "What makes you think so about ...?"* is aimed at finding the presence of data in the argument (Toulmin et al., 1984, pp. 41-44).

Warrant: Warrants explain how the data supports the claim made. In other words, the warrant explains the relationship between the data and the claim. They are supported by statements legitimized by state laws, scientifically proven information, findings based on observation and experiment, scientific research results, and statistical reports; also, they are inferences derived from basic assumptions (Toulmin, 2003a, pp. 110-112).

Backing: These are basic assumptions that increase the acceptability of warrants in the argumentation process if they are not found reliable enough or are approached with doubt. *"You stated your warrant as ... Why do you think this way?" "On what basis do you say such a thing?"* question expressions indicate the existence of backing in argumentation. (Toulmin et al., 1984, pp. 62-65).

Qualifier: The degree of strength the warrant provides to the claim based on data such as definitely, usually, and necessarily (Toulmin, 2003a, pp. 93-94).

Rebuttal: It expresses a situation where the claim is invalid or statements that limit its validity (Toulmin, 2003a, p. 97).

According to Toulmin (2003a), claim, data, and warrant constitute the simplest form of an argument. As the content area of the argumentation changes, the need for other elements may also change. An example of the holistic form of the argument can be given as follows;

Claim: Harry is British.

Data: Harry was born in Bermuda.

Warrant: Individuals born in Bermuda are generally British by nationality.

Qualifier: Therefore, it is likely that.

Backing: As stated in the British constitution...

Rebuttal: His parents may be citizens of another country, or his parents may be Bermuda immigrants.

Argumentation offers students various contributions, such as thinking like a scientist, having a critical perspective, developing reasoning skills, and producing creative ideas (Van Eemeren et al., 2015). Especially in the argumentation process, situations where students develop ideas on various claims, criticize, defend, or try to refute them cause them to gain awareness about obtaining scientific knowledge (Krummheuer, 2015). This situation makes it easier for students to understand the concepts by making them think more about scientific concepts (McDonald & Kelly, 2012). In addition, argumentation causes students to increase and expand their existing knowledge (Von Aufschnaiter, Erduran, & Osborn, 2004). In this process, students encounter some ideas that accelerate the process of conceptual change and review the accuracy of their prior knowledge (Cross et al., 2008). Within the scope of the stated usefulness, the role of argumentation in science education is quite large, and it is crucial to integrate it into science classes to improve students' conceptual understanding (Jiménez-Aleixandre & Erduran, 2007) and also support the process of conceptual change (Nussbaum & Sinatra, 2003).

Osborne et al. (2004a) presented some frameworks facilitating its integration into science classes.

2.5.2 Argumentation Frameworks for Science Class

Osborne et al. (2004a) have presented some general frameworks that encourage and facilitate the initiation of the argumentation process in science classrooms. These frameworks are introduced below.

Table of Statements: Students are presented with a table containing different expressions related to the topic. Their thoughts and choices regarding the expression are discussed in class.

Creating a Concept Map: A concept map consisting of students' misconceptions about a scientifically accepted topic is prepared. Students are asked to discuss the connections in the concept map individually or in groups.

Experiment Report Developed by Students: Students are presented with a report of an experiment previously prepared by other students. Attention is paid to whether the experiment report is incomplete or incorrect, and students are expected to discuss these areas and explain the possible experiment results.

Competing Theories with Concept Cartoons: Students are presented with two or more opposing theories through concept cartoons. Students are asked to discuss with their friends which cartoon they support, with evidence.

Theories Conflicting with Stories: Students are presented with texts containing opposing theories through sources that may attract their attention, such as newspapers and television. Students are asked to discuss with their friends' which text they support, with evidence.

Competing Theories with Ideas and Evidence: Students are presented with two opposing theories about the introduced topic. Then, students are given a series of evidence that supports one, all, or none of the theories. Students are asked to evaluate the role of each piece of evidence in the subject by conducting group discussions.

Constructing an Argument: Students are presented with statements explaining a scientific phenomenon. Students are asked to evaluate and discuss the statement that best explains the phenomenon and then construct an argument about its cause.

Predict—Observe—Explain: Students' preconceptions are reached before the relevant phenomenon is introduced. The phenomenon is introduced, and students are asked to take notes of their observations at this stage. Then, the phenomenon is introduced, and students are asked to explain the changes in their preconceptions. Students are expected to explain the changes in their preconceptions.

Designing an Experiment: Students are asked to design an experiment in groups to test a hypothesis. They are expected to explain each step of the experiment in detail.

Then, groups begin a class discussion to see, evaluate, and criticize other groups' alternative experimental designs.

2.6 Studies on the Effects of Argumentation on Conceptual Understanding of Science Concepts

Hand et al. (2004) studied the effects of supplementing 7th-grade students' biology laboratory courses with the Science Writing Heuristic (SWH) on students' achievement in the subject. This study used the SWH approach, which is an Argument-Based Inquiry (ABI) approach that integrates argument construction into inquiry activities, fostering metacognitive development to help students construct meaning (Hand et al., 2021). The participants in the quantitative part of the study were 93 7th-grade students. The students were randomly assigned to 5 classes taught by the same teacher. The students attended a biology course for 8 weeks, 45 minutes, 5 times a week. Three groups were considered to assess students' conceptual understanding in the quasi-experimental design study: Control Group (CG), Science Writing Heuristic Group (SG), and Science Writing Heuristic and textbook Group (STG). Students in SG and STG used SWH for their lab reports instead of the traditional lab format. Both groups participated in the within-group and between-group argumentation process on the cell topic and structured their questions for the lab activities. Students in CG started the lab activities with the question given to them by the teacher. The content of the questions determined by SG and SGT after the discussions were; "*What is the function of the cell membrane? What constitutes the structure of the cell membrane? What is the relationship between organelles, systems, and the cell?"* SG and STG determined how they would solve the questions they determined through intra-group and inter-group discussions. The discussions were about what data and warrants they could put forward for their claims (their solutions to the problem constituted their claims). After completing the lab activities, students in CG and SG groups were asked to report what they had learned during the process. STG was asked to select a section from the textbook on the cell unit and present a report in the form of a textbook explanation for their peers. In short, after the activities, CG and SG presented their reports on what they had learned; STG prepared a report in the textbook format. The pre-test data of the study were obtained from the concept test consisting of 34 multiple-choice questions focused on topics related to the cell unit, such as DNA, cells, and cell theory. In comparison, the post-test data were obtained from the concept test consisting of 37 questions (3 questions added to the 34-question pre-concept test). The Cronbach alpha value of the pre-test was 0.61, while the post-test was 0.89. The statistical analysis results of the quantitative data showed that STG, which participated in both the SWH and preparing reports in textbook format, and SG, which participated in both the SWH and preparing reports in a laboratory format, were significantly more successful than the other groups in conceptual questions. However, no significant difference was found between SG and STG in conceptual understanding.

The other study, Yeşildağ-Hasançebi and Günel (2013) conducted a study on the effect of an argumentation-based inquiry approach on the achievement of 8th-grade students in the unit "*Structure and Properties of Matter.*" The study is a pretest-posttest quasi-experimental design. The study sample consists of 53 8th-grade students, 29 in the experimental group and 24 in the control group. The lessons related to the relevant unit were taught with question-answer, direct lectures, and experiments conducted by the teacher in the control group. In the experimental group, the students were divided into groups of 3-4. The students taught the lessons with activities compatible with the Argument-Based Inquiry (ABI) approach and provided an environment for in-class argumentation. The activities covered subject areas including atoms, acids and bases, chemical reactions, and classification of elements. During the ABI activities, the students in the experimental group carried out experimental design, group work, observation, and discussions. Group debates were initially conducted within small groups and then turned into whole-class discussions. The qualitative and quantitative data of the study were obtained from the "*Science Achievement Test*" consisting of 13 questions, 9 of which were multiple choice and 4 were open-ended. The Cronbach alpha of the test was 0.60. The study results showed that the ABI approach, which creates an in-class argumentation environment, significantly enhanced the achievement of 8th-grade students in understanding the structure and properties of matter.

Similarly, Şen (2021) conducted a study on the effect of the ABI approach on the content knowledge of 6th-grade students using a one-group pre-test-post-test research design. The study involved 71 students across four classes, all taught by the same teacher. Conducted over six weeks, the "Matter and Heat" unit was covered in the first four weeks, followed by the "Electricity" unit in the remaining two weeks. Quantitative data were collected using the "*Matter and Heat Test*" and the "*Electricity Test*," each comprising 20 multiple-choice questions developed by the researcher. The tests were applied to the participant groups before and after the instruction. The steps followed in the ABI approach were as follows: preparation of research questions and experimental design related to the unit, class discussions on the researchability of the research questions, testing the research questions with designed experiments, using the experimental results in creating individual arguments, discussing individual arguments within the group, creating the group argument and finally presenting the arguments of the groups. The quantitative data analysis results of the research showed a significant increase in the students' content knowledge related to the "*Matter and Heat"* and "*Electricity*" units after the instruction.

Furthermore, Deprem, Çakıroğlu, Öztekin, and Kıngır (2023) conducted a study on the effects of argument-based inquiry (ABI) instruction on students' achievement in science content. The study sample consisted of 60 8th-grade students, 31 in the treatment group and 29 in the comparison group. The study was a quasi-experimental, two-group, treatment-comparison design, and classes were randomly assigned to groups. The study lasted 13 weeks, and the same four science units were presented to all groups. The contents of the science units were *Sound (distribution and properties of sound), Living Things and Energy (respiration and photosynthesis in living things), States of Matter and Temperature (heat exchange, temperature changes, phase change points), and Electricity (effect of current on magnetism and* *heat effect of current).* In the treatment group, lessons were conveyed to the students, along with ABI activities, group discussions, and class negotiations. In ABI activities, students collected data, developed research questions, tested them, developed claims, presented supporting evidence, and shared their arguments through group and class discussions. When the debate was over, students filled out their ABI reports and created concept maps to determine their understanding of the topic. The comparison group's lessons were teacher-centered, textbook-focused, and mainly focused on students asking questions and taking notes. In the comparison group, the tasks were structured through the sequence of the initiate *(teacher wrote down the concepts related to the subject on a blackboard, and students took notes*), respond (*asking questions and answering*), and evaluate (*continuing the process until the correct answer was given*). At the end of the lesson, students participated in a hands-on laboratory activity where they followed the procedures step by step. The study's quantitative data were obtained by applying the "*Science Content Achievement Test*," consisting of 32 multiple-choice questions to the study groups before and after the instruction. The study results showed that the treatment group's science content achievement regarding the relevant units was noticeably better than the comparison group. In other words, the ABI approach positively affected the achievement of 8th-grade students in science content regarding the specified units.

Furthermore, Nussbaum and Sinatra (2003) conducted a study to measure the effectiveness of an argumentation-focused conceptual change intervention. The study sample consisted of 41 undergraduate students and 27% of the participants had only postgraduate physics education, while the other participants had limited physics knowledge. The quantitative data were obtained from a test developed by the researchers on 22 multiple-choice "*Newton's Fundamental Laws of Physics*." The participants were randomly distributed to the experimental and control groups. The experimental group participants answered the simulation questions by thinking about the alternative ideas presented to them through a physics simulation developed by Garry et al. (2001) related to the study's subject. The intervention in the experimental group focused on participants who selected the wrong option from the statements presented in the simulation. They constructed their arguments based on this option and changed their arguments by discussing them with others. During the process, participants who could not create their arguments were encouraged to think by asking questions such as "*Why do you think the event happened?"* After the discussions were completed, participants noted whether there was any change in their preconceptions. Afterward, they completed the test. The participants in the control group evaluated the questions only as true or false without thinking about any alternative views and solved the test. The qualitative data were gathered by asking 26 randomly selected students from the experimental group to discuss their responses within the simulation. The interview data were then coded according to the participant's understanding of the subject. The analysis results of the study showed that the student's problem-solving skills and conceptual understanding of *N*ewton's fundamental laws of physics in the experimental group were more advanced.

In a different study on science, Venville and Dawson (2010) conducted a study to investigate the effect of in-class argumentation on students' conceptual understanding of genetics. The study was a quasi-experimental design that took 10 weeks to complete. The study sample comprised 92 10th-grade students (46 in the experimental and 46 in the control group). The subjects of variation, cell structure, genetics, genetic engineering, inheritance, Mendelian genetics, and genetic diseases were conveyed to the experimental group students through in-class discussions under the supervision of a biology teacher familiar with the argumentation process. The students in the control group were conveyed to the specified subjects without any intervention. In the experimental group, the lessons were conducted by a teacher trained in classroom argumentation frameworks proposed by Osborne (2004a). In the experimental group, the lessons were argumentation-based, including the following steps: reading the scenario text to the students (on Genetics-DNA), eliciting students' thoughts, structuring their arguments, and students discussing their arguments in class. Quantitative data were obtained through multiple-choice tests prepared on the specified subjects. As a result, an improvement was observed in the conceptual understanding of genetics topics of both study groups; however, the conceptual understanding development of the argumentation group was noticeably better.

The findings of the study conducted by Venville and Dawson (2010) are parallel to those undertaken by Zohar and Nemet (2002) on genetics. Zohar and Nemet (2002) studied the effect of argumentation on students' biology knowledge regarding the Genetics Revolution unit. The study sample consisted of 9th-grade students from two different high schools. In both schools, biology courses are taught to students three hours a week, adhering to the same curriculum. The researchers developed a unit on the genetics revolution, dividing participants into an experimental group (N=99) and a control group (N=87). Lessons for the experimental group were presented in an argumentation environment by teachers who had field knowledge about the unit, while the control group received instruction traditionally, using a booklet on the unit without any intervention. The quantitative data were obtained through the Genetic Knowledge Post-Test consisting of 20 multiple-choice questions. After the study, the analysis data revealed that the students in the experimental group, who were taught in an argumentation-based environment, showed more significant improvement in conceptual understanding of the unit compared to the control group.

In another study, Walker et al. (2012) conducted a study to determine the effects of Argumentation *Driven Inquiry (ADI*) on students' conceptual understanding of chemistry concepts and their attitudes toward chemistry. The study sample consisted of 186 undergraduate students taking the General Chemistry Course. In order to make inferences regarding conceptual understanding, the quantitative data were obtained from the two-tier diagnostic test CCI (*Chemical Concept Inventory*). The subjects included in the content of CCI consist of chemical and physical properties, molecular formulas, thermochemistry, solutions, and reactions and have a total of 23 questions. General chemistry courses in the experimental group were processed within the framework of ADI. This framework consists of 7 steps. The first step is the *"identification part,"* where the teacher introduces the subject to the students. The second is *"data production,"* where the students design a method that will enable them to find the same research question related to the subject. Third *is "tentative argument generation,"* in which students create a simple argument of data, claims, and warrants regarding their solutions. Fourth, there is an *"argumentation environment"* in which students participate in intra-group and inter-group discussions with the arguments they create and evaluate different claims. Fifth, after the argumentation process, students are expected to provide answers to the following questions: "What were you planning and why? What was your argument? "What did you do and why? *"Writing reports"*. Sixth, in *"Evaluation of reports,"* the teacher randomly distributes all written reports to the class, tells students some criteria, and expects them to evaluate the reports in line with them. The last step is *"Reviewing the Report,"* which includes distributing the reports that have been peer-reviewed back to their owners and reviewing the reports that students have received feedback. In this last step, the groups take on the role of a researcher who makes changes to their reports and reconstructs their article. While the lessons in the experimental group were processed in line with the ADI steps, no intervention was made in the lessons in the control group. In other words, the students wrote their reports after the chemistry experiments were done without providing a discussion environment. The analysis of the pre-intervention and post-intervention results from the CCI test showed that all groups developed a better conceptual understanding. However, the ADI class students in the study were exposed to fewer activities than the traditional class. When the researchers evaluated all these findings, they concluded that the argumentation process that ADI created in the classroom was more successful in developing students' conceptual understanding than traditional instruction on some chemistry topics.

Similarly, Aydeniz et al. (2012) conducted a study on the effect of argumentation instruction on university students' conceptual understanding of the properties and behavior of gases. The study sample consisted of 108 undergraduate students (52 in the control group, 56 in the experimental group) who received undergraduate chemistry education. The data of the quantitative study were obtained from a 10-question conceptual understanding test prepared by the researchers on the subject. The test was applied to the participant groups as a pre-test and post-test. The lessons were carried out with group work in the control group. In other words, in the control group, the lessons involved group discussion and solutions to the questions posed by the teacher. When a solution could not be found, the teacher gave the students the solutions to the questions. In the experimental group, after the lessons were completed, the students participated in an argumentation process within the framework of the Toulmin Argumentation Pattern. The process consisted of two stages; in the first stage, the students created a written argument using the Toulmin Argumentation Pattern regarding their answers to the two-tier test consisting of 5 questions on gas laws and properties. In the second stage, the students participated in the verbal argumentation by presenting their written arguments in groups. The statistical analysis findings of the quantitative data showed a significant increase in the conceptual understanding post-test scores of the experimental group students compared to the control group. The results of the study are consistent with the findings of the study conducted by Çelik and Kılıç (2014). In the semi-experimental research design with a pre-test-post-test control group conducted by Çelik and Kılıç (2014) with 9th-grade students, it was concluded that the conceptual understanding of the nature of the matter of the experimental group students who studied in an argumentation environment developed more compared to the control group.

In a study conducted on a different sample group, Kaya (2013) investigated the effect of argumentation instruction on the conceptual understanding of prospective teachers on the subject of chemical equilibrium. The sample of the quasi-experimental design study consisted of 100 prospective science teachers studying in their second year at a State University. The quantitative data were obtained by applying the "*Chemical Equilibrium Concept Test (CECT)* (Hackling & Garnett, 1985)" to the study groups before and after the 4-week training period. In the experimental group, concepts such as the properties of chemical equilibrium, factors affecting equilibrium, and concepts related to concentration and temperature factors were taught using argumentation activities. In contrast, the control group studied the same topics through a traditional teaching approach. The same teacher instructed both groups. After analyzing the quantitative data, it was determined that argumentation instruction created a significant difference in conceptual understanding in favor of the experimental group. In the same science branch, Niaz et al. (2002) conducted a study on the effectiveness of an in-class argumentation environment in improving chemistry students' conceptual understanding of the atomic models of J. J. Thomson, E. Rutherford, and N. Bohr. The study sample consisted of 160 students who were studying in the undergraduate General Chemistry course. In the experimental group of 83 students and the control group of 77 students, lessons on atomic models were taught using traditional methods, including textbook-based instruction and direct lectures. After the lessons were completed in the experimental group, six different questions, three related *to* Thomson's, two to Rutherford's, and one to Bohr's model, were discussed with the students during the argumentation process. Different alternatives were developed for the models, and time was spent on all ideas within the argumentation process. The content of the questions was as follows: *What do you find most important in the Bohr atomic model? Why do you think so? What is your comment on the finding that alpha particles pass through metal foil without deflection?* The alternative answers that emerged during the argumentation process were transferred to written documents, and the experimental group participants were asked to make choices regarding the alternative answers in question. Then, the selected alternative ideas were discussed again. The qualitative data were obtained through written tests presented to the study groups at 3-week intervals after completion. The student's exam responses were coded as "*conceptual, partially conceptual, retroactive, and no response."* The analysis of the data concluded that argumentation improved the students' conceptual understanding of atomic models.

In the same vein, Pabuçcu and Erduran (2017) conducted a study on the argument quality and conceptual understanding of prospective science teachers in the context of organic chemistry, more specifically, on the conformational analysis of butane. The study sample consisted of 2nd-year prospective science teachers studying at a state university. None of the participants had received formal training in argumentation before. The study data were obtained through written responses, audio recordings, and aptitude tests. After analyzing qualitative and quantitative data (SAT scores), it was concluded that prospective teachers who included more than one rebuttal in their arguments had higher argumentation skills and that this situation positively affected their conceptual understanding. The findings of this study align with those of Riyatti et al. (2023), who examined the effect of argumentation instruction on the conceptual understanding of science teacher candidates regarding the Excretory System. The quasi-experimental pre-test and post-test study design sample consisted of 72 teacher candidates. The participants were randomly assigned to the groups. The study data were obtained through a three-tier concept test. The experimental group was taught the relevant concepts through activities developed within the Toulmin (1958) Argumentation Pattern framework, while the control group received question-and-answer-based instruction without any additional intervention. After the statistical analysis of the quantitative data, it was found that argumentation activities caused a significant decrease in the misconceptions of teacher candidates.

CHAPTER 3

METHODOLOGY

The methodology chapter presents the research design, research group, data collection, preparation process before starting the study, treatment validity and verification, validity, limitations, and assumptions.

3.1 Design of the Study

The research aims to achieve two significant goals. Firstly, it aims to identify the misconceptions about the particulate nature of matter and dissolution concepts among 7th-grade students and examine the effectiveness of argumentation and curriculum-based instruction in eliminating the identified misconceptions. Secondly, it aims to position identified misconceptions into ontological categories and analyze the effectiveness of instructional methods in eliminating the misconceptions arising from ontological reasons. To achieve these goals, it was decided to conduct the research using an experimental design, one of the quantitative research methodologies.

The experimental study examines the cause-effect relationships between kinds of variables and the effect of manipulations the researcher performs on the dependent variable. In other words, experimental studies are one of the most effective and reliable quantitative study methodologies in detecting the effect of independent variables (Fraenkel et al., 2012). For this reason, it is frequently preferred by researchers in education and training studies (Cohen & Manion, 1994). In this research, the researcher plans the group to which the independent variable will be applied, the implementation plan, and the implementation duration (Fraenkel & Wallen, 2006). Experimental research is a system consisting of dependent, independent, and controlled variables (Büyüköztürk et al., 2023). The dependent variable of this research is the 7th-grade students' degree of understanding of the particulate nature of matter and dissolution concepts, the independent variable is argumentation instruction and curriculum-based instruction, and the controlled variable is the science teacher who carried out the in-class implementation of the study. There is no interaction between the study’s groups.

In the experimental research design where the effect of independent variables (applied teaching methods) on the dependent variable (conceptual understanding level) is examined, the "static group pretest-posttest design" should be preferred in cases where the researcher cannot randomly assign the participants to groups. Sometimes, it is impossible to randomly assign participants to groups, ensure group equivalence, and match subjects on gender, achievement, and ability. In such cases, researchers usually work with different groups that already exist. Even if equivalence cannot be achieved in groups in terms of certain variables, applying a pre-test to the comparison and experimental groups gives the researcher information about the initial levels of the groups. In this way, the researcher can determine the progress of the groups during the experiment with the post-test application. Thus, at the end of the research, if the changes within and between groups are measured and the post-test scores create a significant difference in favor of the experimental group, it shows that the teaching method applied to the experimental group is more effective than the teaching method applied to the comparison group. (Büyüköztürk et al., 2023). Based on these statements, "the static group pretest-posttest design" was determined as the research design, considering the purpose of the study, main problems, sub-problems, and number of groups for which the researcher received administrative legal permission. The researcher randomly assigned two different 7th-grade classes, 7/B and 7/C classes, as the experimental and comparison groups. The intermittent line “----” in Table 3.1 symbolizes that the groups are randomly assigned (Büyüköztürk et al., 2023). The symbolic design of this study is included in Table 3.1. A summary of the research study design is given in Table 3.2.

Table 3. 1 Symbolic Notation of Weak-experimental Design of the Study: The Static-Group Pretest-Posttest Design

Group	*Randomization*	*Pre-test*	*Treatment*	*Post-test*
E	R	O	X	O
C	R	O		O

The explanations of the symbolic patterns are shown in Table 3.1:

E: Experimental Group (Group receiving argumentation-based instruction)

C: Comparison Group (Group receiving curriculum-based instruction)

X: Independent variable (Argumentation Instruction)

O: Instrument “Particulate Nature of Matter Concept Test”

R: Randomization

Table 3.2 presents a summary of the research study design.

Table 3. 2 Weak-experimental Design of the Study: The Static-Group Pretest-Posttest Design

Group	Pre-test	Treatment	Pos-test
Experimental	Particulate Nature of Matter Concept Test	Argumentation Instruction	Particulate Nature of Matter Concept Test
Comparison	Particulate Nature of Matter Concept Test	Curriculum-Based Instruction	Particulate Nature of Matter Concept Test

The second main goal of this research is to find out the ontological reasons for 7th-grade students' misconceptions about the particulate nature of matter and dissolution terms and to reveal the effect of argumentation instruction and curriculum-based instruction in eliminating misconceptions placed in lateral and superordinate ontological categories. Within the scope of this purpose, the responses of the experimental and comparison groups to the pre-study and post-study concept tests were determined by in-depth analysis, and the detected misconceptions were placed on the ontological category representation maps designed by the researcher as pre-test and post-test. Then, by examining the change in the data, whose frequency and percentage distributions were calculated, the effect of argumentation instruction and curriculum-based instruction on the misconceptions regarding the particulate nature of matter and dissolution concepts existing in the lateral and upper ontological categories was determined.

3.2 Participants of the Study

The research's target population comprises all 7th-grade students studying in public middle schools in Ankara. The accessible population is all 7th-grade students who receive education at a public middle school in the district of Etimesgut in Ankara. Until the number of participants required for the research is reached, the researcher works with an accessible sample to gain time (Cohen & Manion, 1994). Convenience sampling, one of the non-random sampling methods (Fraenkel et al., 2012), was chosen as this research's sampling method to save the researcher's money, time, and road. In this regard, a public school in the district of Etimesgut in Ankara was selected for the 2023-2024 education term. The determined study school is close to the researcher's location, and the school administration provided the researcher with the necessary facilities to complete the research. To implement the research, compulsory permission was received from the Ankara Provincial Directorate of National Education before starting the research. (Appendix A). 7/B and 7/C sections at the school consist of students who are different from each other in terms of gender, academic success score, reading comprehension skills, class participation potential, socio-economic level, and family structure. These sections are heterogeneous within themselves and have a similar structure but are not equal to each other. The science teacher and the school administration conveyed this situation to the researcher for informational purposes before the study. Since it was not possible to randomly assign participants to groups, the researcher randomly assigned the groups as comparison and experimental groups. The concepts in the "Pure Substance and Mixtures / Matter and Its Nature" unit in the science curriculum were taught to the students in the 7/B section, who were determined as the experimental group, through argumentation instruction. The concepts in the "Pure Substance and Mixtures / Matter and Its Nature" units in the science curriculum were taught to the students in the 7/C section, which was determined as the comparison group through curriculum-based instruction. As indicated in Table 3.3, the study sample consists of 35 students. 19 students constitute the experimental group, and 16 are the comparison group. Of the

19 students in the experimental group, 11 are male, and 8 are female. Of the 16 students in the comparison group, 9 are male, and 7 are female.

Table 3. 3 Frequencies Distribution of the Study Sample into Research Groups

	Experimental Group (E)		Comparison Group (C)	
	Male	Female	Male	Female
Frequency (f)	8	11	9	7
Total	19		16	

The researcher did not make any intervention in the classroom seating arrangement of the comparison group students. The experimental group, where argumentation instruction will be applied, was divided into four groups of four participants and one group of three, considering the classroom seating arrangement and class size. In line with the recommendations of the science teacher, in each group, students whose science course academic average was good (GPA ≥ 85; 84.99 ≥GPA ≥70), satisfactory (60≥GPA≥69.99), and sufficient (59.99 ≥GPA≥ 50) (MoNE, 2008) has taken place. Apart from their academic success, students' potential to participate in class discussions was also considered. Therefore, while the five groups involved in the argumentation process have a heterogeneous structure within the group in terms of academic success averages and class participation levels, they have a similar structure to the other groups. Before starting the research, participants were asked whether they were satisfied with the group they belonged to. No changes were made to the group members' seating arrangements during the research since there was no unwanted feedback. However, roles within the group were changed for each activity. Accordingly, the group secretary and group spokesperson were differentiated in each activity. This provides a more influential discussion environment than dull, monotonous "feedback" sessions. (Cengiz &Kabapınar, 2017). The classroom seating arrangement figures of the experimental and comparison groups are given in Figure 3.1. The participants in the experimental group are symbolized by the *E* letter, and the participants in the comparison group are designated by the *C* letter.

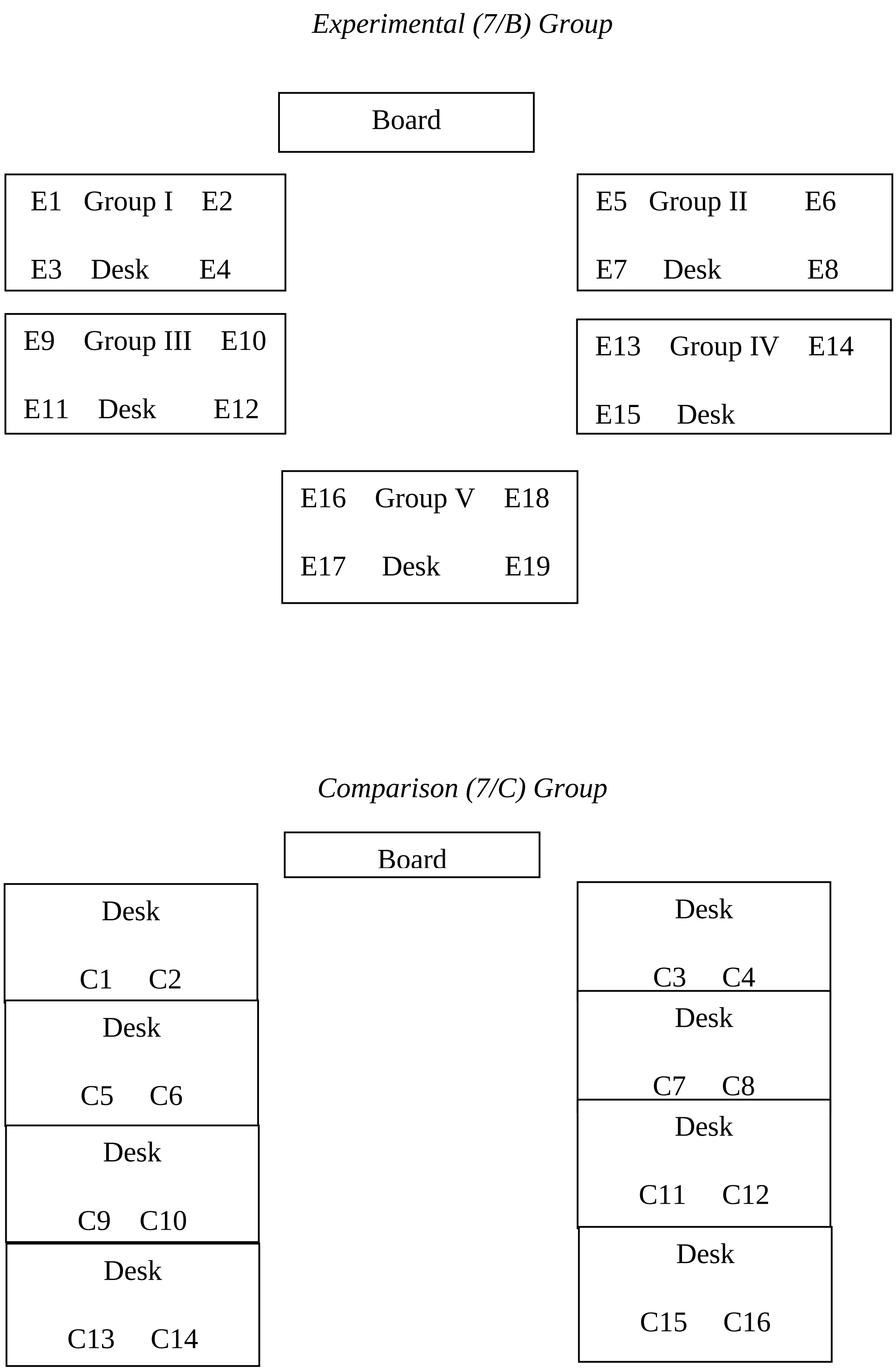

Figure 3. 1 Classroom Seating Plans

3.3 Data Collection

The study involves two essential parts of data collection. The first section presents information about the data collection instrument used in the study, and the second section describes the treatment conducted in the study in detail.

3.3.1 Instrument

A concept test on the particulate nature of matter and dissolution was used to discover the essential answers to all research questions. Detailed information about the data collection instrument is described below.

3.3.1.1 Particulate Nature of Matter Concept Test (PNMCT)

The "Particulate Nature of Matter Concept Test" is a two-tier diagnostic test with 17 questions. This test aims to reveal the misconceptions of 7th-grade students about the particulate nature of matter and dissolution subjects and to understand the ontological foundations of these misconceptions. Of the 17 questions in the PNMCT (Appendix I), 11 were taken from the "Particulate Structure of Matter Test" developed by Özalp (2008), while the remaining six were taken from the "Structure and Properties of Matter Concept Test" developed by Sarı (2014). In the two-tier diagnostic tests introduced to educational research by Treagust (1988), the first tier includes a question item or information proposition followed by various answer options. (Chen et al., 2002 & Briggs et al., 2006). In the next stage, the student is asked to explain why they selected the option in the first tier. The different numbers of justifications included here are prepared depending on the existing misconceptions identified in the relevant literature. Unlike multiple-choice tests, two-tier diagnostic tests effectively recognize students' non-scientific prior knowledge and identify misconceptions that develop in students accordingly (Bernhisel, 1999). Each test item in the PNMCT belongs to a specific ontological category (Özalp,2008; Sarı, 2014). In other words, the options for the PNMCT items were designed by developers so that the concept asked in the question could be placed in different ontological categories. A misconception occurs if students place the correct answer to the question and why they think this way in a different category instead of the correct category. The ontological categories in the PNMCT presented by Sarı (2014) and Özalp (2008) are given in detail under the title "The Use of Ontological Categories in the Particulate Nature of Matter Concept Test."

A total of 10 questions in the PNMCT, specifically numbered 2, 3, 4, 5, 6,7, 8, 9, 10, and 12, were taken from the "Particulate Structure of Matter Test" developed by Özalp (2008). The original instrument, provided by Özalp, consists of 25 questions, including 15 two-tier and 10 multiple-choice questions. Four two-tier questions, including the concepts of the lattice structure of ionic compounds, formation of chemical reactions, conservation of mass, physical change, and chemical change, were removed because they were unsuitable for the 2018 7th-grade science curriculum (MoNE, 2018). The one question of the test (number 1) belongs to Özalp (2008), but its revised version by Sarı (2014) was used in this study. Özalp (2008) conducted a pilot study of the test with 128 middle school students (6th, 7th, and 8th grade) and 50 high school students (9th, 10th, and 11th grade) during the 2007-2008 academic year. As a result of the developer's analyses, the Cronbach's Alpha reliability coefficient of the test was calculated as 0.78.

In the PNMCT, 7 questions, numbered 1,11, 13, 14, 15, 16, and 17, were taken from the "Structure and Properties of Matter Concept Test " developed by Sarı (2014) and consisting of two-tier questions. Sarı's original 20-question instrument included seven questions from the "Particulate Structure of Matter Test" developed by Özalp (2008), and 4 questions were inspired by this test. However, seven questions related to strong interactions, which are ionic, covalent, and metallic bonds, anion and cation terms, and physical and chemical changes, were not included in PNMCT because they were unsuitable for the 2018 7th-grade science curriculum. Sarı (2014) conducted a pilot study with 117 7th-grade students to evaluate the test questions' difficulty and discrimination indices and the test's Cronbach's Alpha coefficient. The analysis revealed that the difficulty index of the questions ranged from 0.42 to 0.59, the discrimination index ranged from 0.44 to 0.75, and the Cronbach's Alpha coefficient was calculated to be 0.818. Also, ethical permission was obtained from the researchers for the use of PNMCT in the study (Appendix J)

The PNMCT, in its final form, consists of 17 questions covering the following conceptual areas: the particulate nature of matter, pure substances, and mixtures.

Propositional knowledge statements defined the content boundaries on the particulate nature of matter and dissolution concepts. These statements are necessary for a deep understanding of the relevant topic. Relevant studies on the particulate nature of matter and dissolution, the science curriculum outline, and learning objectives (MoNE, 2018) were used to define propositional knowledge statements. The propositional knowledge statements defined are presented in Table 3.4.

Table 3. 4 Propositional Knowledge Statements Necessary for Understanding the Particulate Nature of Matter and Dissolution

1. Atom is the smallest building block of all matter.
2. Atoms do not have the property of being alive.
3. The nucleus is located at the center of the atom.
4. The volume of the nucleus is approximately ten thousand times smaller than that of the atom, and most of it is space.
5. The particles that make up solid matter make a vibrating motion.
6. The space (not air) between particles that make up solid matter is almost non-existent, allowing the matter to have a distinct shape.
7. Liquids take the shape of their container due to the translational motion of the particles that make up the liquid.
8. Whether a substance is solid, liquid, or gaseous depends on the arrangement of the particles that make up the substance.
9. The macroscopic properties observed in substances (brightness, shape, brittleness, hardness, phase state, melting point, color... etc.) are not observed in the smallest structural units that show the properties of the substance itself.
10. If a substance receives or gives off heat, matter undergoes a phase change, but there is no significant change in the size and volume of its particles
11. As a result of the matter receiving or giving off heat, the distance between the particles that make up the matter changes without causing any structural change in the particles.
12. When solid substances receive heat, they heat, their temperature increases, and melt; this situation is not observed in the particles that make up the substance.
13. When liquid substances give off heat, they cool, decrease in temperature, and freeze; this situation is not observed in the particles that make up the substance.

Table 3.4 (Continued)

14. A molecule is a group of independent atoms formed by combining two or more identical or different atoms.
15. Pure substances are composed of the same type of atoms or molecules.
16. Elements are pure substances formed by combining atoms of the same type.
17. The smallest particle that carries the chemical properties (non-physical properties) of an element is the atom.
18. Elements frequently used in daily life are gold, silver, copper, zinc, lead, mercury, iron, platinum, and iodine.
19. The interaction and differences between the atoms that make up the elements give the elements their uniqueness.
20. Compounds are pure substances formed due to the combination of two or more different kinds of elements losing their characteristics.
21. Compounds frequently encountered daily include water (H_2O), table salt (NaCI), sugar ($C_6H_{12}O_6$), carbon dioxide (CO_2), and alcohol.
22. Compounds composed of molecules are called "molecular compounds."
23. Atoms, molecules, and ion clusters cannot be seen with the naked eye.
24. The smallest particles of molecular structured compounds, such as water and sugar, that show their chemical properties are molecules specific to the compounds.
25. The smallest particle of a non-molecular compound such as NaCI with its chemical properties (non-physical properties) is not an atom or molecule but a cluster of ions.
26. A mixture is formed by combining more than one substance in the desired proportion without losing its properties.
27. Mixtures are not pure.
28. Homogeneous mixtures (solutions) appear to be a single substance when viewed outside.

Table 3.4 (Continued)

29. Examples of homogeneous mixtures (solution) include seawater, sugar water, and saltwater.
30. When the solute (usually in lesser quantity) is added to the solvent (usually in greater quantity) while the solution is being formed, the solute particles are separated, and the solvent is distributed evenly within the particles of the substance.
31. Dissolution is a physical event in which a substance is separated into particles (atoms, molecules) that are too small to be seen with the naked eye (usually in large amounts) in another solvent.
32. In heterogeneous mixtures, the substances that make up the mixture do not appear to be a single substance when viewed from the outside, which distinguishes heterogeneous mixtures from homogeneous mixtures.
33. Melting is the transition of a solid substance into a liquid state when heated.
34. No new substance formation is observed after a physical event.
35. Blending is a factor that increases the speed of dissolution.
36. NaCl (Table Salt) is an ionic compound formed through electron transfer.
37. If the atoms that make up the elements are in free form, they are defined as atomic-structured elements (gold, sulfur, mercury, iron); if not, they are called molecular-structured elements (hydrogen, oxygen).

Table 3. 5 Specification Grid Showing the Topic Areas and Propositional Knowledge Statements Addressed by the Questions in the Particulate Nature of Matter Concept Test

Item	Topic Area	Propositional Knowledge Statements
1	Particulate Nature of Matter	1,2
2	Particulate Nature of Matter	3,4,9,12,17
3	Mixtures	20,21,26,29,30,31
4	Particulate Nature of Matter	10,14
5	Particulate Nature of Matter	5,6
6	Particulate Nature of Matter	7,9,14
7	Particulate Nature of Matter	8,9,14
8	Pure Substances	14,21,22,23,24
9	Particulate Nature of Matter	10,13,14
10	Particulate Nature of Matter	10,12
11	Mixtures	26,29,30,35
12	Pure Substances	9,17,19,37
13	Mixtures	26,27,31,33,32,34
14	Particulate Nature of Matter	10,11,12
15	Pure Substances	21,23,25
16	Pure Substances	16,17,18,23,37
17	Pure Substances	14,25,36

Item analysis is required for classroom tests. In cases where the class size is between 20 and 40, it is appropriate to evaluate the responses of the 10 students with the highest and those of the 10 with the lowest scores (Miller et al., 2009). The item difficulty index in the item analysis is obtained by dividing the correct answers given to an item by the number of students who responded, varying between 0.00 and +1.00. An item difficulty index of around 0.50 is considered medium difficulty (Jang, 2003). As this value approaches 0.00, the item becomes more difficult. It is considered appropriate to include questions with an item difficulty value above 0.30 in tests (Bernhisel, 1999). Item discrimination index is the power of the item to distinguish between students with a high level of the characteristic it aims to measure and those with a low level. It is calculated using the formula $D=(RU-RL)/(.5T)$. *D*, item-discriminating index; *RL*, the number of students in the upper group who answered correctly; *RU*, the number of students in the lower group who answered incorrectly; *T*, the total number of students who answered (Miller et al., 2009). If *D* value is 0.19 and below, it is a poor item and should be rejected; if it is between 0.20-0.29, corrections should be made; if it is between 0.30-0.39, it is reasonably good and can be used in the test; if it is 0.40 and up, it is evaluated that the item is perfect (Ebel & Frisbie,1991). Information on the item analysis of PNMCT is presented in Table 3.6.

As indicated in Table 3.6, the difficulty range of test items 7 and 11 is between 0.20 and 0.25. This situation shows that the specified questions are difficult. The average item difficulty is 0.44, and this is a feature expected results for research tests (Hasançebi et al.,2020). This result shows that 44% of the students participating in the PNMCT answered the questions correctly. Also, the *D* values of the items included in the PNMCT indicate that the test items are reasonably good or excellent. The fact that these values are positive shows that the more successful students answered the test items correctly at a higher rate (Popham, 2005). To check the internal consistency of the PNMCT, calculate the reliability of items with the KR20 formula. Because tests where wrong and right scoring are performed, the reliability of the items can be explained through the KR-20 value. For the research, this value should be more than or equal to 0.70 (Fraenkel et al., 2012). This value was found to be 0.92 for PNMCT. This result shows that PNMCT items are highly reliable for research.

Table 3. 6 Item Difficulty and Item Discrimination Index of Particulate Nature of Matter Concept Test

Item	Item Difficulty Index	Item Discriminating Index
1	0.50	1.00
2	0.40	0.80
3	0.45	0.90
4	0.50	1.00
5	0.60	0.80
6	0.50	0.80
7	0.25	0.50
8	0.55	0.90
9	0.45	0.90
10	0.50	0.80
11	0.20	0.40
12	0.50	0.30
13	0.35	0.70
14	0.50	0.80
15	0.45	0.90
16	0.40	0.80
17	0.40	0.90
Average	**0.44**	

The characteristics of the PNMCT are summarized in Table 3.7.

Table 3. 7 Summary of the Particulate Nature of Matter Concept Test Characteristics

Topic Areas Evaluated	:	Particulate Nature of Matter	Items 1,2,4,5,6,7,9,10,14
		Pure Substances	Items 8,12,15,16,17
		Mixtures	Items 3,11,13
Content Validity	:	Propositional Knowledge Statements	
Item Number	:	17	
Format	:	Two-tier Diagnostic Test	
		First Tier of the Test – Content Knowledge	
		Second Tier of the Test – Reason for the First Tier	
Required Time	:	40 minutes	
Level	:	7th Grade Level	
Index of Discrimination	:	Range (items)	Mean
		0.90 - 1.00 (7 items)	0.77
		0.89 – 0.70 (7 items)	
		0.69 - 0.50 (1 item)	
		0.49 - 0.30 (2 items)	
Index of Difficulty	:	Range	Mean
		0.60 - 0.50 (8 items)	0.44
		0.49 - 0.30 (7 items)	
		0.29- 0.10 (2 items)	
KR-20 Reliability	:	0.92	

3.3.2 Treatment

The implementation process of the present study consists of three essential parts. First, this research aims to identify the misconceptions of 7th-grade students regarding the concepts of "Particle Nature of Matter and Dissolution" and to categorize these misconceptions based on ontology. To carry out this part, PNMCT was administered to the experimental (7/B) and comparison (7/C) groups as a pre-test within 40 minutes. In the second part, "Argumentation Instruction" and "Curriculum Based Instruction" were applied to the experimental and comparison groups to achieve conceptual understanding and eliminate the identified misconceptions. The completion period of this stage was seven weeks and 26 lesson hours. The last part of the application includes the effect of different teaching methods applied to the experimental and comparison groups to eliminate the identified misconceptions and re-examine this effect ontologically. PNMCT was applied to the experimental and comparison groups as a post-test for the final stage within 40 minutes.

Before the general implementation plan of the study mentioned above, the researcher made several preliminary preparations. First, activities were developed using argumentation strategies, designed for the experimental group, and included in their lesson plans. Additionally, the implementing teacher was informed about the process.

3.3.2.1 Designing Improved Instructional Materials with Strategies Provide Argumentation Environment

According to Odom and Kelly (2001), propositional knowledge statements determine the content boundaries of the relevant topic while constituting the content of the activities in the treatment groups. In this context, the instructional materials in this study consist of the content boundaries of the particulate nature of matter and dissolution topics (see Table 3.4). In line with science education expert opinions, considering the research design, the other relevant learning objectives which means the part that is included in the curriculum but is not included in the subject content of the study unit of Pure Substances and Mixtures (MoNE, 2018) and possible misconceptions in the literature on this topic were also included in the instructional materials. To achieve the purpose of the study, the researcher designed 13 activities using argumentation strategies that foster an argumentation environment based on the "Toulmin Argument Model.” At this point, some frameworks recommended by (Osborne et al., 2004a) were used to facilitate the argumentation process in the science course. These include "Table of Statements, Competing Theories with Cartoons (Concept Cartoons featured in the events were designed on (https://www.pixton.com), Competing Theories with Ideas and Evidence, Argumentation with Models, Predicting - Observing - Explaining, Constructing an Argument, and Evidence Cards." Different activities were designed for the research by examining the various activities included in the workshop kit named "Ideas, Evidence, and Argument in Science (IDEAS Resource Pack)," developed by Osborne, Erduran, and Simon (2004b). The teaching materials developed for argumentation instruction were examined by three Science Education Field Experts and one Chemistry Education Field Expert regarding suitability for purpose, clarity of expression, and content validity, and necessary adjustments were made. The arrangements made in line with the opinions of field experts can be expressed as follows: question expressions in the activities were simplified for students to understand easily, and complicated expressions were avoided; the corresponding Toulmin argument element was stated in parentheses at the end of each question expression, the speech bubbles in the concept cartoons were numbered from left to right in a way that would comply with the book reading habits of the students, the instructions were stated understandably and clearly in the activity where students would design a model (Activity - VI) and in the activity where students would participate in argumentation through a table (Activity IX).

The "Toulmin Argument Model" structure is included in all activities in this research. Although this argument model has advantageous features for educational studies, its content has some limitations (Mitchell & Riddle, 2000; Riddle, 2000; Driver, Newton & Osborne, 2000; Osborne et al., 2004a; Aldağ, 2006; Sampson & Clark, 2006; Paglieri, 2006). Necessary solutions were created by considering these limitations when rearranging the activities.

a. There are no clear boundaries between the argument elements in the Toulmin argument model. In other words, the same content may correspond to another statement in a different discussion area. At this stage, the name of the desired argument element is clearly stated next to each question so that students can more easily create the elements of the argument.
b. There is an indirect definition between the elements of the argument. Similar question patterns were used for certain argument elements in each activity for this situation. Thus, as the process progressed, students became more familiar with the question patterns and could put their ideas into writing more efficiently during the process. The question patterns used were inspired by the structures recommended in the relevant literature. For example, a “claim” is a statement accepted and put forward to convince others, which is believed to be accurate and defended as true. "What exactly are you advocating?" The expression can be used to identify the claim (Toulmin et al., 1984)."Why do you make such a claim?" "What caused you to make this claim?" "On what basis do you make this claim?" questions regarding the claim in the form of answers to the data item (Toulmin, 2003; Toulmin et al., 1984). It allows the formation of warrants in questions where data is associated with a claim (Toulmin, 2003).
c. Argumentation is a natural discussion process, so the lesson plan may not go in the desired order. At this stage, students were asked to follow the questions sequentially. In addition, in the design of the activities, students were required to write their claims first, then their data, and finally their warrants. In addition, unique lesson plans for the practitioner teacher were prepared for each activity.

d. Some ideas can be expressed with gestures and facial expressions during argumentation. At this stage, the teacher shared the need for students to express all their ideas in writing and verbally within the framework of argumentation rules with the students during the process.
e. The Toulmin argument model should be arranged depending on the field used (law, philosophy, politics, or education). At this stage, the teaching materials received expert opinion approval after the final revisions and were implemented to the experimental group participants during the 2023-2024 academic year.

3.3.2.2 Designing of the Lesson Plan

The Toulmin argument model provides several benefits to the students. One of the advantages is that if students know the questions and explanations they should ask at the stages of the argumentation process, they can become a part of the argumentation and thus become a part of the teaching process (Aldağ, 2005). To ensure that this positive impression is present in the students, it is crucial that the teacher provides the students with the necessary clues at each stage of the argumentation and indicates the appropriate question expressions and rules for the students to use during the process. The researcher prepared detailed lesson plans in this direction and examined many resources (Cömert, 2019; Erduran et al., 2004; Erduran & Pabuçcu, 2012; Osborne et al., 2004a; Osborne et al., 2004b; Owen, 2014; Simon et al., 2006; Şen, 2021; Temiz Çınar, 2006; Uluçınar Sağır, 2008). Lesson plans consist of objectives, preliminary knowledge that students may have, possible misconceptions about the subject, course materials, technological materials that need to be used, and the steps of the teaching process. The general structure and content of the lesson plans for the argumentation process, which takes place in the form of individual, group, and, finally, class discussions, are presented below.

1. ***Lesson Preparation:*** In this process, the teacher groups the students by considering certain variables. Group writer and group spokesperson are

determined for each group. (In the following period, the group members remained the same to facilitate the treatment process.)

2. ***Introduction:*** At this stage, students' possible prior knowledge is revealed, and thus, their attention to the lesson is attracted.
3. ***Middle:*** At this stage, the teacher distributes the activity sheets to the students and discusses the rules they must follow during argumentation. These rules;

- *Work with your group.*
- *Be quiet while filling out the activity sheet individually or in groups, and avoid any noise that may distract others.*
- *Try to fill out all the questions on the activity sheet given to you.*
- *Ask for help from the teacher when you have difficulty filling out the activity sheet.*
- *When working in a group, include all members in intra-group communication.*
- *During the class discussion, please raise your hand if you want to participate and intervene with your group spokespersons. (Cengiz,2017)*

3.1 Individual Study Process: At this stage, students fill in the required sections of the activity sheet individually within the time given to them. At this stage, each participant creates arguments consisting of "claims, data, and warrants."

3.2 Group Decision-Making Process: At this stage, a form called *" Group Decision"* is distributed to each group (Appendix D). In this form, each group determines the claim it defends with its justifications and makes preliminary preparations for possible rebuttal claims to the class argumentation. Group writers are held responsible for this task. The teacher uses some questions to ensure the students participate in the group discussion and make them part of the argumentation process.

- *Why do you think like that?*
- *What evidence cards did you use to support your claim? Why?*
- *What can you say to defend your opinion against the opinions you noted?*

- *Are there any situations where the views you noted are invalid? What can you say to refute them?*

"Dialogical Argument" in science classes allows individuals to create and present counterarguments. In this way, individuals' obstacles to becoming scientifically literate are minimized. This is possible by reaching a consensus and considering possible counterclaims (Ritchie & Tobin, 2001; Duschl & Osborne, 2002). For this reason, it is aimed for students to share the arguments they have created individually in the Individual Study Process section with the group members in the Group Decision-Making Process section and then try to reach a common consensus by discussing all opposing arguments in these lesson plans.

3.3 Announcement of Group Decisions and Start of Class Argumentation Process:

In this process, group spokespersons share group decisions with other groups. Then, a class discussion begins in which all individuals participate—depending on the course of the teacher's discussion, "*How do this group's views differ from the other group's views?* Alternatively, *"How does this group's justification differ from another group's justification?"* asks questions to the whole class.

4. ***Closure:*** At this stage, the teacher re-explains the decision after the class discussion, summarizes the entire subject by considering the students' misconceptions, and provides an ending lesson that will refute all misconceptions. The researcher presented the sample speech text in detail to give the teacher an easy and complete application.
5. ***Assessment:*** An open-ended assessment question was written on each activity sheet to observe conceptual change and evaluation. *"After sharing your ideas with your classmates during the class discussion, if there has been any change in your ideas, explain what your changed ideas are. In other words, write down the change in thought that occurred by comparing the thoughts you had at the beginning of the lesson with those you formed at the end. Additionally, what did you know about the subject before starting the*

course? What did you learn about the subject at the end of the lesson? Please write". At this stage, it is also used in all written expressions on the activity sheet.

Since it was necessary to complete all activities within the limited time for which administrative permission was obtained, changes were made only in the middle of the lesson plans. In this context, in lesson plan III (Appendix D), the individual study process is given a shorter time and integrated into the group decision-making process. In Lesson Plan VII (Appendix D) and Lesson Plan XIII (see Appendix D), where the Predict-Observe-Explain framework that provides an argumentation environment is used, the middle part of the lesson plans is designed following the steps of this argumentation framework. In these activities, students participated individually and then in class discussions. Within the framework of POE (White & Gunstone, 1992), the aim is to reveal preliminary information about an event, which educators can use in a discussion environment since it is in the field of constructivism. When conceptual change is desired, students' prior knowledge must be visible. In the Predict phase, the aim should be for students to be able to convey their preliminary knowledge in a written and precise manner (Köseoğlu et al., 2002). Since conceptual change is significant in this study, the first step of the prepared POE activity was to express students' thoughts and warrants individually. This situation also prevented the changing opinion from being seen in a group discussion. In the Observe phase, students were asked to take notes individually by writing or drawing their observations. The fact that the students did not know the correct answer for sure and did not have doubts, that is, did not engage in any discussion, enabled the students to take observation notes objectively. If this situation is not achieved, it has been determined that students take observation notes based on the result they want to achieve rather than based on what they see in some previous research (Yazan, 2017). The purpose of the Explain phase is to make students aware of the inconsistencies between the prediction and observation steps and thus create confusion in the mind for conceptual change. Students first identify the inconsistencies or consistencies between the explain and observe sections, then discuss and develop new ideas based on the discrepancies (Köseoğlu et al., 2002). Thus, students can consider alternative ideas through group discussions (Driver & Bell, 1986). For this reason, it was planned that students would participate in individual and then class discussions in the designed POE-framed activities. In this way, the researcher aimed for the students to develop alternative thoughts based on different ideas within the class discussion and achieve conceptual change by ensuring they became aware of the contradiction between their prior knowledge and observations. Experts in science education reviewed all lesson plans to ensure their suitability and clarity of expressions for the teaching process of the experimental group of students. Based on expert opinions, the following adjustments were made. Since the teacher is unfamiliar with the argumentation process, the lesson plan includes detailed guidelines on what students should do at each stage and the appropriate time frames. Sample argument structures expected from the students were added to the lesson plans. Additionally, a sample speech text addressing all objectives and misconceptions was included in the closure section of the lesson. The lesson plan also indicates when students should participate in individual, in-group, or inter-group discussions. Leeson's plans, names of the instructional materials that provide an argumentation environment, the argumentation framework used in them, and the propositional knowledge statements addressed each of the instructional materials, and MoNE 2018 learning objectives within the scope of the unit are presented in Table 3.8.

Table 3. 8 The Details of Lesson Plans and Instructional Materials Used in Argumentation Instruction

Lesson Plan	Name of the Instructional Material	Argumentation Framework	Learning Objectives	Propositional Knowledge Statements
Lesson Plan I	Find the smallest unit	Competing Theories with Cartoons	F.7.4.1.1. Explain the atom's structure and the fundamental particles in its structure.	1, 2
Lesson Plan II	Story of the atom from the past to present.	Competing Theories with Cartoons	F.7.4.1.1. Explain the atoms' structure the fundamental particles in its structure. F.7.4.1.2. Interpret how ideas about the atom have evolved over time.	1, 3, 4
Lesson Plan III	Learning the structure of the atom and the particles in the structure of atom	Table of Statements	F.7.4.1.1. Explain the atoms' structure the fundamental particles in its structure.	1, 3, 4
Lesson Plan IV	Let's get to know molecule	Competing Theories with Ideas and Evidence	F.7.4.1.3. Define the molecule consisting of when two or more identical or different atoms come together.	14
Lesson Plan V	Let's design molecular models	Argumentation with models	F.7.4.1.4. Design and demonstrate various molecules models.	14
Lesson Plan VI	Particles sizes of substances Who do you think is right?	Competing Theories with Cartoons	F.7.4.1.3. Define the molecule consisting of when two or more identical or different atoms come together.	16, 17 18, 19, 20 21, 22, 23, 24

Table 3.8 (Continued)

Lesson Plan	Name of the Instructional Material	Argumentation Framework	Learning Objectives	Propositional Knowledge Statements
Lesson Plan VII	Let's know the properties of particles closely-1	Predict- Explain Observe	F.7.4.1.3. Define the molecule consisting of when two or more identical or different atoms come together.	5, 6, 7, 8, 9 10, 12, 13, 19
Lesson Plan VII	Let's know the properties of particles closely-2-	Constructing an Argument	F.7.4.1.1. Explain the atom's structure and the fundamental particles in its structure. F.7.4.1.3. Define the molecule consisting of when two or more identical or different atoms come together.	1, 9, 14 19, 23
Lesson Plan IX	Let's know pure substances	Evidence Cards	F.7.4.2.1. Classify elements and compounds as pure substances and list some exemplify.	15, 16, 17 18, 22, 23 24,36
Lesson Plan X	Learning the symbols and uses of the elements	Evidence Cards	F.7.4.2.2. Explain the names, symbols, and usage areas of the first 18 elements in the periodic system and also common elements.	16, 18
Lesson Plan XI	Learning the formulas and use of compounds	Competing Theories with Cartoons	F.7.4.2.3. Explain the names, formulas, names and specific uses of commonly used compounds.	20, 21
Lesson Plan XII	Learning Mixtures	Competing Theories With Ideas and Evidences	F.7.4.3.1. Classify mixtures as homogeneous and heterogeneous and list their examples.	26, 27 28, 29, 30 31, 32,34, 35,37
Lesson Plan XIII	Let's know dissolution And melting closely	Predict- Observe Explain	F.7.4.3.1. Classify mixtures as homogeneous and heterogeneous and list their examples.	24, 29 30, 31, 33

3.3.2.3 Teacher Training

"Practitioner Teacher Information Material on Argumentation and Strategies Providing an Argumentation Environment" was prepared by the researcher to inform the teacher about argumentation (Appendix E). Apart from face-to-face meetings, it is essential to have a guiding source that the teacher can constantly access to facilitate the process. Before each activity, documents were sent to the teacher online in advance every week. At this stage, the questions in the teacher's mind about the lesson plans and activities were answered, and the necessary explanations were provided. At the same time, the researcher was with the teacher throughout every process and communicated with her about any problem that occurred, especially while using interactive science simulations. Lesson plans were prepared in detail for the teacher, and some details were added. These are the literature section containing the misconceptions that need to be eliminated, the sample argument structures expected from the students, the approximate time required for each section, the sample sentence structures that the teacher should express in each section, and the sample speech text expected from the teacher in the closure part of the lesson. In addition, the "Lesson Observation Form for Argumentation (Ozcan et al., 2018)" (Appendix F and Appendix J for permission), the experimental group in-class lesson observation form, was also presented to the teacher. During the implementation, the teacher was asked to pay attention to the items in the observation form. Thus, an effort was made to increase the quality of the ABI application.

3.3.2.4 Argumentation Instruction

The experimental group (7/B) research was completed in 7 weeks and 28 class hours in the 2023-2024 academic year. Students receive 4 lesson hours per week. The science teacher carried out the implementation process of the lessons, and the researcher took part in the classroom as an observer. Before the research, permission to join this study was obtained from each of the students and their parents (Appendix G).

In the first week, after the researcher introduced herself to the students, PNMCT was distributed, and pre-test data were obtained. Next, to create an infrastructure for students to understand the Toulmin argument model and its elements, reinforce the argumentation process, and build their arguments, “Activity 1: What is Argumentation? I am Learning!” (Appendix D) The researcher implemented the activity within three lesson hours. In the first part of the activity, the example frequently used by Toulmin (1958) to illustrate argument elements was shared with the students through cartoons. Selected students then animated the activity, making the subject more understandable, applicable, and eye-catching. The second part of the activity focused on the students identifying the elements in a Toulmin argument model. In the final part of the activity, students observed which questions each element corresponds to during the argumentation process through examples of daily life dialogue. Thus, students were prepared for the argumentation process.

In the second week, the first lesson hour, Activity 2 – “Find the Smallest Unit!” (Appendix C), was applied by the teacher following the instructions specified in Lesson Plan I (Appendix D). The activity aims to evaluate which of the three views on the definition of the atom, the atom-living relationship and the atom-cell relationship is correct using appropriate evidence cards, and thus to provide the concept that atoms do not have the feature of animacy by stating the definition of the atom. Among the reasons why students see the atom as a living structure is that it resembles a cell (Pideci, 2002). For this reason, the teacher started with the concept of a cell and made the students think about a structure smaller than a cell. Then, the students completed the argumentation process individually, in groups, and in-class discussion. The second and third lesson time, Activity 3 – “Story of the Atom from Past to Present” (Appendix C), was carried out following the instructions in Lesson Plan II (Appendix D). First, a short question and answer session was held for the students regarding the “atom-living” relationship discussed in the previous lesson. After asking the students what they think about the validity of scientific knowledge, activity sheets were distributed to them, stating that they would start an argumentation process on scientific studies on the structure of the atom. Students were asked to examine the information in the speech sheets containing the scientist and the atomic theory of the scientist, presented in the form of a cartoon speech on the activity sheet, and to find the atomic theory that is valid today as a result of their evaluation using appropriate evidence cards. After the rules were explained to the students, the argumentation process was completed individually, within the group, and finally as a class discussion. As a result of the debate, the class reached a consensus that "Modern Atomic Theory" is valid today. After the teacher shared the sample text in the "Closure" section of Lesson Plan II with the students, the students answered the 5th question on the activity page. Then, all papers were returned to the teacher. This part, which was first designed as homework, was decided to be written immediately after the activity based on the teacher's advice. In the last class hour, in the previous activity, "y, students questioned more about how the ideas about the concept of an atom have changed from past to present and the changeability of scientific knowledge during the argumentation process. In alignment with the objective, "F.7.4.1.1. Explains the structure of the atom and the fundamental particles in its structure. Activity 4 was designed to teach students about atomic structure and its fundamental particles. This activity was conducted according to the guidelines outlined in Lesson Plan III to promote the students' learning effectively. To reveal the information students had in their minds after the previous activity, the teacher asked: *Which atomic model is valid today? What do we know today about the structure of the atom and the particles in its structure? Is scientific knowledge specific? Do theories change over time?* Then, activity IV was distributed to the students without changing the groups. The students first examined the expressions in the table given to them individually. Then, by adhering to their in-group argumentation process, the students determined whether the claims in the table were true or false by presenting appropriate evidence. After the group writers filled in the sections in the table, the teacher directed each claim in the statements table to the class and asked the groups to explain what they thought. At this stage, other group members were also included as group spokespeople. In addition, to ensure that the students know the differences of opinion between the groups, the teacher asks, "*How are the explanations of this group different from the explanations of the other group?" "How does this group's justification differ from the other?"*. After all the statements were discussed, the teacher opened the interactive atom simulation on the smartboard via the following link https://ogmmateryal.eba.gov.tr/panel/upload/etkilesimli/kitap/kimya/9/unite2/index.html#p=12 and the lesson was concluded by transferring the sample text in the Lesson Plan III closure section to the students and explaining it through simulation.

In the third week, the Particulate Nature of Matter topic continued this week. The first lesson hour, "Activity 5 – Let's Get to Know the Molecule! (Appendix C)," was carried out by following the instructions specified in Lesson Plan IV (Appendix D). The teacher asked, *"What did you learn about the particles in the structure of the atom in our previous lesson?"* The activity started with asking the students questions. Then, after informing the students that they would move on to the topic of molecules, the activity sheet was dedicated to each student. The activity sheet contains some shapes and claims about whether these shapes are molecule models. Students are asked to choose one of the stated claims and justify why they chose this claim using appropriate evidence on the activity page. Some of the evidence presented to students contains scientifically correct, completely incorrect, and partially correct information. The aim here is for students to evaluate the accuracy of existing evidence by using the science textbook as an additional source. In this way, the discussion process was made more active, and the students' careful handling of the evidence was observed. First, the students selected their claims and scored the evidence to present their justifications. Then, the form called "Group Decision" and a statement table were redistributed to each group, and the students were asked to discuss, reach a common consensus, and make a group decision. Since the specified activity was planned to be carried out within one class hour, to use the time better, after expert feedback, the form called "Group Decision" (Appendix C) was included in the form where the groups could only state their claims and why they thought this way. Then, a class discussion occurred, and the group spokespersons explained each group's decision and justifications. Meanwhile, the discussion process between groups with different views began, and the groups put forward strong evidence, that is, the evidence they gave 2 points and the information in the textbook, to convince each other and refute the opposing group's opinion. After the discussion ended, the teacher stated the sample text in the closure section of the lesson plan and ended the lesson by giving homework to the students. During the second and third lesson hours, Activity 6 – "Let's Design Molecular Models" (Appendix C), was carried out following the instructions in Lesson Plan V. The teacher asked questions such as" What *is a molecule?" "Can you give examples of molecules?" "How many atoms are in a molecule?" "How did we find out what it contained and how many types of atoms it contained?"* The lesson started by asking the students these questions. After giving a small reminder to the students, the Activity VI paper and materials with which they could design the molecule model were distributed to each student. These materials included toothpicks, colored cardboard, glue, and play dough. By carrying out steps 1- 2 and 3, they created their arguments, which consisted of claims, data, and warrants. Students first shared their individual arguments and molecule models with their groupmates. Meanwhile, students answered questions about their models and responded to rebuttals against their models. Students wrote and recorded rebuttals to their models in step IV. Then, they moved on to step V. All students placed their molecule designs on the desks, and a mini exhibition was organized. The groups examined all the models individually and started the discussion by asking the designers some questions. These are; *"Why do you think this model represents a molecule? Can you specify whether the molecule model is an element or compound molecule? Why did you use play dough or cardboard in the same color/different colors? "What do the materials you use correspond to? What is the purpose of using different sizes of play dough or cardboard? Can you explain your design and claim? Why did you cut the cardboard like this?".* The teacher always took an active role in the classroom discussions and participated in the discussions as an observer. After completing the considerable class discussion, students were asked to note any changes or developments regarding their first molecule model designs or claims. The existing design in step I was desired to be compared with the design created after step V. After step V was completed, the teacher concluded the lesson by summarizing the topic. In the last class hour, Activity 7 – "Particle Size of Substances – Who Do You Think is Right? " (Appendix C), followed the instructions specified in Lesson Plan VI (Appendix D). After the teacher determined whether the students had any questions about the previous lesson, the teacher asked them: *"Well, have you ever thought about what the smallest structural unit of a substance is that shows its properties or has its properties?"* The activity started with asking questions and distributing the activity sheets to the students. In the activity, which specifically aimed to eliminate students' misconceptions about *"Misconceptions on the Sizes of Particles"* in Lesson Plan VI, students participated in the course first individually, then in groups, and finally in the form of a class discussion. During the individual study process, students determined the idea of one of the cartoons presented to them using appropriate evidence cards and additional source information like the science textbook. After this stage, the students shared their arguments, which consisted of claims, data, and warrants, with their group members and tried to get their ideas accepted by them by entering the discussion process. At this stage, they took note of the opinions of people with different views than themselves. After reaching a consensus, the group writers filled out the group decision form. The writing process of all groups was completed, and the class discussion started. The teacher allowed each group to share their claims with the other groups, using their justifications. It was discussed why groups that made similar claims thought this way, and the similarities and differences between the reasons were presented in the discussion environment. At this stage, the teacher asks, "*How does this group's justification differ from the other group?"*. In the discussion between groups with different opinions, students cited the information in their textbooks as justification, in addition to the evidence cards. The scientific nature of the justifications was also included in the discussion. After the class discussion, where a consensus was reached, the teacher summarized the topic by transferring the sample speech text to the students, including all misconceptions and objectives that the students may have. As a final, the 5th part of Activity VII was given to the students as homework.

In the fourth week, during the first and second lesson hours, as we move on to this week, the topic “Particle Nature of Matter” has been completed, and “Pure Substances” has started. In the first two hours of the week, Activity 8 – “Let’s Know the Properties of Particles Closely-1” (Appendix C), was carried out within the scope of the instructions specified in Lesson Plan VII (Appendix D). The activity includes Predict-Observe-Explain (POE), a strategy that provides an in-class argumentation environment based on the Toulmin Argument Model. The teacher started the lesson by having a conversation based on the question-answer method with the students about the preliminary information specified in the lesson plan. Then, after informing the students about the course process method, she distributed the activity sheets. POE was processed in three steps. In step 1 (Predict-Explain), students individually read each statement and stated why they thought this way. Students were told to use textbooks to strengthen their commitment further. Then, step 2 (Observe) was started. In line with the school’s physical facilities, the teacher opened the “States of Matter: Basic Information” interactive PhET simulation (https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_all.html?locale=tr) with the help of a smart board. First, the teacher herself and then the students examined the necessary situations in the simulation to observe whether the statements were true or false. Meanwhile, other students noted the observations they saw on the board. Finally, pass on to step 3 (Explain). Since this stage is crucial for argumentation, the researcher met with the teacher again about what should be done in this part before the activity. In step 3, students compared their predictions and observations and provided warrants. At this stage, the teacher used question patterns to initiate class discussion and involve students in argumentation. The teacher asked the following questions;

- *Is this statement you described true or false in your point of view?*

- *Who thinks it is correct and why?*
- *Who thinks it is wrong and why? (At this stage, the class was divided into those who believed in right and wrong)*
- *How can you convince the other party who thinks it is right?*
- *How can you convince the other party who thinks it is wrong?*
- *Have there been any changes in your ideas due to your observations? If so, which ones? Who is experiencing similar changes?*
- *Which of your information changed during the event? How?*
- *What made you change your mind in this direction?*

During the discussion process, students used the following phrases;

- *The statement … is true/false.*
- *I thought the statement … was true/false, but I learned from my observations…*
- *I thought that the statement … was true/false, but during class discussion or when comparing my ideas with my friends, … I learned.*
- *… is proof that the statement is true/false. This way, I can persuade someone who disagrees with me.*
- *There has been no change in my predictions and observations, so I … anyone who disagrees with me. I can persuade by providing information such as:*
- *… I cannot entirely agree with the person. Because as a result of my observations, I saw this …*
- *… I agree with his person. Because as a result of my observations …I found the information.*
- *… I think the same as the … person, but … (warrants and data obtained during observation differed)*
- *Well, why do you think this is true? (Although the statement is false, some students still fail to observe that their predictions are wrong through observation). Because I disagree with you;*

After deciding whether each statement was scientifically true or false after a class discussion, the teacher demonstrated the simulation to avoid any question marks in their mind. The lesson ended with a class discussion for each statement, an evaluation of step 3 of POE, a discussion of how ideas changed, and a re-demonstration of the interactive simulation. The third and fourth lesson hours, Activity 8 – “Let’s Know the Properties of Particles Closely-2” (Appendix C), were carried out following the instructions in Lesson Plan VIII (Appendix D), first individually and then as a class discussion. The lesson started with the teacher reminding the subjects of the previous lesson and showing the necessary preliminary information through the lesson video via the smart board. At this stage, care was taken to ensure the initial information was aimed at the misconceptions planned to be minimized in the preceding lesson. Then, after informing the students that they would teach the lesson in an argumentation instruction, the Activity VIII paper was distributed to them. Students structured an argument for Simay’s problem during their time. After the students had created their arguments, the class discussion started, and the students evaluated the argument elements they had written individually in the classroom with their classmates. The teacher conveyed the sample closing text, which includes the misconceptions and objectives planned to be eliminated and specified in the closure section of the lesson plan. Then the lesson ended.

In the fifth week, the topic of Pure Substances continued this week. For the first and second lesson hours, Activity 9 – “Let’s Know Pure Substances” (Appendix C), was implemented by following the instructions specified in Lesson Plan IX (Appendix D). After completing the necessary preparations before the lesson, the teacher started with a question (see Lesson Plan IX-Introduction Part) that enabled the students to move on to the new sub-heading and cause them to think. The activity sheet was distributed to all students. In the activity, students must carefully examine the models presented to them and mark the feature to which each model belongs. In this process, students benefited from the science textbook, which enabled them to form more robust justifications. In addition, for the students who had difficulty making inferences from the pictures of the models whose three-dimensional representations were presented on the image, the teacher also showed the models to the students with the help of video on the smart board. The students first shared the arguments they created individually with their group friends. The group members tried to reach a consensus following the argumentation process and filled out the "Group Decision" form that was presented to them. After all group writers completed their tasks, a class discussion was held. At this stage, the teacher asked the groups what features each model had, and the process of convincing each other began among groups that thought differently. The differences in the proposed warrants were discussed in groups with the same opinion. In the last part of the lesson, the teacher shared the sample text with the students, which included the misconceptions and objectives that needed to be eliminated and stated in the lesson plan. Then, the students filled out the part called "My Changing Ideas, What Did I Learn?" In the third and fourth lesson hours, in these two lesson hours, a process similar to the previous activity was carried out following the instructions in Activity 10 – "Learning the Symbols and Uses of the Elements" in Lesson Plan X (Appendix D). In the activity, students first participated in individual, group, and class discussions. Using the evidence cards presented, they created their argument for each element's usage area and symbol. The first 18 elements in the periodic table are included, depending on the objective of the science course. To avoid confusion between individual and in-group arguments, the activity sheet was redistributed after the personal study, one to each group. After each element was presented for discussion in the closure part of the lesson, students reached a common consensus. Then, the lesson ended with the students filling out the form titled "My Changing Ideas, "What Did I Learn?" (Appendix C).

In the sixth week, the topic of mixtures was started. For the first and second lesson hours, Activity 11 – "Learning the formulas and uses of compounds" (Appendix C) was carried out under the instructions in Lesson Plan XI (Appendix D). In this activity, students participated first individually, then in groups, and finally in the class discussion with the arguments they created. After a brief reminder of the previous lesson, students were asked to think about why compounds are expressed with formulas. Then, the students read the claims in three different cartoons in the activity presented to them, and then they tried to reach a consensus by sharing the arguments consisting of claim, data, and warrant with their group friends. The compounds included in the activity consisted of compounds frequently encountered in daily life, such as water, carbon dioxide, and table salt, and caused students to participate more actively in the discussion. The lesson ended after the group decisions were discussed in class. When the lesson finished, students wrote down the last question on the activity sheet: what they had learned and their changed ideas and handed it over to the teacher. For the third and fourth lesson hours, Activity 12 – "Learning Mixtures" (Appendix C) was carried out according to the sequence in Lesson Plan XII (Appendix D). Four theories were presented regarding the difference in the final state by presenting images of sugar-water and sand-water mixtures after a particular time. Only one of the theories is scientifically correct. Students created their arguments individually, consisting of claims, data, and warrants. They used the evidence cards presented to them and the information in the textbook to strengthen their claims. Then, they discussed it with their group mates and devised a joint group decision. It was noted that the students gained familiarity with the argumentation process as the activity progressed. In addition, since the subject is new for the students, the information on the evidence cards supports the theory that is considered scientifically correct or is in a way that will make it easier for students to choose the correct theory. After the group writers had completed their duties, the teacher asked each group, in turn, about their decision. At this stage, while there was a discussion between groups with different opinions, the reasons of the groups with the same opinion were discussed. The lesson ended with the teacher presenting the sample speech text, which was included in the closure section of the lesson plan. It included all objectives and misconceptions for the students. Then, the students answered the 5th question in the activity sheet and handed the activity sheet to the teacher.

In the seventh week of the study, mixtures were discussed. Activity 13 – "Let's Know Dissolution and Melting Closely" (Appendix C), has been completed following the instructions in Lesson Plan XIII (Appendix D). In the last study activity, students performed the activity in a computer-supported laboratory environment. After completing the necessary preliminary preparations, the teacher reminded the students about the topics they needed to learn in the previous activity by following the question-answer method. Then, the students moved on to the prediction step of POE to understand the differences between melting and dissolution and eliminate possible misconceptions on this subject. They individually formed their justifications by stating the expressions in the first part of the activity sheet as melting or dissolving. During the second step (Observation), each student opened the interactive science simulation called PhET-Sugar and Salt Solutions (https://phet.colorado.edu/sims/cheerpj/sugar-and-salt-solutions/latest/sugar-and-salt-solutions.html?simulation=sugar-and-salt-solutions&locale=tr), which was presented to them on the computer, and researched whether the answers they gave in the first step were correct or incorrect. At this stage, most students did not have difficulty exploring the simulation and taking notes of their observations since the activity sheet included steps on how the simulation should be examined to avoid any possible challenges. In addition, the teacher constantly circulated among the students and guided them using the simulation. Then, the class discussion started, with the students writing down the consistency of their claims and observations in the last step (Explanation). During the class discussion, students formed new ideas based on inconsistencies and participated in the debate by defending these ideas. In addition, the student's individual work leading up to the class discussion led to more diverse justifications and observations in the class discussion part. During the debate, the teacher used the question patterns in Activity 8. Then, the teacher summarized the topic through the simulation and again demonstrated the situations in Step 1 of the science simulation. The lesson was completed after the students handed the activity sheet to the teacher. In the third class hour, the researcher thanked the students for participating in this research, the PNMCT was redistributed to the students, and the post-test data were collected.

3.3.2.5 Curriculum-Based Instruction

In the comparison group (7/C), the "Pure Substances and Mixtures" unit was taught for 7 weeks (28 class hours), which is in line with the 2018 Science Curriculum. In this group, where curriculum-based instruction was used, no activities were carried out for the argumentation process. The teacher used lectures and questioning in the lessons. After the PNMCT pre-test data was collected in the first week, the teacher introduced the Pure Substances and Mixtures Unit to the students. Students were asked to think about what the unit might include and then draw their thoughts. Then, the best image was selected, which reflected the impression created by the Pure Substances and Mixtures Unit topic on students that could represent the unit.

In the second week, the subject of the Particulate Structure of Matter was explained to the students. After the teacher introduced the concepts of atom (nucleus, layer, proton, neutron, and electron) to the students, the students read the relevant sections in the textbook. The relevant video in EBA, a free online education resource for all students by the General Directorate of Innovation and Educational Technologies, was shown after the teacher had the students write down the areas that needed to be noted. In line with expert opinions, it was decided that the same propositional knowledge statements and learning objectives related to the "F.7.4 Pure Substances and Mixtures" unit would be transferred to both groups as per the study; only the instruction method would be different. The teacher verbally expressed a number of 1, 2, 3, and 4 propositional knowledge statements. For example, atoms are not alive. At the end of the lesson, the teacher asked some questions like, "What is an atom?", "Can scientific knowledge change over time?" "Which atomic model is valid today?".

In the third week, the concept of molecules was introduced to the students through the information presented in the Science Textbook (MoNE, 2018). Then, the students re-read the relevant part, and the teacher had the students take notes. Concepts included in the content of the notes include the definition of a molecule, the definition and examples of element and compound molecules, and the determination of the type and number of atoms in a molecule. In the last two class hours of the week, students designed their molecule models with various materials. Then, the teacher told the students that the smallest size of matter should not be evaluated in the dimensions we see or perceive in daily life. She gave the following examples: A minor water particle is not a raindrop. Also, in the last part of the lesson, using a model of a molecule made from play dough, she engaged the students with various questions and answers to convey several vital points: molecules should not be interpreted based on observable properties; a physical effect applied to matter does not affect the molecules and atoms that constitute it; and that the colors of matter are independent of the atoms that make up matter. The teacher verbally relayed the numbered 9, 14, and 23 proposition knowledge statements to the students.

In the fourth week, the topic of Pure Substances was discussed. The teacher started the lesson by asking the students, "Are the atoms that make up gold and water the same?". Then, adhere to the relevant section in the science textbook (MoNE, 2018). After the students read the subject from the textbook, the necessary notes were noted in the notebook. The content of the notes includes the classification of pure substances as elements and compounds, the definition and examples of elements and compounds, the definition and examples of elements with atomic structures and compounds with molecular structures, and although table salt is a compound, it does not have a molecular structure. The lesson ended after watching the relevant EBA videos showing that table salt exists in the form of ion clusters. Propositional knowledge statements numbered 15, 16, 17, 19, 20, 21, 24, 25, and 37 were assessed verbally. In the last two lesson hours of the week, after the periodic system was introduced to the students, the standard 18 elements of the periodic system were read through the textbook in order. Then, the teacher wrote only the names of some of the first 18 elements and the symbols of others on the board and asked the selected students to fill in the blanks. This means propositional knowledge statement number 18 was discussed. Then, the lesson ended by watching the relevant EBA video on the smart board and solving a sample test on the subject.

In the fifth week, students were informed about propositional knowledge statements numbered 5, 6, 7, 8, 9, 10, 11,12, 13, and 19. The teacher bent a water bottle in her hand and then asked the students whether the particles forming the water bottle were affected by this situation. She then stated that the particles are not affected by any changes made to the matter, that the physical properties seen in the substances are not present in the particles, and that the particles can vibrate in the solid state, vibration and translation in the liquid state, and vibration, translation, and rotation in the gas state. Then, the students were asked if they had any questions about the subject, and the first lesson hour was completed. The teacher wanted the students to design a poster during the second lesson. After stating that the poster should include the names and usage areas of the first 18 elements in the periodic system, the posters were hung on the classroom board. In the last two lesson hours of the week, students were informed about the common compound formulas, their names, and where they are used, which was in line with the information in the science textbook (MoNE, 2018). Then, the teacher wrote only the names of some compounds and the formulas of others on the board and asked the students to fill in the blanks. The compounds mentioned were water, ammonia, carbon dioxide, sodium chloride, hydrogen chloride, and nitric acid. In this way, it was focused on propositional knowledge statements numbered 16,18,20,21 and 22. The lesson ended with watching the relevant EBA video after noting the names, formulas, and usage areas of the specified compounds in the notebook and assessing them using the question-and-answer method.

In the sixth week, the topic of mixtures was explained to the students in line with the information in the science textbook (MoNE, 2018). After introducing the concepts of mixture, homogeneous, and heterogeneous mixture to the students through examples, notes were taken in the notebook. Then, students gave examples of mixtures from daily life. Then, various mixture samples were presented to the students on the smart board, and they were asked whether they were homogeneous or heterogeneous, so the lesson ended by watching the relevant EBA videos. Thus, it was focused on propositional knowledge statements numbered 26,27, 28,30, and 31; in the last two class periods of the week, students created homogeneous and heterogeneous mixtures using various materials in the science laboratory and assessed numbers 28, 29, 32, 34, and 35 for propositional knowledge statements. During the activity, the class was divided into two separate groups, and the groups asked each other whether the different mixtures they prepared were homogeneous or heterogeneous.

In the seventh week, relevant experiment simulations were shown as videos in EBA so that the students could better understand the dissolution phenomenon. In this way, students could see the dissolution phenomenon at the micro-scale. Then, it was emphasized that homogeneous mixtures can also be called solutions. The teacher provided different examples of melting and dissolution, enabling the students to see the difference between melting and dissolving. Then, the course ended by addressing the numbers 24, 29, 30, 31, and 33 propositional knowledge statements. At the end of the course, the students were expected to understand clearly (number 36 propositional knowledge statements) that salt is an ionic compound (featured in the EBA video), that sugar dissolves in water, and that the substances that make up the solution do not lose their properties (number 26, 30 31, and 33 propositional knowledge statements). So, students tried to understand that dissolution is not annihilation (dissolution at the micro level is shown in the EBA video). The course ended after the necessary lecture notes were written in the notebook. Then, the researcher thanked the comparison group students for participating in the test. PNMCT post-test data were collected from the comparison group during one class hour. The lesson plan template for the comparison group is presented in Appendix H. In the application, the working process is summarized in Table 3.9.

Table 3. 9 Application Program of "Particulate Nature of Matter" Unit to Study Groups

Week	Date/ Duration	Topic/Core	Research Group	Application Process	Instrument &Instructional Materials
Week 1	21.02.2024 (40 '+40 ')	Pre-Test	Experimental Group	Application of the Concept Test on the Particulate Nature of Matter and Dissolution	Particulate Nature of Matter Concept Test (Appendix E)
		Preparation Argumentation Process	Comparison Group	Explaining the Argumentation Process through Toulmin Argument Model	Activity-1 Part 1 (Appendix C)
	22.02.2024 (40 '+40 ')	Pre-test		Application of the concept test on the Particulate Nature of Matter and Dissolution	Particulate Nature Matter Concept Test (Appendix E)
		F.7.4 Pure Substance and Mixtures	Comparison Group	Introduction of the Unit, Designing Posters About the Unit Concepts	Science textbook
	23.02.2024 (40 '+40 ')	Preparation Argumentation Process	Experimental Group	Explaining the Argumentation Process Through Toulmin Argument Model	Activity -1 Part 2 (Appendix C)
		F.7.4 Pure Substance and Mixtures	Comparison Group	Introduction of the Unit Designing Poster About Unit Concepts	Science textbook

Table 3.9. Application Program of "Particulate Nature of Matter" Unit to Study Groups (Continued)

	28.02.2024 (40 '+40 ')	Misconceptions on Animism	Experimental Group	Revealing Prior Knowledge, Individual-In group- Class Argumentation Process, Summarizing the topic, Assessment	Lesson Plan- I (Appendix D) Activity-2 (Appendix)
		F.7.4.1 Particulate Nature of Matter Atom Scientific Knowledge	Comparison Group	Revealing Prior Knowledge Individual- In group- Class Argumentation Process	Leeson Plan - II (Appendix D) Activity-3 (Appendix C)
Week 2	29.02.2024 (40 '+40 ')	F.7.4.1 Particulate Nature of Matter Atom Scientific Knowledge	Comparison Group EBA Monitoring	Introduction of Topic and Concepts, Reading and Note-taking, Assessment	Science textbook
	01.03.2024 (40 '+40 ')	F.7.4.1 Particulate Nature of Matter Atom Scientific Knowledge	Experimental Group	Argumentation Process Summarizing the topic, Assessment	Leeson Plan - II (Appendix D) Activity-3 (Appendix C)
		F.7.4.1 Particulate Nature of Matter Structure of Atom Elementary Particles	Experimental Group	Revealing Prior Knowledge Individual-In Group- Class, Argumentation Process Summarizing the Topic Assessment	Lesson Plan -III (Appendix D) Activity- 4 (Appendix C)
			Comparison Group	Introduction of Topic and Concepts, Reading and Note-taking Assessment Eba Monitoring	Science textbook

Table 3.9. Application Program of "Particulate Nature of Matter" Unit to Study Groups (Continued)

	06.03.2024 (40 '+40 ')	F .7.4.1 Particulate Nature of Matter Definition of the Molecule	Experimental Group	Revealing Prior Knowledge, Individual-In group- Class Argumentation Process, Summarizing the topic, Assessment	Lesson Plan- IV (Appendix D) Activity-5 (Appendix C)
		F.7.4.1Particulate Nature of Matter Design of the Molecule Model		Revealing Prior Knowledge, Individual Argumentation Process	Leeson Plan - V (Appendix D) Activity-6 (Appendix C)
	07.03.2024 (40 '+40 ')	F.7.4.1 Particulate Nature of Matte Definition of the Molecule	Comparison Group	Introduction of Topic and Concepts, Reading and Note-taking, Assessment	Science textbook
Week 3	08.03.2024 (40 '+40 ')	F.7.4.1 Particulate Nature of Matter Design of the Molecule	Comparison Group	Designing a Molecule Model Exhibition and Assessment Explaining Misconceptions on the Attributing Macroscopic Properties to Particles	Science textbook
	08.03.2024 (40 ')	F.7.4.1 Particulate Nature of Matter Design of the Molecule	Experimental Group	Exhibition of Models, In Group Class Argumentation Process Assessment	Lesson Plan -V (Appendix D) Activity-6 (Appendix C)
	(40 ')	F.7.4.1 Particulate Nature of Matter		Revealing Prior Knowledge, Individual- In Group -Class Argumentation Process About the Topic and Misconceptions on Size of Particles, Summarizing and Assessment	Lesson Plan -VI (Appendix D) Activity- 7 (Appendix C)

Table 3.9. Application Program of "Particulate Nature of Matter" Unit to Study Groups (Continued)

Week 4	13.03.2024 (40 '+40 ')	F.7.4.1Particulate Nature of Matter	Experimental Group	Revealing Prior Knowledge, Individual - Class Argumentation Process About the Misconceptions on Size, Shape and Structure with Interparticle Gaps and Movement of Particles, Summarizing and Assessment	Lesson Plan VII (Appendix D) Activity- 8 Part I (Appendix C)
	14.03.2024 (40 '+40 ')	F.7.4.2 Pure Substances Elements and Compounds	Comparison Group	Introduction Topic and Concepts Reading and Note-Taking EBA Monitoring Assessment	Science textbook
	15.03.2024 (40 '+40 ')	F.7.4.1 Particulate Nature of Matter	Experimental Group	Revealing Prior Knowledge, Individual – Class Argumentation Process on the Attributing Macroscopic Properties to Particles, Summarizing and Assessment	Leeson Plan -VIII (Appendix D) Activity- 8 Part II (Appendix C)
		F.7.4.1 Pure Substance Names and Symbols of The first 18 Elements in the Periodic Table	Experimental Group	Introduction of the Concepts, Reading- Note Taking Fiil in the Blanks Activity about Concepts, EBA Monitoring Assessment	Science textbook

Table 3.9. Application Program of “Particulate Nature of Matter” Unit to Study Groups (Continued)

Week 5	20..03.2024 (40 '+40 ')	F.7.4.2Pure Substances Elements and Compounds	Experimental Group	Revealing Prior Knowledge, Individual – In Group -Class Argumentation Process About the Smallest Module and Structure of Element and Compounds, Summarizing and Assessment	Lesson Plan IX (Appendix D) Activity- 9 (Appendix C)
	21.03.2024 (40 '+40 ')	F.7.4.2 Pure Substances Usage area of first 18 Elements in Periodic Table	Comparison Group	Introduction Misconception on the Size, Shape, Structure with Interparticle Gaps and Movement of Particles, Introduction of the concepts Designing Poster on Concepts	Science textbook
	22.03.2024 (40 '+40 ')	F.7.4.2 Pure Substances Names, Symbols, and Usage Areas of The First 18 Elements in the Periodic Table	Experimental Group	Revealing Prior Knowledge, Individual –In Group- Class Argumentation Process on the Concepts Summarizing and Assessment	Lesson Plan X (Appendix D) Activity- 10 (Appendix C)
		F.7.4.1 Pure Substance Formulas, Names, and Usage Areas of Common Compounds	Comparison Group	Introduction of the Concepts, Reading- Note Taking Fiil in the Blanks Activity about Concepts, EBA Monitoring Assessment	Science textbook

Table 3.9. Application Program of “Particulate Nature of Matter” Unit to Study Groups (Continued)

	27..03.2024 (40 '+40 ')	F.7.4.2 Pure Substance Formulas, Names, and Usage Areas of Common Compounds	Experimental Group	Revealing Prior Knowledge, Individual – In Group -Class Argumentation Process About the Concepts Summarizing and Assessment	Lesson Plan XI (Appendix D) Activity- 11 (Appendix C)
	28.03.2024 (40 '+40 ')	F.7.4.3 Mixtures Mixtures, Homogeneous and Heterogeneous Mixtures, Dissolution	Comparison Group	Introduction of the Concepts Reading and Note-Taking EBA Monitoring	Science textbook
Week 6	29.03.2024 (40 '+40 ')	F.7.4.3 Mixtures Mixtures, Homogeneous and Heterogenous Mixtures, Dissolution	Experimental Group	Revealing Prior Knowledge, Individual –In Group- Class Argumentation Process on the Concepts and Misconceptions on Mixtures and Dissolution Summarizing and Assessment	Lesson Plan XII (Appendix D) Activity- 12 (Appendix C)
		F.7.4.1 Pure Substance Formulas, Names, and Usage Areas of Common Compounds	Comparison Group	Experiment on Concepts, Introduction about Misconceptions on the Mixtures and Dissolution Summarizing	Science textbook

Table 3.9. Application Program of "Particulate Nature of Matter" Unit to Study Groups (Continued)

Week 7	03.03.2024 (40 '+40 ')	F.7.4.3 Mixtures Differences Melting and Dissolving	Experimental Group	Revealing Prior Knowledge, Individual – Class Argumentation Process About the Concepts and Misconceptions on the Concepts and Melting - Dissolution Summarizing and Assessment	Lesson Plan XIII (Appendix D) Activity- 13 (Appendix C)
	04.03.2024 (40 '+40 ')	F.7.4.3 Mixtures Mixtures, Differences Melting and Dissolution	Comparison Group	Introduction of the Concepts and Misconceptions on the Concepts Melting - Dissolution EBA Monitoring and Note-Taking	Science textbook
	05.03.2024 (40 ')	Post-Test	Experimental and Comparison Group	Application of the concept test on the Particulate Nature of Matter and Dissolution	Particulate Nature of Matter Concept Test (Appendix E)

3.4 Data Analysis

In the analysis of two-tier diagnostic tests, the answers given by the students to the first tier of each question and the reasons they chose for these answers are tabulated. In this way, the percentage values are determined by looking at the first and second-tier combinations of the student answers created (Haslam & Treagust, 1987; Odom & Barrow, 1995). In this context, in the first step of the data analysis, to determine the students' misconceptions about the particulate nature of matter and dissolution concepts, the answers given by the students to PNMCT were tabulated by presenting the frequency and percentage values. Then, the students' misconceptions were determined in line with the combinations presented in the prepared table before and after the instruction.

The second step of the data analysis includes analyzing the quantitative data from the PNMCT two-tier diagnostic test. If the student answered correctly in both tiers of the test, they received 1 (one) point; if they answered incorrectly in both tiers or one tier and left blank any of the tiers, they received 0 (zero) points. Thus, the highest score a student can receive from PNMCT is 17, and the lowest score is 0. Based on this, a low score from PNMCT indicates that the student has more misconceptions about the particulate nature of matter and dissolution. In contrast, a high score received from PNMCT demonstrates that the student has fewer misconceptions about this subject. The Shapiro-Wilk normality test was applied to determine whether the dependent variables obtained from the comparison and experimental groups showed normal distribution. Shapiro-Wilk is the normality test that provides the most sensitive results in cases where the sample level is below 50 participants (Uttley, 2019; Razali & Wah, 2011). The analyses were performed using the SPSS 21.0 program, and the significance value was accepted as min. 0.05. According to the Shapiro-Wilk Normality test results (see page…), only the experimental group's PNMCT post-test results showed normal distribution. In this context, to determine whether there was a significant mean difference between the pre-test and post-test scores of the experimental and comparison groups, the

Wilcoxon Signed Ranked Test, one of the non-parametric tests, was used. The Mann-Whitney U test, a non-parametric test, was used to determine whether there were significant differences in mean scores between the experimental and comparison groups, both in the pre-test and post-test results

The last part of the data analysis includes the ontological categorization of students' identified misconceptions. In this direction, the correct ontological categories to which the concepts in the questions should belong and the incorrect ontological categories to which the misconceptions belong were analyzed by presenting frequency and percentage values through ontological category maps.

3.5 Treatment Validity and Verification

In research, fidelity of treatment means verifying that the independent variable is performed as planned (Moncher & Prinz, 1991). This study's treatment fidelity involves applying argumentation instruction to the experimental group (7/B) and curriculum-based instruction to the comparison group (7/C) as planned. To ensure the fidelity of the treatment, the lesson plans and activities to be applied to the experimental group were defined in detail after reviewing the literature on argumentation instruction. The procedures to be implemented in curriculum-based teaching were also determined before the study. The study plan, lesson plans, and course activities presented in the study were reviewed by four Science Education field experts and one Chemistry Education field expert, and necessary arrangements were made.

The study ensured treatment verification by using the "Lesson Observation Form for Argumentation" (Aktamış et al., 2018) (Appendix F). This form, consisting of 24 items including the expected teacher characteristics during the argumentation process, has been used in many studies that integrate the argumentation process into lessons. During the observations, the researcher used this form to document how the teacher implemented the ABI application. After each activity, the results were shared with the teacher, thus aiming to improve the implementation quality of the current study. Based on the findings obtained from the form, from the beginning of the research process, the teacher started the lesson with a highly motivated approach to attract the student's interest by frequently reminding them of their prior knowledge and asking questions. The teacher effectively managed time and classroom order during argumentation, demonstrating tolerance and patience while encouraging students to express their ideas. She guided the argumentation process by asking specific questions to help students when they got stuck (e.g., “Why do you think this way?”, “Which evidence cards did you use to support your claim? Why?”, “How would you defend your idea against the different opinions?”). Additionally, the teacher presented the lesson materials to the class in a complete manner, informed students that they could use science textbooks as resources when necessary, and conducted the lesson by following the instructions in the lesson plan. Furthermore, she displayed an impartial attitude. In addition, the teacher was not observed to be biased toward any groups.

3.6 Validity

In the most general definition, validity is the degree to which research instruments can accurately measure the feature they aim to measure without mixing it with any other feature. In other words, validity can be defined based on the suitability, accuracy, and meaningfulness of the results obtained from research data. In quantitative research methodologies, validity is examined as internal and external (Fraenkel et al., 2012). Considering the research design of the presented research, validity is explained as follows.

3.7 Internal Validity

Fraenkel et al. (2012) state that internal validity means that any other factor does not cause an observed relationship between the dependent and independent variables. With a similar definition, internal validity is the ability of the changes observed from the dependent variable to be explained only by the independent variable (Büyüköztürk et al., 2023). The internal validity of research may be exposed to some threats; other factors may cause the observed changes in the dependent variables. Minimizing possible threats in the study is very beneficial for the accuracy, meaningfulness, usefulness, and appropriateness of the possible results of the research (Fraenkel et al., 2012). This section lists the possible factors that threaten internal validity and how the researcher minimized these threats.

Fraenkel et al. (2012) state that subject characteristics may threaten internal validity in studies comparing groups. This study's experimental and comparison groups are similar in terms of average age, gender ratio, sociocultural status, and academic achievement average in science education. School administrators and the teacher conveyed this situation to the researcher.

Fraenkel et al. (2012) state that mortality may threaten internal validity in studies comparing groups and covering a specific period. The fact that the sample losses are the same in both groups does not pose any problem. Since no students in the experimental and comparison groups left the study during the process, there was no loss of participants. Therefore, this situation does not pose a threat to this study.

Location is among the factors threatening internal validity (Fraenkel et al., 2012). To minimize this threat, the researcher applied pre-test and post-test applications in equal lesson time and a noiseless classroom environment. Their physical competencies are the same in the classes where the experimental and comparison groups were located. The objectives conveyed as a result of some activities carried out in the laboratory in the experimental group were presented to the comparison group in the laboratory environment. Thus, this threat was tried to be eliminated by keeping the location opportunities of the study sample equal and constant.

One of the factors that threatens internal validity in studies is instrumentation. It is discussed under three subheadings: instrument decay, characteristic features of the researcher, and the researcher's bias. If the evaluation of the instrument is quite long and open to different interpretations, this threat may pose a problem (Fraenkel et al., 2012). PNMCT used in this study mainly consists of multiple-choice answers, and its evaluation can only be handled within the framework of scientific answers. Thus, the mentioned threat does not pose a problem for this study. The data obtained in the study were analyzed objectively by the researcher through the SPSS program. The same researcher planned the process throughout the study, thus eliminating other instrumentation threats. In addition, the researcher stated that the tests and activities applied to all participants were a part of their teaching, minimizing the students' feeling that they were in a unique study. Thus, precautions were taken by the researcher against the threat of the subject's attitude (Fraenkel et al., 2012).

A pre-test can be applied to study participants where data are collected over a specific time. This raises awareness among participants before the study and warns them about what the study might be about. This threat, called testing, resulted from the changes observed in the students at the end of the study. It represents that the change is not only due to the independent variables but also as a result of the awareness of the students after the pre-test (Fraenkel et al., 2012). Although this threat could not be eliminated entirely in this study, it was tried to be minimized with some necessary precautions. In this context, before the pre-test, it was emphasized to the students that the study would not affect their report card grades and that they should transfer their thoughts to the test rather than doing wrong or right in the study. Thus, the situation was normalized by ensuring that the students were in a comfortable psychological state.

In research, any unexpected event during the application process may affect the study's result and threaten internal validity. This situation, called history

(Fraenkel et al., 2012), does not threaten this study because it was completed without any problems in accordance with the lesson plans prepared beforehand.

Another factor that is not a threat to this study is maturation. In long-term studies, the aging of the participants and their increasing experience may threaten internal validity (Fraenkel et al., 2012). However, this study was completed within a short period of seven weeks – 26 lesson hours.

Regression also is another factor that threatens internal validity in studies (Fraenkel et al., 2012). The participants' extreme success may overshadow the treatment's effectiveness. This study included student groups whose academic achievements in science courses were not at extreme levels.

The last factor that threatens internal validity in experimental research can be considered as implementation. The shortest and most effective solution research method must be taught to the practicing teacher to minimize this threat. The same science teacher taught unit topics to all research groups in this study. In addition, the implementing teacher was informed about the argumentation process before the study, and the created lesson plans were presented to the teacher in great detail. Additionally, to control the treatment effect, the researcher observed the teacher's steps in applying the treatment, and an observation form was used.

3.8 Limitations

The limitations of this study can be expressed as follows;

- The study participants are limited to 7^{th}-grade students who are available to participate in the study studying in a public school in the Etimesgut district of Ankara in the 2023-2024 academic year.
- The implementation period of the research was limited to 7 weeks – 26 course hours.
- 13 activities supported by strategies that provide an argumentation environment used in the research are limited to the Toulmin Argument Model.

- The findings obtained from the research can only be generalized to identical study groups.
- The research is limited to the misconceptions in the "F.7.4.1. Particulate Nature of Matter, F.7.4.2. Pure Substances, F.7.4.3 Mixtures" in the "F.7.4 Pure Substances and Mixtures" unit presented in science curriculum (MoNE, 2018, pp. 42-43).
- The practitioner teacher's knowledge of argumentation instruction may limit the observation of the desired treatment effectiveness in the study.
- Due to the reasons for misconceptions, the ontological categories to which they belong are limited to the subcategories of the substance category.
- The study sample is limited to 35 participants.
- It was unknown which of the activities designed in line with different argumentation frameworks within the scope of the study is more effective in the conceptual change process.

3.9 Assumptions

The assumptions of this study can be expressed as follows;

- Participants responded to the research instrument sincerely, impartially, and honestly.
- The time and environmental conditions provided are sufficient for the instrument to respond.
- The results observed in the dependent variable were not affected by any other variable other than the dependent variables.
- Experimental and comparison group students did not interact with each other at a level that would affect the study results.

CHAPTER 4

RESULTS

This section includes the findings obtained regarding the research results. In the first part, the misconceptions obtained by evaluating the PNMCT responses of the study groups are presented. The second part presents the statistical analysis results regarding the conceptual understanding of the study groups before and after the instruction on the particulate nature of matter and dissolution. In the last section, the ontological reasons for the detected misconceptions are determined, and the effect of the applied instructional methods on eliminating misconceptions originating from incorrect placement in lateral and superordinate ontological categories is presented.

4.1 Results for the Identifying Misconceptions on Particulate Nature of Matter and Dissolution

The study's first main research question is, "What are the misconceptions of 7th-grade students about the particulate nature of matter and dissolution?" To find an answer to this research question, the analysis steps recommended by Haslam and Treagust (1987), Odom (1995), and Peterson et al. (1989) were followed thoroughly. First, all the response combinations given by the participant groups to each item in the PNMCT were analyzed by indicating the percentages. The analysis of the tables obtained from the responses given by the participant groups to each item in the concept test before and after the instruction provided the researcher with detailed information about the students' misconceptions related to the topic in the item. In the second stage, a summary table of the correct content and correct content-reason combination given by the participant groups to each item was prepared from the results obtained from the response combinations (see Table 4.52). This table is essential in revealing whether the students have achieved a satisfactory understanding of the concept and the expressions related to the concept in the test item (Odom, 1995; Peterson et al., 1989). At this stage, to make more detailed comments on the item, the correct content-reason combinations given by the participant groups to the items before and after the instruction were presented on graphs (see Figure 4.1 and Figure 4.2). At the last stage, the misconceptions detected within the scope of the particulate nature of the matter, pure substances, and mixtures, which constitute the content of PNMCT, were presented.

The first item of PNMCT is given in Table 4.1. The percentages of each response combination selected by the experimental group and comparison group for item 1 of the PNMCT before the instruction are presented in Table 4.2. after the instruction presented in Table 4.3.

The 1st item of PNMCT tests the knowledge that the atom, the basic building block of all living and non-living entities, is not alive. As indicated in Table 4.2., before the instruction, the correct content option was chosen by 6.25% of the comparison group and 21.05% of the experimental group, while 6.25% and 21.05% of the participants chose the correct content and reason options, respectively. As indicated in Table 4.3., after the instruction, the correct content option was chosen by 6.25% of the comparison group and 94.74% of the experimental group, while 0% and 94.74% of the participants chose the correct content and reason combination, respectively.

Table 4. 1 Item 1 of the Particulate Nature of Matter Concept Test

Green leaves (those that have not been plucked) comprise living cells containing atoms. The element iron is also made up of iron atoms. Accordingly,

a) The atoms in the leaf are alive.

b) The atoms in iron are alive.

*c) The atoms in the leaf and iron are inanimate.

d) The atoms in the leaf and iron are alive.

e) Leaf atoms are alive; Iron atoms are inanimate

Reason:

1. The atoms in iron are alive because they are mobile.

* 2. Atoms do not have the property of vitality.

3. Since the leaf is alive, its atoms are also alive.

4. All atoms are alive, no matter what type of atom they are.

5. Since the leaf is alive, its atoms are alive, and since iron is inanimate, its atoms are inanimate.

6. None. In my opinion, the reason:

*Correct Statements

Table 4. 2 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 1 of the Particulate Nature of Matter Concept Pre-Test

		Reason						
Group	First Tier	1	2	3	4	5	6	Total
Comparison Group	a	0.0	0.0	12.5	6.25	0.0	0.0	18.75
	b	0.0	0.0	25.00	0.0	0.0	0.0	25.00
	c	0.0	6.25*	0.0	0.0	0.0	0.0	6.25
	d	6.25	0.0	0.0	6.25	0.0	0.0	12.5
	e	0.0	0.0	0.0	0.0	37.5	0.0	37.5
Experimental Group	a	0.0	10.53	0.0	0.0	0.0	0.0	10.53
	b	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	c	0.0	21.05*	0.0	0.0	0.0	0.0	21.05
	d	0.0	0.0	0.0	15.79	0.0	0.0	15.79
	e	0.0	0.0	5.26	0.0	47.37	0.0	52.63

*Correct Answer

Table 4. 3 The percentage of the Comparison Group and Experimental Group Answer Combination for Item 1 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	6	Total
Comparison Group	a	6.25	0.0	6.25	0.0	0.0	0.0	12.50
	b	6.25	6.25	0.0	0.0	0.0	0.0	12.50
	c	0.0	0.0*	0.0	0.0	6.25	0.0	6.25
	d	0.0	0.0	12.5	25.0	0.0	0.0	37.50
	e	0.0	0.0	0.0	0.0	31.25	0.0	31.25
Experimental Group	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	c	0.0	94.74*	0.0	0.0	0.0	0.0	94.74
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	e	0.0	0.0	0.0	0.0	5.26	0.0	5.26

*Correct Answer

The second item of PNMCT is given in Table 4.4. The percentages of each response combination selected by the experimental group and comparison group for item 2 of the PNMCT before the instruction are presented in Table 4.5. after the instruction presented in Table 4.6.

The 2nd item of the PNMCT examines whether the macroscopic properties of matter are also present in the atoms that make up the matter, specifically focusing on the gold element. As indicated in Table 4.5, before the instruction, no one in the comparison group gave the desired content answer, while 5.26% of the experimental group gave the correct content answer. At the same time, 5.26% of the experimental group chose the correct content and reason options. As indicated in Table 4.6, no correct content or correct content-reason combination was found in the comparison group students after the instruction. In the experimental group, 78.95% of the participants chose the correct content, while 73.69% chose the correct content-reason combination.

Table 4. 4 Item 2 of the Particulate Nature of Matter Concept Test

Which of the following statements about the properties of gold atoms is true?

I. Gold atoms are shiny and stiff.

II. If gold is heated, its atoms also heat up

III. When gold is shaped, its atoms take the same shape.

IV. The bulk of the volumes of gold atoms is void.

a) Only I b) Only II c) Only III *d) Only IV e) I, II and III

Reason:

1. Every change made to gold from the outside affects its atoms similarly.

* 2. Considering the volume of the atom and the volume of its nucleus, the volume of the nucleus is minimal compared to the volume of the atom. Therefore, the rest of the atom is a vacuum (If the atom's volume is considered as much as the football field, the volume of the nucleus is as much as the ball on this field).

3. Every property of gold is also found in its atoms.

4. None. In my opinion, the reason:

*Correct Answer

Table 4. 5 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 2 of the Particulate Nature of Matter Concept Pre-Test

		Reason				
Group	First Tier	1	2	3	4	Total
Comparison Group	a	6.25	6.25	6.25	6.25	25.00
	b	12.5	0.0	6.25	0.0	18.75
	c	0.0	0.0	0.0	0.0	0.0
	d	0.0	0.0*	0.0	0.0	0.0
	e	37.5	6.25	12.5	0.0	56.25
Experimental Group	a	0.0	5.26	0.0	0.0	5.26
	b	0.0	5.26	5.26	10.52	21.05
	c	0.0	5.26	0.0	0.0	5.26
	d	0.0	5.26*	0.0	0.0	5.26
	e	47.36	10.53	5.26	0.0	63.16

*Correct Answer

Table 4. 6 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 2 of the Particulate Nature of Matter Concept Post-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison Group	a	0.0	0.0	6.25	0.0	0.0	6.25
	b	0.0	12.50	6.25	0.0	6.25	25.0
	c	0.0	6.25	0.0	0.0	0.0	6.25
	d	0.0	0.0*	6.25	0.0	0.0	6.25
	e	25.0	6.25	12.5	0.0	0.0	43.75
	No Content	6.25	6.25	0.0	0.0	0.0	12.5
Experimental Group	a	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	10.53	0.0	0.0	0.0	10.53
	c	5.26	0.0	5.26	0.0	0.0	10.52
	d	0.0	73.69*	0.0	0.0	5.26	78.95
	e	0.0	0.0	0.0	0.0	0.0	0.0

*Correct Answer

The third item of PNMCT is given in Table 4.7. The percentages of each response combination selected by the experimental group and comparison group for item 3 of the PNMCT before the instruction are presented in Table 4.8. and after the instructions presented in Table 4.9.

The 3rd item of the PNMCT, using the example of a sugar-water solution, demonstrates that dissolution is not a chemical event. According to the findings in Table 4.8, before the instruction, 18.75% of the comparison group and 15.79% of the experimental group chose the correct content, while 6.25% and 10.53% of them chose the correct content-reason combination, respectively. As indicated in Table 4.9, after the instruction, 12.5% of the comparison group and 84.21% of the experimental group chose the desired content, while 6.25% and 68.43% of them chose the desired content and reason options, respectively.

Table 4. 7 Item 3 of the Particulate Nature of Matter Concept Test

When a teaspoon of sugar is thrown into a glass of room-temperature water, the sugar reacts chemically with the water.

a) True

*b) False

Reason:

1. When sugar dissolves in water, a new compound is formed
2. Sugar melts in water.
3. When sugar dissolves in water, it turns into water

*4. Water molecules surround the sugar particles when sugar dissolves in water.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 8 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 3 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison	a	12.5	31.25	12.50	25.0	0.0	81.25
Group	b	0.0	12.25	0.0	6.25*	0.0	18.75
Experimental	a	5.26	42.11	15.79	21.05	0.0	84.21
Group	b	5.26	0.0	0. 0	10.53*	0.0	15.79

*Correct Answer

Table 4. 9 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 3 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	18.75	25.00	0.0	37.5	0.0	6.25	87.5
Group	b	6.25	0.0	0.0	6.25*	0.0	0.0	12.5
Experimental	a	0.0	0.0	15.79	0.0	0.0	0.0	15.79
Group	b	0.0	5.26	5.26	68.43*	0.0	5.26	84.21

*Correct Answer

The fourth item of PNMCT is given in Table 4.10. The percentages of each response combination selected by the experimental group and comparison group for item 4 of the PNMCT before the instruction are presented in Table 4.11., and after the instruction presented in Table 4.12. The purpose of the fourth item of PNMCT is to ask whether there is any change in the volume of the particles of the substance while the substance is undergoing a phase change. With this question, the information on the water sample is tested to determine whether there is any change in the volume, i.e., the dimensions, of the water molecules due to the phase change.

Table 4. 10 Item 4 of the Particulate Nature of Matter Concept Test

Which of the following is true about water molecules?

a) The size of the molecules is largest when water is in the solid state and most minor when it is in the liquid state.

b) When water is solid, the size of its molecules is the smallest, and when it is gaseous, it is the largest.

*c) Water molecules are the same size in all three states.

d) When water is in a liquid state, the size of its molecules is the largest, and in a solid state, it is the smallest.

Reason:

1. From solid to liquid, from liquid to gas, the volume of molecules increases.

2. From solid to liquid, from liquid to gas, the volume of molecules decreases.

*3. The volume of the molecule does not change with the change of state.

4. None. In my opinion, the reason is:

*Correct Answer

Table 4. 11 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 4 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison Group	a	0.0	12.5	0.0	0.0	0.0	12.5
	b	18.75	6.25	6.25	0.0	0.0	31.25
	c	0.0	12.5	31.25*	0.0	6.25	50.00
	d	0.0	0.0	0.0	0.0	6.25	6.25
Experimental Group	a	15.78	21.05	0.0	0.0	0.0	36.83
	b	10.53	10.53	0.0	0.0	0.0	21.06
	c	0.0	0.0	31.58*	0.0	0.0	31.58
	d	10.53	0.0	0.0	0.0	0.0	10.53

*Correct Answer

Table 4. 12 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 4 of the Particulate Nature of Matter Concept Post-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison Group	a	6.25	18.75	6.25	0.0	0.0	31.25
	b	0.0	0.0	6.25	0.0	0.0	6.25
	c	0.0	6.25	12.5*	0.0	6.25	25.0
	d	18.75	6.25	6.25	6.25	0.0	37.5
	No Content	0.0	0.0	0.0	0.0	6.25	6.25
Experimental Group	a	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	5.26	0.0	0.0	5.26
	c	0.0	0.0	89.48*	0.0	0.0	89.48
	d	5.26	0.0	0.0	0.0	0.0	5.26
	No Content	0.0	0.0	0.0	0.0	0.0	0.0

*Correct Answer

As shown in Table 4.11, before the instruction, 50% of the comparison group and 31.58% of the experimental group chose the correct content option, while 31.25% and 31.58% chose the correct content-reason combination, respectively. This rate decreased in the comparison group after the instruction and increased in the experimental group. When the data in Table 4.12. is evaluated, 25% of the comparison group and 89.48% of the experimental group gave the correct content answer, while 12.5% and 89.48% answered the correct content and reason, respectively.

The fifth item of PNMCT is given in Table 4.13. The percentages of each response combination selected by the experimental group and comparison group for item 5 of the PNMCT before the instruction are presented in Table 4.14., and after the instruction presented in Table 4.15.

Table 4. 13 Item 5 of the Particulate Nature of Matter Concept Test

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When iron is solid, <u>its atoms</u> do not move.

a) True

*b) False

Reason:

1. In the solid state, the atoms do not move because there is no space between the atoms.

2. Atoms do not move because the solid state is the most ordered state of matter.

* 3. In the solid state, atoms make a vibratory motion.

4. None. In my opinion, the reason is:

---

*Correct Answer

Table 4. 14 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 5 Of the Particulate Nature of Matter Concept Pre-Test

		Reason				
Group	First Tier	1	2	3	4	Total
Comparison	a	43.75	0.0	0.0	0.0	43.75
Group	b	6.25	12.50	37.50*	0.0	56.25
Experimental	a	42.11	5.26	5.26	0.0	52.63
Group	b	0.0	0.0	47.37*	0.0	47.37

*Correct Answer

Table 4. 15 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 5 Of the Particulate Nature of Matter Concept Post-Test

		Reason				
Group	First Tier	1	2	3	4	Total
Comparison	a	68.75	0.0	6.25	0.0	75.0
Group	b	6.25	0.0	18.75*	0.0	25.0
Experimental	a	0.0	0.0	0.0	0.0	0.0
Group	b	0.0	0.0	100.0*	0.0	100.0

*Correct Answer

The 5th item of the PNMCT tests the knowledge that particles of solid matter make vibrational movements independent of the physical properties of the matter within the scope of the particulate structure of matter topic. According to Table 4.14, before the instruction, 56.25% of the comparison group and 47.37% of the experimental group provided the expected content response, while 37.50% and 47.37% provided the expected content and reason combination, respectively. After the instruction, the indicated rates increased in the experimental group and decreased in the comparison group. In other words, when the data in Table 4.15 is examined, 25% of the comparison and entire experimental groups provided the desired content response. Meanwhile, 18.75% of the comparison and 100% of the experimental group chose the correct content-reason combination.

The sixth item of PNMCT is given in Table 4.16. The percentages of each response combination selected by the experimental group and comparison group for item 6 of the PNMCT before the instruction are presented in Table 4.17., and after the instruction presented in Table 4.18.

Table 4. 16 Item 6 of the Particulate Nature of Matter Concept Test

---

Liquids take the shape of the container they are in. According to this information, the shape of water molecules varies depending on the container in which it is located.

a) True

*b) False

Reason:

1. Since water molecules are solid, their shape does not change.

2. Water molecules are flexible.

* 3. No matter the container's shape, the molecules' shape does not change.

4. Water molecules are shaped like water drops.

5. None. In my opinion, the reason is

---

*Correct Answer

Table 4. 17 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 6 of the Particulate Nature of Matter Concept Pre-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	6.25	18.75	6.25	6.25	25.0	6.25	68.75
Group	b	12.5	0.0	18.75*	0.0	0.0	0.0	31.25
Experimental	a	5.26	26.32	0.0	15.79	5.26	5.26	57.89
Group	b	5.26	0.0	36.84*	0.0	0.0	0.0	42.1

*Correct Answer

Table 4. 18 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 6 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	0.0	31.25	12.5	25.0	0.0	0.0	68.75
Group	b	12.5	0.0	18.75*	0.0	0.0	0.0	31.25
Experimental	a	0.0	5.26	0.0	5.26	0.0	0.0	10.52
Group	b	10.53	0.0	78.95*	0.0	0.0	0.0	89.48

*Correct Answer

In the 6th item of PNMCT, within the scope of the particulate structure of matter, the knowledge that the shapes of the particles constituting matter are not evaluated at the macro level was tested. In the question addressed through the example of the shape of water molecules, as indicated in the information in Table 4.17, 31.25% of the comparison group and 42.1% of the experimental group marked the correct content answer, while 18.75% and 36.84% marked the correct content-reason combination, respectively. While no change was observed in the rates of the comparison group after the instruction, there was a positive increase in the experimental group. When

Table 4.18 is examined, 89.48% of the experimental group selected the desired content, and 78.95% selected the desired content-reason combination.

The seventh item of PNMCT is given in Table 4.19. The percentages of each response combination selected by the experimental group and comparison group for item 7 of the PNMCT before the instruction are presented in Table 4.20., and after the instruction presented in Table 4.21.

In the 7th item of PNMCT, within the scope of the particulate structure of matter, the knowledge that the phases of matter are related to particle motion is tested. As indicated in the rates presented in Table 4.20 before the instruction, the desired content and the desired content-reason combination were relatively low for both groups. While only 18.75% of the comparison group and 15.78% of the experimental group chose the correct reason, 12.5% of the comparison group and only 5.26% of the experimental group chose the content and reason combination correctly. According to the rates in Table 4.21, the rate of the desired content response after the instruction increased to 68.42% in the experimental group, while it decreased to 12.5% in the comparison group. In addition, 47.37% of the experimental group and 6.25% of the comparison group chose the correct content-reason combination.

Table 4. 19 Item 7 of the Particulate Nature of Matter Concept Test

Which of the following statements would be correct for ice and water molecules?

a) Ice molecules are solid, and water molecules are liquid.

b) Both ice and water molecules are solids.

c) Both ice and water molecules are liquids.

* d) Molecules do not exist in liquid or solid form.

Reason:

*1. Whether matter is solid or liquid is related to the interactions between its molecules.

2. Molecules are always present in liquid form.

3. Since ice is solid, its molecules are solid, and since water is liquid, the molecules are liquid.

4. Molecules are always present in the solid state.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 20 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 7 of the Particulate Nature of Matter Concept Pre-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison Group	a	31.25	0.0	25.0	0.0	0.0	0.0	56.25
	b	0.0	0.0	6.25	12.5	0.0	0.0	18.75
	c	0.0	0.0	6.25	0.0	0.0	0.0	6.25
	d	12.5*	0.0	0.0	6.25	0.0	0.0	18.75
Experimental Group	a	10.53	0.0	52.64	0.0	0.0	0.0	63.17
	b	0.0	0.0	5.26	10.53	0.0	0.0	15.79
	c	0.0	0.0	0.0	5.26	0.0	0.0	5.26
	d	5.26*	0.0	0.0	5.26	0.0	5.26	15.78

*Correct Answer

Table 4. 21 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 7 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison Group	a	12.5	0.0	25.0	6.25	0.0	0.0	43.75
	b	0.0	0.0	6.25	18.75	0.0	0.0	25.0
	c	6.25	6.25	0.0	0.0	0.0	6.25	18.75
	d	6.25*	0.0	6.25	0.0	0.0	0.0	12.5
Experimental Group	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	0.0	15.80	0.0	0.0	15.80
	c	5.26	5.26	5.26	0.0	0.0	0.0	15.78
	d	47.37*	5.26	0.0	0.0	5.26	10.53	68.42

*Correct Answer

The eighth item of PNMCT is given in Table 4.22. The percentages of each response combination selected by the experimental group and comparison group for item 7 of the PNMCT before the instruction are presented in Table 4.23. after the instruction presented in Table 4.24.

Table 4. 22 Item 8 of the Particulate Nature of Matter Concept Test

The smallest particle that makes up alcohol is the alcohol droplet, and the smallest particle that makes up granulated sugar is the sugar crystal.

a) True

*b) False

Reason:

1. The particles of sugar and alcohol are identical.

*2. Alcohol is from alcohol molecules; sugar, conversely, is made up of sugar molecules.

3. The smallest particles of sugar and alcohol are their most minor visible parts.

4. None. In my opinion, the reason is:

*Correct Answer

Table 4. 23 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 8 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison Group	a	6.25	25.0	18.75	0.0	0.0	50.0
	b	6.25	37.5*	0.0	0.0	6.25	50.0
Experimental Group	a	0.0	26.32	21.05	0.0	0.0	47.37
	b	5.26	31.58*	10.53	5.26	0.0	52.63

*Correct Answer

Table 4. 24 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 8 of the Particulate Nature of Matter Concept Post-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison	a	31.25	37.5	6.25	0.0	0.0	75.0
Group	b	0.0	25.0*	0.0	0.0	0.0	25.0
Experimental	a	0.0	10.53	0.0	0.0	0.0	10.53
Group	b	0.0	78.95*	5.26	0.0	5.26	89.47

*Correct Answer

The 8th question of PNMCT tests the knowledge that the smallest particles of compounds that carry their chemical properties are molecules within the scope of the subject of pure substances through alcohol and sugar compounds. As indicated in Table 4.23, almost half of the study groups gave the desired content answer before the instruction. This rate was 50.0% in the comparison group and 52.63% in the experimental group. After the instruction, the expected correct content rate decreased to 25.0% in the comparison group and increased to 89.47% in the experimental group. Before the instruction, the correct content-reason combination was determined to be 37.5% in the comparison group and 31.58% in the experimental group. After the instruction, this rate decreased to 25.0% in the comparison group and increased to 78.95% in the experimental group, as indicated in Table 4.24.

The ninth item of PNMCT is given in Table 4.25. The percentages of each response combination selected by the experimental group and comparison group for item 9 of the PNMCT before the instruction are presented in Table 4.26. after the instruction presented in Table 4.27.

Table 4. 25 Item 9 of the Particulate Nature of Matter Concept Test

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When some water is left in the refrigerator, it freezes and turns into ice. During this event, water molecules ....

I. Cools II. Freezes III. Shrinks IV. Grows V. Immutable

a) Only IV

*b) Only V

c) I and II

d) I, II, and III

e) I, II, and IV

Reason:

1) Since the temperature decreases during freezing, the temperature of the molecules also decreases, so the molecules freeze.

2) Since the temperature decreases during freezing, the temperature of the molecules also decreases, so the molecules freeze and their volume decreases.

*3) Freezing does not cause a change in the size of the molecules.

4) Since the temperature decreases during freezing, the temperature of the molecules also decreases, so the molecules cool, freeze, and increase in volume.

5) Since water is a substance whose volume increases when freezing, the molecules grow.

6) None. In my opinion, the reason is:

---

*Correct Answer

Table 4. 26 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 9 of the Particulate Nature of Matter Concept Pre-Test

		Reason						
Group	First Tier	1	2	3	4	5	6	Total
Comparison Group	a	0.0	6.25	0.0	6.25	0.0	0.0	12.5
	b	0.0	0.0	12.5*	0.0	0.0	0.0	12.5
	c	0.0	0.0	6.25	0.0	0.0	0.0	6.25
	d	18.75	18.75	0.0	0.0	0.0	6.25	43.75
	e	12.50	12.50	0.0	0.0	0.0	0.0	25.0
Experimental Group	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	5.26*	0.0	0.0	0.0	5.26
	c	15.80	5.26	5.26	5.26	0.0	0.0	31.58
	d	15.80	5.26	0.0	10.52	5.26	0.0	36.84
	e	15.80	5.26	5.26	0.0	0.0	0.0	26.32

*Correct Answer

Table 4. 27 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 9 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	6	Total
Comparison Group	a	0.0	0.0	0.0	6.25	0.0	0.0	6.25
	b	0.0	0.0	12.5*	0.0	0.0	0.0	12.5
	c	25.0	0.0	12.5	0.0	0.0	0.0	37.5
	d	0.0	25.0	6.25	6.25	0.0	0.0	37.5
	e	6.25	0.0	0.0	0.0	0.0	0.0	6.25
Experimental Group	a	0.0	5.26	5.26	0.0	0.0	0.0	10.52
	b	0.0	0.0	68.42*	0.0	0.0	0.0	68.42
	c	0.0	0.0	5.26	0.0	0.0	0.0	5.26
	d	0.0	5.26	0.0	0.0	0.0	0.0	5.26
	e	0.0	0.0	0.0	5.26	5.26	0.0	10.52

*Correct Answer

The 9th item of PNMCT tests the knowledge that the temperature and volume changes observed in the phase change of matter are not observed in particles within the scope of the particulate structure of matter. In the pre-test results of the question on the example of water molecules in Table 4.26, 5.26% of the experimental group and 12.5% of the comparison group gave the desired content answer. There was no change in the data regarding the correct content-reason combination. As indicated in Table 4.27, after the instruction, the rate of valid content and valid content-reason combination remained constant at 12.5% in the comparison group. In comparison, 68.42% of the experimental group marked the desired content answer with the reason.

The tenth item of PNMCT is given in Table 4.28. The percentages of each response combination selected by the experimental group and comparison group for item 10 of the PNMCT before the instruction are presented in Table 4.29., and after the instruction presented in Table 4.30. As indicated in Table 4.28., the purpose of the 10th item of PNMCT is to test the knowledge that there is no change in the particles of solid matter due to heat transfer within the scope of the subject of the particulate nature of matter. In this item asked on the example of iron, it was questioned whether there is any change in the amount of heat, temperature change, and volume of the particles forming the iron as the iron receives heat; in other words, the necessity of not attributing macroscopic properties to the particles. In the pre-test results in Table 4.29, 56.25% of the comparison group and 10.53% of the experimental group gave the correct content answer. The correct content-reason combination was given by 10.53% of the experimental group and 18.75% of the comparison group. After the instruction, the correct content answer and content-reason combination rate decreased in the comparison group and regressed to 12.5%. This rate increased in the experimental group to 63.16%.

Table 4. 28 Item 10 of the Particulate Nature of Matter Concept Test

Iron atoms when a piece of iron is melted by giving heat...............

I. Heats II. Melts III. Grows IV. Does not change V. Shrinks

*a) Only IV b) Only V c) I and II d) II and III e) I, II, and III

Reason:

1. Iron atoms shrink as the volume decreases during melting.

2. Since iron receives heat during melting, its atoms also heat up, so the atoms melt, increasing their volume.

*****3. Melting does not cause a change in atoms.

4. During melting, the temperature of the atoms does not change, but the atoms melt, and thus, the volume of the atoms increases.

5. As the temperature increases during melting, the atoms heat up and melt. There will be no further changes.

6. None. In my opinion, the reason is

*Correct Answer

Table 4. 29 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 10 of the Particulate Nature of Matter Concept Pre-Test

Group	First Tier	Reason						
		1	2	3	4	5	6	Total
Comparison	a	12.5	0.0	18.75*	25.0	0.0	0.0	56.25
Group	b	6.25	0.0	0.0	0.0	0.0	0.0	6.25
	c	12.5	6.25	6.25	0.0	12.5	0.0	37.5
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	e	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Experimental	a	0.0	0.0	10.53*	0.0	0.0	0.0	10.53
Group	b	0.0	0.0	5.26	0.0	0.0	0.0	5.26
	c	0.0	26.32	0.0	0.0	26.32	0.0	52.64
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	e	5.26	21.05	0.0	5.26	0.0	0.0	31.57

*Correct Answer

Table 4. 30 The percentage of the Comparison Group and Experimental Group Answer Combination for Item 10 of the Particulate Nature of Matter Concept Post-Test

Group	First Tier	Reason						
		1	2	3	4	5	6	Total
Comparison	a	0.0	0.0	12.5*	0.0	0.0	0.0	12.5
Group	b	6.25	6.25	0.0	0.0	0.0	0.0	12.5
	c	6.25	6.25	12.5	6.25	12.5	0.0	43.75
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	e	6.25	12.5	0.0	12.5	0.0	0.0	31.25
Experimental	a	0.0	0.0	63.16*	0.0	0.0	0.0	63.16
Group	b	0.0	0.0	10.54	0.0	0.0	0.0	10.54
	c	5.26	0.0	5.26	0.0	5.26	0.0	15.78
	d	0.0	0.0	0.0	0.0	5.26	0.0	5.26
	e	0.0	0.0	0.0	0.0	5.26	0.0	5.26

*Correct Answer

The eleventh item of PNMCT is given in Table 4.31. The percentages of each response combination selected by the experimental group and comparison group for item 11 of the PNMCT before the instruction are presented in Table 4.32., and after the instruction presented in Table 4.33.

The 11th item of PNMCT tests the knowledge that dissolution is a physical event within the scope of mixtures by considering the dissolution of sugar in water in particle size. As indicated in Table 4.32 before the instruction, more than half of the study groups answered correctly to the content answer. This rate was 81.25% in the comparison group and 84.22% in the experimental group. The correct content-reason combination was relatively low. While it was only 6.25% in the comparison group, it was only 5.26% in the experimental group. As indicated in Table 4.33 after the instruction, while 75.0% of the comparison group gave the correct content answer, all students in the experimental group could give the correct content answer. Again, the correct content-reason combination rate was relatively low. While this rate was 18.75% in the comparison group, it was 26.31% in the experimental group.

Table 4. 31 Item 11 of the Particulate Nature of Matter Concept Test

A few sugar cubes are placed in a beaker (heat-resistant glass container) containing water (case I). The figure shows that if the mixture is left at room temperature long enough, the sugar cubes will become invisible, and the water will taste sugary (case II).

Is this sentence true or false?

*a) True

b) False

Reason:

1. Sugar molecules melt and form a liquid by receiving heat from the environment. This liquid mixes with water.

2. The sugar fills the water's air spaces and is lost.

*3. Water molecules surround the sugar molecules from the surfaces of the cubes and push them away from each other.

4. Sugar cubes are only soluble in water when mixed. Stirring causes the sugar cubes to break into smaller pieces, which spread out in the water and cannot be seen.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 32 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 11 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison	a	50.0	0.0	6.25*	25.0	0.0	81.25
Group	b	0.0	6.25	0.0	12.5	0.0	18.75
Experimental	a	42.11	10.53	5.26*	26.32	0.0	84.22
Group	b	5.26	5.26	5.26	0.0	0.0	15.78

*Correct Answer

Table 4. 33 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 11 of the Particulate Nature of Matter Concept Post-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison	a	31.25	12.5	18.75*	12.5	0.0	75.0
Group	b	12.5	6.25	6.25	0.0	0.0	25.0
Experimental	a	5.26	52.64	26.31*	15.79	0.0	100.0
Group	b	0.0	0.0	0.0	0.0	0.0	0.0

*Correct Answer

The twelfth item of PNMCT is given in Table 4.34. The 12th item of PNMCT tests the knowledge that an element's properties result from the interaction of the particles that make up the element within the scope of the subject of pure substances. The percentages of each response combination selected by the experimental group and comparison group for item 12 of the PNMCT before the instruction are presented in Table 4.35., and after the instruction presented in Table 4.36.

Table 4. 34 Item 12 of the Particulate Nature of Matter Concept Test

Information: Sulphur is an element with the symbol S, atomic number 16, and is in group VI A of the periodic table. It exists at room temperature as a solid in lemon yellow. An example of sulfur in solid form has the following properties:

(I) Brittle, (II) Melting point 113°C.

If so, which properties above are the same for a single sulfur atom taken from the sample?

a) I and II

b) Only I

c) Only II

*d) None

Reason:

1. Sulphur is a nonmetal, so the sulfur atom melts at a comparatively lower temperature.

*2. The properties of an element are the result of the interaction between the particles of this element.

3. An atom is the smallest particle with all an element's properties.

4. A sulfur atom has a flat surface and sharp edges, so it breaks easily when a force is applied to the sulfur atom.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 35 The Percentage of The Comparison Group and Experimental Group Answer Combination for Item 12 of the Particulate Nature of Matter Concept Pre-Test

Group	First Tier	Reason 1	2	3	4	5	No Reason	Total
Comparison Group	a	0.0	6.25	6.25	6.25	0.0	0.0	18.75
	b	6.25	12.50	6.25	6.25	0.0	0.0	31.25
	c	6.25	18.75	12.5	0.0	0.0	6.25	37.50
	d	0.0	0.0*	0.0	6.25	0.0	0.0	6.25
Experimental Group	a	5.26	0.0	0.0	5.26	0.0	0.0	10.52
	b	0.0	0.0	0.0	21.07	0.0	0.0	21.07
	c	5.26	10.53	5.26	10.53	0.0	0.0	31.58
	d	5.26	15.78*	0.0	5.26	0.0	10.53	36.83

*Correct Answer

Table 4. 36 The Percentage of The Comparison Group and Experimental Group Answer Combination for Item 12 of the Particulate Nature of Matter Concept Post-Test

Group	First Tier	Reason 1	2	3	4	5	No Reason	Total
Comparison Group	a	6.25	6.25	6.25	12.5	0.0	0.0	31.25
	b	12.50	6.25	6.25	12.5	0.0	0.0	43.75
	c	0.0	12.5	18.75	0.0	0.0	0.0	31.25
	d	0.0	0.0*	0.0	6.25	0.0	0.0	0.0
Experimental Group	a	5.26	5.26	0.0	5.26	0.0	5.26	21.04
	b	0.0	0.0	0.0	15.79	0.0	0.0	15.79
	c	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	d	0.0	26.32*	31.58	0.0	0.0	5.26	63.17

*Correct Answer

When the pre-instruction results in Table 4.35 are examined, no one from the comparison group gave the correct content answer and the correct content-reason combination. Only 36.83% of the experimental group gave the correct content, and 15.78% gave the correct content-reason answer. As indicated in Table 4.36, the comparison group students did not answer the question correctly after the instruction. However, in the experimental group, the percentage of correct answers and the correct content-reason answer increased to 63.17% and 26.32%, respectively.

The thirteenth item of PNMCT is given in Table 4.37. The percentages of each response combination selected by the experimental group and comparison group for item 13 of the PNMCT before the instruction are presented in Table 4.38. after the instruction presented in Table 4.39

Table 4. 37 Item 13 of the Particulate Nature of Matter Concept Test

Ayşe mixes two sugar cubes into a glass of water. She says that the substance she obtains is pure. Do you agree with Ayşe's statement?

a) Yes *b) No

Reason:

1. A new substance is formed when sugar dissolves in water.

2. In sugar water, sugar and water have lost their properties.

3. Sugar melts in water.

*4. There are different particles in sugar water.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 38 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 13 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison	a	12.5	6.25	31.25	6.25	0.0	56.25
Group	b	18.75	0.0	12.5	6.25*	6.25	43.75
Experimental	a	10.53	5.26	21.06	0.0	0.0	36.85
Group	b	21.05	5.26	0.0	31.58*	5.26	63.15

*Correct Answer

Table 4. 39 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 13 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	18.75	6.25	0.0	6.25	0.0	0.0	31.25
Group	b	25.0	18.75	18.75	0.0*	0.0	0.0	62.5
	No Content	0.0	0.0	0.0	0.0	0.0	6.25	6.25
Experimental	a	0.0	0.0	5.26	0.0	0.0	0.0	5.26
Group	b	26.32	5.26	15.79	47.37*	0.0	0.0	94.74

*Correct Answer

The 13th item of PNMCT tests the knowledge that mixtures are not pure substances within the scope of the subject of mixtures, using the example of a sugar-water mixture. As indicated in Table 4.38, before the instruction, 43.75% of the comparison group and 63.15% of the experimental group gave the correct content answer, while only 6.25% and 31.58% of them marked the correct content-reason combination. As indicated in Table 4.39, after the instruction, the comparison group's correct content and correct content-reason combination answering rates significantly decreased to 62.5% and 0%. The experimental group showed a positive increase; correct content was determined as 94.74%, and correct content-reason combination was determined as 47.37%.

The fourteenth item of PNMCT is given in Table 4.40. The percentages of each response combination selected by the experimental group and comparison group for item 14 of the PNMCT before the instruction are presented in Table 4.41., and after the instruction, presented in Table 4.42.

Table 4. 40 Item 14 of the Particulate Nature of Matter Concept Test

When a solid is heated, its particles grow. Is this statement;

a) True

*b) False

Reason:

1. The particles of the heated substance also heat up.

2. Heat causes the particles of the substance to expand.

*3. Heat affects the interparticle distance but does not affect the structure of the particles.

4. None. In my opinion, the reason is:

*Correct Answer

Table 4. 41 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 14 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison	a	18.75	25.0	0.0	0.0	0.0	43.75
Group	b	18.75	0.0	37.5*	0.0	0.0	56.25
Experimental	a	0.0	42.10	0.0	0.0	0.0	42.10
Group	b	5.26	10.53	26.32*	0.0	15.79	57.9

*Correct Answer

Table 4. 42 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 14 of the Particulate Nature of Matter Concept Post-Test

		Reason					
Group	First Tier	1	2	3	4	No Reason	Total
Comparison	a	6.25	50.0	6.25	0.0	0.0	62.50
Group	b	12.5	0.0	18.75*	0.0	0.0	31.25
	No Content	0.0	0.0	0.0	0.0	6.25	6.25
Experimental	a	5.26	0.0	5.26	0.0	0.0	10.52
Group	b	0.0	5.26	73.69*	5.26	5.26	89.48

*Correct Answer

In the 14th item of PNMCT, within the scope of the particulate structure of matter, the knowledge that the distance between the particles of a substance receiving heat changes and that there will be no change in the structure of the particles is tested. As indicated in Table 4.11, more than half of the study groups gave the correct content answer before the instruction. While this rate was 56.25% in the comparison group, it was 57.9% in the experimental group. The rate of selecting the correct content-reason combination in the groups was 37.5% in the comparison group and 26.32% in the experimental group. As indicated in Table 4.42, after the instruction, the rate of answering the question correctly decreased in the comparison group and increased in the experimental group. 31.25% of the comparison group and 89.48% of the experimental group answered the first stage correctly, and 18.75% and 73.69% answered both stages correctly, respectively.

The fifteenth item of PNMCT is given in Table 4.43. The percentages of each response combination selected by the experimental group and comparison group for item 15 of the PNMCT before the instruction are presented in Table 4.44, and after the instruction is presented in Table 4.45. In the 15th item of PNMCT, the knowledge that the smallest particle showing the chemical properties of ionic compounds is in the form of an ion cluster is tested within the scope of the subject of pure substances. Over half of the study groups gave the correct content answer to the question designed on the example of table salt (NaCI) before the instruction. This rate is 50% in the comparison group and 73.68% in the control group, as indicated in Table 4.44. The correct content-reason combination is encountered in 12.5% of the comparison group and 21.05% of the experimental group. After the instruction, according to the data in Table 4.45, while the rate of providing correct content and correct content-reason answers decreases in the comparison group, it increases in the experimental group. While these rates are 37.5% and 0% for the comparison group, they are 84.21% and 78.95% in the experimental group, respectively.

Table 4. 43 Item 15 of the Particulate Nature of Matter Concept Test

The smallest particle that makes up table salt (NaCl) is the smallest piece of salt in powdered form.

a) True *b) False

Reason:

1. The smallest particle of salt is the smallest part of it that is visible.

2. Since salt is a molecular compound, its smallest particle is the salt molecule

3. Since salt is an element, its smallest particle is the salt atom.

*4. Since salt is a compound with an ionic structure, its smallest particle is neither an atom nor a molecule.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 44 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 15 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison Group	a	25.0	0.0	6.25	18.75	0.0	50.0
	b	12.5	12.5	6.25	12.5*	0.0	50.0
Experimental Group	a	5.26	5.26	5.26	10.53	0.0	26.32
	b	5.26	10.53	36.84	21.05*	0.0	73.68

*Correct Answer

Table 4. 45 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 15 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	31.25	18.75	6.25	0.0	0.0	0.0	56.25
Group	b	0.0	25.0	12.5	0.0*	0.0	0.0	37.5
	No Content	0.0	0.0	0.0	0.0	0.0	6.25	6.25
Experimental	a	0.0	5.26	10.53	0.0	0.0	0.0	15.79
Group	b	0.0	5.26	0.0	78.95*	0.0	0.0	84.21

*Correct Answer

The sixteenth item of PNMCT is given in Table 4.46. The percentages of each response combination selected by the experimental group and comparison group for item 16 of the PNMCT before the instruction are presented in Table 4.47, and after the instruction is presented in Table 4.48.

Table 4. 46 Item 16 of the Particulate Nature of Matter Concept Test

The smallest particle of mercury used in thermometers is a drop of mercury.

a) True * b) False

Reason:

1. The smallest particle of mercury is the smallest drop we can see with the naked eye.

2. Mercury is a compound whose smallest particle is a molecule.

3. Mercury is an element whose smallest particle is the molecule

*4. The smallest particle of mercury is the mercury atom.

5. None. In my opinion, the reason is:

*Correct Answer

Table 4. 47 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 16 of the Particulate Nature of Matter Concept Pre-Test

		Reason					
Group	First Tier	1	2	3	4	5	Total
Comparison	a	0.0	0.0	6.25	25.0	0.0	31.25
Group	b	0.0	37.5	18.75	12.5*	0.0	18.75
Experimental	a	10.53	5.26	10.53	5.26	0.0	31.58
Group	b	0.0	26.32	15.79	26.32*	0.0	68.42

*Correct Answer

Table 4. 48 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 16 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	25.0	12.5	6.25	25.0	0.0	0.0	68.75
Group	b	12.5	6.25	12.5	0.0*	0.0	0.0	31.25
Experimental	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group	b	0.0	10.53	15.79	68.42*	0.0	5.26	100.0

*Correct Answer

Item number 16 of PNMCT tests the knowledge that mercury is an example of an element within the scope of pure substances and that the smallest particle with an element's chemical properties is an atom. As indicated in Table 4.47, more than half of the study groups gave correct content answers before the instruction. While this rate was 50% in the comparison group, it was 73.68% in the experimental group. The correct content-reason combination response rates were 12.5% and 21.05%, respectively. When the data in Table 4.48 is examined, the accurate content answer and correct content-reason combination response rates of the comparison group after the instruction decreased considerably, 37.5% and 0%, respectively. However, in the experimental group, there was an increase in both types of responses, and the rates were 84.21% and 78.95%, respectively.

The last item of PNMCT is given in Table 4.49. The percentages of each response combination selected by the experimental group and comparison group for item 17 of the PNMCT before the instruction are presented in Table 4.50, and after the instruction is presented in Table 4.51. In the last question of PNMCT, within the scope of pure substances, the knowledge that table salt, which does not have a molecular structure, exists as a cloud of sodium and chloride ions under room conditions is tested. In the pre-test data in Table 4.50, 12.5% of the comparison group and 15.80% of the experimental group gave the correct content answer, while 6.25% and 15.80% gave the correct content-reason answer. After the instruction, an increase was observed in both study groups, but the increase in the experimental group was more significant. As stated in Table 4.51, 43.75% of the comparison group gave the correct content answer, and 12.5% gave the correct content-reason answer. These rates were recorded as 73.68% and 63.16% for the experimental group.

Table 4. 49 Item 17 of the Particulate Nature of Matter Concept Test

Sodium chloride (NaCl) is a molecule that is present at room temperature.

A) True *B) False

Reason:

1. The sodium atom forms a molecule by sharing an electron with the chlorine atom.

2. The sodium atom forms a molecule with the chlorine atom because it wants to donate an electron in its last layer to the chlorine atom.

*3. Sodium chloride exists as an ion clump consisting of sodium and chlorine ions.

4. A hook/spring/rope-like physical structure between the sodium and chlorine atoms holds them together.

5. None. In my opinion, the reason Is:

*Correct Answer

Table 4. 50 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 17 of the Particulate Nature of Matter Concept Pre-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	25.0	31.25	25.0	6.25	0.0	0.0	87.5
Group	b	6.25	0.0	6.25*	0.0	0.0	0.0	12.5
Experimental	a	21.05	21.05	5.26	5.26	0.0	0.0	52.63
Group	b	0.0	5.26	15.80*	21.06	0.0	5.26	47.37

*Correct Answer

Table 4. 51 The Percentage of the Comparison Group and Experimental Group Answer Combination for Item 17 of the Particulate Nature of Matter Concept Post-Test

		Reason						
Group	First Tier	1	2	3	4	5	No Reason	Total
Comparison	a	18.75	12.5	6.25	6.25	0.0	12.5	56.25
Group	b	6.25	12.5	12.5*	12.5	0.0	0.0	43.75
Experimental	a	0.0	26.32	0.0	0.0	0.0	0.0	26.32
Group	b	5.26	0.0	63.16*	5.26	0.0	0.0	73.68

*Correct Answer

Table 4.52 presents the percentages of correct content and correct content-reason combinations chosen by the comparison group and experimental group students for each item in the PNMCT.

According to Gilbert (1977), in multiple-choice tests, if a question has four to five distracting answer options, the rate of correct answers to conceptual understanding is 75% and above highly satisfactory, 74-50% is sufficient, 49-25% is insufficient, and 24% and below is entirely inadequate. As indicated in Table 4.52, while the percentage of correct answers to the first tier in the pre-instruction results of the comparison group was 0.0% to 81.25%, this rate increased the range of 0.0 % to 84.22% in the post-instruction results. The rate of correct answers to both tiers was 0.0% to 37.5% for the pre-test, while it was reduced to the range of 0.0% to 18.75% for the post-test. In the experimental group, the correct answer to the first tier was 5.26% to 84.22% in the pre-instruction, and this rate was increased to the range of 63.16% to 100.0% in the post-instruction. The rate of correct responses in both tiers was 5.26% to 47.37% in the pre-instruction and 100% to 26.31% in the post-instruction.

Table 4. 52 The Percentages of Correct Content and Correct Content-Reason Combinations Chosen by The Comparison and Experimental Group Students in The Particulate Nature of Matter Concept Test Before and After Instruction

	Pre- Instruction				Post- Instruction			
	Comparison Group		Experimental Group		Comparison Group		Experimental Group	
PNMCT Item	Content	Combination	Content	Combination	Content	Combination	Content	Combination
1	6.25	6.25	21.05	21.05	0.0	0.0	94.74	94.74
2	0.0	0.0	5.26	5.26	6.25	0.0	78.95	73.68
3	18.75	6.25	15.79	10.53	12.5	6.25	84.21	68.43
4	50.0	31.25	31.58	31.58	25.0	12.5	89.48	89.48
5	56.25	37.50	47.37	47.37	25.0	18.75	100.0	100.0
6	31.25	18.75	42.1	36.84	31.25	18.75	89.48	78.95
7	18.75	12.5	15.78	5.26	12.5	6.25	68.42	47.37
8	50. 0	37.5	52.63	31.58	25.0	25.0	89.47	78.95
9	12.5	12.5	5.26	5.26	12.5	12.5	68.42	68.42
10	56.25	18.75	10.53	10.53	12.5	12.5	63.16	63.16
11	81.25	6.25	84.22	5.26	75.0	18.75	100.0	26.31
12	6.25	0.0	36.83	15.78	0.0	0.0	63.17	26.32
13	43.75	6.25	63.15	31.58	62.5	0.0	94.74	47.37
14	56.25	37.5	57.9	26.32	31.25	18.75	89.48	73.69
15	50.0	12.5	73.68	21.05	37.5	0.0	84.21	78.95
16	18.75	12.5	68.42	26.32	31.25	0.0	100.0	68.42
17	12.5	6.25	47.37	15.80	43.75	12.5	73.68	63.16

In addition, when Table 4.52 is examined, it is concluded that the students in the experimental group are more sufficient in understanding concepts related to the particulate nature of matter, pure substances, and mixtures than the students in the comparison group. While no item in the PNMCT was answered correctly by 50% of the comparison group, 13 questions were answered correctly by more than 50% of the experimental group. To better describe how the percentage change in conceptual understanding related to the related topic changed for the study groups in the pre-test and post-test, the percentage change in the PNMCT answers given by the comparison group before and after the instruction is shown in Figure 4.1 and the experimental group in Figure 4.2.

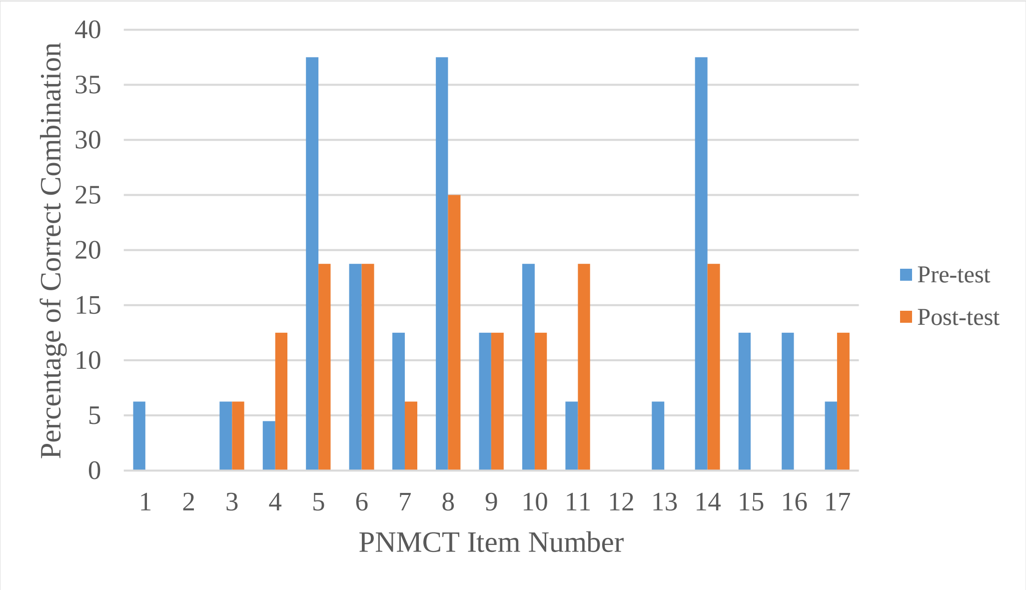


Figure 4. 1 Distribution of the Percentage of Correct Combination in the Pre-test and Post-test of the Comparison Group

As seen in Figure 4.1, the conceptual understanding of the comparison group students regarding the particle nature of matter, pure substances, and mixtures topic areas after curriculum-based instruction is unsatisfactory because the percentage of selecting the correct content and reason combination after instruction remained well below 75% for each item. The students' correct content-reason answering performance increased in three, decreased in nine, and remained constant in three of the 17 items. In two items, 2 and 12, correct answers could not be obtained from the participants during the study. A remarkable result is that both items are related to macroscopic properties of matter that do not exist in its particles. The three items where correct response performance increased were item 4, which tested the knowledge that there was no change in the volume of molecules due to the change of state of matter; item 11, which tested the phenomenon of sugar dissolving in water at particle size; and item 17, which tested that NaCl exists as an ion cluster at room temperature. Another critical finding obtained from Figure 4.1 is that the correct response rates in questions 1, 13, 15, and 16 before the instruction have entirely disappeared after the instruction.

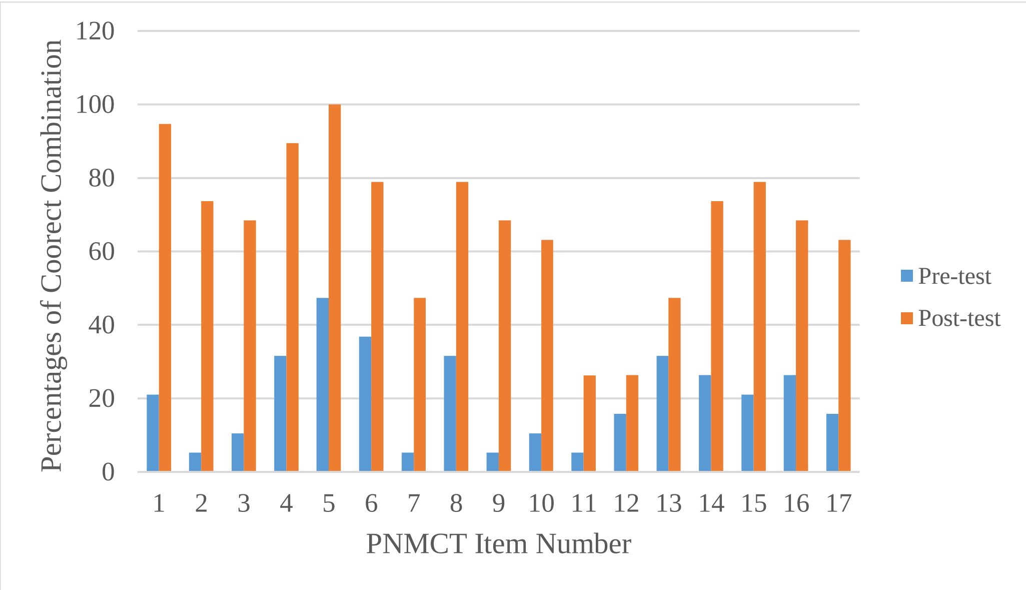


Figure 4. 2 Distribution of the Percentage of Correct Combination in the Pre-test and Post-test of the Experimental Group

As shown in Figure 4.2, the correct content-reason answering performance of the students in the experimental group who received argumentation instruction increased in all 17 items after the instruction. The students achieved a highly satisfactory conceptual understanding of the particulate structure of matter and pure substances in six items, which are 1, 4, 5, 6, 8, and 15. Seven items, 2, 3, 9, 10, 14, 16, and 17, achieved sufficient success in conceptual understanding related to the particulate structure of matter, pure substances, and mixtures. In four items, 7, 11, 12, and 13, although the rate of students giving correct answers increased, the desired level of conceptual understanding could not be achieved. Item 7 is about the physical state of matter resulting from an interaction of its particles; item 11 is about the interpretation of dissolution in the particle size; item 13 is about mixtures, not pure substances. Also, as in the comparison group, failing to reach a highly satisfactory conceptual understanding of item 12 is a noteworthy finding for the study.

The information in Figure 4.1 and Figure 4.2 shows that argumentation instruction is more effective than curriculum-based instruction in conceptual understanding of the particulate nature of matter and dissolution. The statistical findings and interpretations of this kind of instruction effect were addressed as the study's second main research question. In the last stage of this analysis, the misconceptions that existed or newly occurred in the students were presented from the answer combination tables. According to Peterson, Treagust, and Garnett (1989), the answer can be accepted as accurate if the student selects the correct content with the correct reason. Answering both tiers incorrectly, or answering the first tier correctly and the second tier incorrectly, is a sign of misconception. Items containing no response and nonsense or irrelevant responses are considered nonconception rather than misconception because these indicate the student’s lack of conception of the relevant concept in the item (Tan et al., 2001).

In the b3 option in the 1st item of PNMCT, since there is no logical relationship between why the atoms in the iron are alive and the leaf being stated as a living entity, the option is evaluated as a nonconception, not a misconception. Similarly, in the a1 option, the reason why the atoms in the leaf are alive is associated with the movement of the atoms in the iron, and in the d3 option, the reason why the atoms in the leaf and the iron are alive is associated only with the leaf being alive, which is not a misconception but a nonconception because there is any sense between content and reason. Also, as in the studies conducted by Othman et al. (2008) and Haslam and Treagust (1987), in which misconceptions were determined with two-tier diagnostic tests, in this study, the student's answer to the reason section was taken into account when determining the cause of the misconception. Misconceptions identified in this direction for the study groups are presented in Table 4.53.

Table 4.53 presented 52 misconceptions about the research topic, and their reasons were identified before and after the instruction in the study groups. When the misconceptions presented within the scope of the three main topic areas are examined, the misconceptions that the majority of the students had before and after the instruction about the particulate nature of matter can be summarized as follows: living beings have living atoms, and non-living beings have non-living atoms (Item 1), physical intervention applied to the element can be observed in its atoms (Item 2), stating that the volumes of molecules change due to phase change (Item 4), stating that since solids cannot move, their atoms cannot vibrate (Item 5), relating the reason for water being fluid to the flexibility of water molecules (Item 6), stating that the physical forms of molecules can exist depending on the substance they belong to (Item 7), stating that atoms will also change depending on the temperature and state change in the substance (Item 9-Item 10), stating that heat will affect particles (Item 14). The misconceptions frequently encountered in the items in the topic area of pure substances are the particles of matter being the most minor visible form (Item 8, Item15), the concept of the atom being defined incorrectly, and claiming that it has all the properties of an element (Item 12), the relationship between element-atom and compound-molecule being expressed incorrectly (Item 16). The salt is stated as a molecule (Item 17). The misconceptions frequently encountered in the articles on the subject area of dissolution are that sugar dissolves in water (Item 3,13), and another reason for this misconception is that sugar receives heat from outside (Item 11), stating that dissolution is a chemical event (Item 13). *Also, similar misconceptions were detected in Item 4 and Item 9.

Table 4. 53 Percentages of Comparison and Experimental Group Students with Misconceptions Identified in Particulate Nature of Matter Concept Pre-Test and Post-Test

	Comparison Group (N=16)		Experimental Group (N=19)		
	Pre Test	Post Test	Pre Test	Post Test	Item &Choice Combination
Particulate Nature of Matter					
1. The atoms of living things are also alive.	12.5	6.25	0.0	0.0	1 (a3)
2. The atoms of all living and nonliving species are are alive.	12.5	25.0	15.8	0.0	1 (a4, d4)
3. The atoms of non-living things are inanimate, while the atoms of living things are alive.	37.5	37.5	47.4	5.26	1 (c5, e5)
4. Atoms are alive because they have the ability to move.	0.0	6.25	0.0	0.0	1 (b1)
5. The external modifications applied to the element are also, in its atoms, in the same manner.	50.0	25.0	47.36	0.0	2 (a1,b1, e1)
6. All the properties of the element (brightness, ri-, gitiy, and form) are also present in their atoms.	25.0	25.0	10.52	0.0	2(a3, b3) 2(c3, e3)
7. Atom is the smallest unit of an object, so if an object heats up, and so do its atoms.	0.0	0.0	5.26	0.0	2 (b4)
8. Molecules 'volumes increase from solid to the liquid phase, and the liquid to the gas phase.	18.75	25.0	36.82	5.26	4(a1, b1,d1)
9. The volume of molecules decreases from the solid phase to the liquid phase, and the liquid phase to to the gas phase.	31.25	31.25	31.56	0.0	4(a2, b2) 4(c2, d2)
10. Water downsizes when it freezes, so as water changes from liquid to solid, its molecules also go down in size.	0.0 0.0	6.25 0.0	0.0 5.26	0.0 5.26	4(d4)* 9 (d5, e5)*
11. Since there is no space between particles in the solid state, the particles of the solid-state do not move.	50.0	75.0	42.08	0.0	5 (a1, b1)

Table 4.53. (Continued)

12. The atoms of matter in solid form remain in state because the highest-ordered form of matter is the solid form.	12.50	0.0	5.26	0.0	5 (a2, b2)
13. Since water molecules are in solid form, their shape is fixed.	18.75	12.5	10.53	10.53	6 (a1, b1)
14. The molecules of substances that take the shape of, their containers are elastic.	18.75	31.25	26.32	5.26	6 (b2)
15. The shape of molecules is the tiniest visible form of the substance to which they belong.	6.25	25.0	15.79	5.26	6(a4)
16. Some properties of liquids (physical form, inter particle space and liquidity) are also present in those molecules.	18.75	0.0	5.26	0.0	6 (a5, b5)
17. Molecules are in the liquid state.	0.0	6.25	0.0	10.53	7(c2, d2)
18. Solid molecules are in a solid state, and liquid molecules are in a liquid state.	37.5	37.5	57.9	5.26	7(a/b/c/d3)
19. Molecules are in the solid state.	18.75	25.0	21.06	15.80	7(a/b/c/d4)
20. When the matter's temperature drops, it freezes; which causes its molecules to cool and freeze.	31.25	31.25	47.4	0.0	9(c/d/e1)
21. When the matter's temperature drops, it freezes; which causes its molecules to cool, freeze, and decrease of volumes.	37.5	25.0	15.78	10.52	9(a/c/d/e2)
22. When the matter's temperature drops, it freezes; which causes its molecules to cool, freeze, and increase of volumes.	6.25	12.5	15.78	5.26	9(a/c/d/e4)
23. When the substance melts, its volume decreases, and therefore, its atoms become smaller.	31.25	18.75	5.26	5.26	10 (a/b/c/e 1)
24. When the substance melts, it absorbs heat, which causes its atom also to absorb heat, melt, and expand in volume.	6.25	25.0	47.37	0.0	10 (b/c/e 2)

Table 4.53. (Continued)

25. When the substance melts, which causes its atom to melt, expand in volume, and any change in temperature.	25.0	18.75	5.26	0.0	10 (a/c/e 4)
26. When the substance melts, which causes it's atom to absorb heat, melt, and any change volume.	12.5	12.5	26.32	15.78	10 (c/d/e 5)
27. Heat causes particles to become warmer.	37.5	18.75	5.26	5.26	14 (a1, b1)
28. Heat causes the particles to expand.	25.0	50.0	52.63	5.26	14 (a2, b2)
Pure Substances					
29. The particles of granulated sugar and alcohol are similar.	12.5	31.25	5.26	0.0	8(a1, b1)
30. The smallest particles of granulated sugar and alcohol are the most minor forms that can be seen.	18.75	6.25	31.58	5.26	8 (a3, b3)
31. An atom is the smallest particle of an element that retains all its physical and chemical properties.	25.0	31.25	5.26	31.58	12 (a/b/c3)
32. An atom of an element has some physical properties (brittleness, melting point, shape) of the element.	37.5	50.0	68.38	36.83	12 (a/b/c)
33. The particles that make up the salt can be seen with eye.	37.5	31.25	10.53	0.0	15 (a1, b1)
34. Table salt is a molecular compound, so its smallest particle is a molecule.	12.5	43.75	15.79	10.53	15 (a2, b2)
35. Table salt is an element, so its smallest particle is an atom.	12.5	18.75	42.0	10.53	15 (a3, b3)
36. A mercury droplet is the smallest particle of mercury.	0.0	37.5	10.53	0.0	16 (a1, b1)
38. Since mercury is an example of a compound, it's minor unit is a molecule.	37.5	18.75	31.56	10.53	16(a2, b2)
39. Since mercury is an example of an element, it’s minor unit is a molecule.	25.0	18.75	26.32	10.53	16(a3, b3)

Table 4.53 (Continued)

40. NaCl is an example of a molecule.	56.25	37.5	47.37	26.32	17 (a)
41. Because sodium wants to give electrons to the chlorine atom, NaCl is a molecule.	6.25	6.25	0.0	5.26	17(b2)
42. NaCI molecule is formed because a physical the link between its atoms.	0.0	12.5	21.06	5.26	17 (b4)
Mixtures					
43. When some sugar is added to a glass of water at room temperature, it dissolves, and the sugar engages in chemical reactions with the water because a new compound exists.	12.5	25.0	10.52	0.0	3(a1, b1)
44. At room temperature, when some sugar is added to some water, sugar melts.	43.5	25.0	42.08	5.26	3(a2, b2)
45. When some sugar is added to a glass of water at room temperature, it dissolves, and the sugar engages in chemical reactions with the water because sugar transforms into water.	12.5	0.0	15.79	21.04	3(a3, b3)
If sugar is thrown into the water after a certain period,					
46. Sugar melts and mixes with water because of heat it receives from the environment.	50.0	32.75	47.37	5.26	11 (a1, b1)
47. Sugar molecules settle into the air pockets present in the water and disappear.	6.25	18.75	15.78	52.68	11(a2, b2)
48 Only mixing it in will cause the sugar to dissolve in water and become invisible.	37.5	12.5	26.32	15.79	11(a4, b4)
If sugar is thrown into a glass full of water,					
49. Sugar dissolves in water, but a new substance is formed.	31.25	43.75	31.58	26.32	13 (a1, b1)
50. Sugar loses its properties in water.	6.25	25.0	10.53	5.26	13(a2, b2)
51 Melting occurs.	43.75	18.75	21.06	21.06	13 (a3, b3)
52. The sugar molecules change color.	6.25	0.0	0.0	0.0	13(b5)

4.2 Results of the Descriptive Statistics for the Particulate Nature of Matter Concept Test

The second main research question of the study is “What is the effect of argumentation instruction compared to curriculum–based instruction on 7th-grade students’ conceptual understanding of the particle nature of matter and dissolution concepts?”

The study's sub-main problems were statistically analyzed to investigate the main problem, which aims to examine the effect of the different instruction methods on students' conceptual understanding of the particulate nature of matter and dissolution. In this context, to determine whether the PNMCT scores applied to the experimental and comparison group students as pre-test and post-test showed a normal distribution, the Shapiro-Wilk normality test was used because the sample size was below 50 participants.

Table 4. 54 Results of the Shapiro-Wilk Normality Test of Particulate Nature of Matter Concept Pre-Test Scores of the Experimental and Comparison Group

Group	Statistic	df	Sig.
Experimental	0.787	19	0.001
Comparison	0.816	16	0.004

As indicated in Table 4.54., the Shapiro-Wilk value of the experimental group is $p= 0.001$, and the Shapiro-Wilk value of the comparison group is $p= 0.004$. This supports that the experimental and comparison pre-test of PNMCT scores does not show a normal distribution ($p<0.05$). This means non-parametric tests can be used to analyze the experimental and comparison group pre-test data.

Table 4. 55 Results of the Shapiro-Wilk Normality Test of Particulate Nature of Matter Concept Post-Test Scores of the Experimental and Comparison Group

Group	Statistic	df	Sig.
Experimental	0.934	19	0.207
Comparison	0.728	16	0.000

As indicated in Table 4.55., the Shapiro-Wilk value of the experimental group is *p= 0.207*, and the Shapiro-Wilk value of the comparison group is *p= 0.000*. This supports that the experimental group students' post-test PNMCT scores show a normal distribution ($p>0.05$), and the comparison group students' post-test scores of PNMCT do not show a normal distribution ($p<0.05$). This indicates that parametric tests can be used only in analyses that include data on the experimental group post-test. In contrast, non-parametric tests can be used in analyses that include data on the comparison group post-test.

4.3 Results of the Inferential Statistics for the Particulate Nature of Matter Concept Test

The first sub-question of the second main question of the research is, “Is there a statistically significant difference between the pre-test of the particulate nature of matter and dissolution concepts scores of the comparison group receiving curriculum-based instruction and the experimental group receiving argumentation instruction?”. The Mann-Whitney U test was used to investigate this first sub-problem. The findings regarding the test results of the Mann- Whitney U test of the pre-test of PNMCT scores of the experimental and comparison groups are presented in Table 4.3. Moreover, both groups' related median values are presented in Table 4.4.

Table 4. 56 Results of the Mann- Whitney U Test of Particulate Nature of Matter Concept Pre-Test Scores of the Experimental and Comparison Group

Ranks				Test Statistics		
Group	N	Mean Rank	Sum of Ranks	U	z	p
Experimental	19	18.84	358.00	136.00	-.541	.612
Comparison	16	17.00	272.00			

Table 4. 57 Results of the Particulate Nature of Matter Concept Pre-Test Median Values for Experimental and Comparison Groups

Group	N	Median
Experimental	19	2
Comparison	16	2

As stated in Table 4.56. Moreover, in Table 4.57, a Mann-Whitney U Test revealed that there is no statistically significant difference in the PNMCT scores of the comparison group receiving curriculum-based instruction (*Md =2, n =16*) and the experimental group receiving argumentation instruction *(Md =2, n =19*), *U* = 136.00, *z* = -.541, *p* = .612 (*p*>0.05). This result indicates that before the instruction, the conceptual understanding levels of the students in both experimental and comparison groups on the particulate nature of matter and dissolution concepts can be considered equal.

The second sub-problem of the second main research question is “Is there any statistically significant difference between the pre-test and post-test of the particulate nature of matter and dissolution concepts scores of the comparison group receiving curriculum-based instruction?”. The Wilcoxon Signed Rank test was used to investigate this second sub-problem. The findings regarding the comparison group's Wilcoxon Signed Rank test results are presented in Table 4.58. The results of the descriptive statistics on the comparison groups' pre-test and post-test results are presented in Table 4.59.

Table 4. 58 Results of the Wilcoxon Signed Rank Test of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Comparison Group

	Ranks		Test Statistics	
Posttest- Pretest	Mean Rank	Sum of Ranks	z	p
Negative Ranks	7.40	74.00		
Positive Ranks	5.67	17.00	-2.030	.042

Table 4. 59 Results of the Descriptive Statistics of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Comparison Group

Test	N	Median
Pre-test	16	2
Post-test	16	1

As indicated in Table 4.58., and Table 4.59., the results of the Wilcoxon Signed Rank Test revealed a statistically significant decrease in the scores of PNMCT of the comparison group receiving curriculum-based instruction, $z = –2.03$, $p < .05$, with a medium effect size ($r = .36$). The pre-test median score (*Md* = 2) decreased from to post- test median score (*Md* = 1) on PNMCT. This suggests that curriculum-based instruction leads to a significant negative impact on the conceptual understanding of students on the concepts of the particulate nature of matter and dissolution.

The third sub-problem of the second main research question is "Is there any statistically significant difference between the pre-test and post-test of the particulate nature of matter and dissolution concepts scores of the experimental group receiving argumentation instruction?". The Wilcoxon Signed Rank test was used to investigate this third sub-question. The findings regarding the Wilcoxon Signed Rank test results of the experimental group are presented in Table 4.60. The results of the descriptive statistics on the experimental groups' pre-test and post-test results are presented in Table 4.61.

Table 4. 60 Results of the Wilcoxon Signed Rank Test of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Experimental Group

	Ranks		Test Statistics	
Posttest- Pretest	Mean Rank	Sum of Ranks	z	p
Negative Ranks	0.00	0.00		
Positive Ranks	10.00	190.00	-3.831	.000

Table 4. 61 Results of the Descriptive Statistics of Particulate Nature of Matter Concept Post-Test and Pre-Test Scores of the Experimental Group

Test	N	Median
Pre-test	19	2
Post-test	19	11

Considering the analysis results in Table 4.60 and Table 4.61, the Wilcoxon Signed Rank test demonstrated a statistically significant increase in the PNMCT of the experimental group receiving argumentation instruction, $z = –3.83$, $p < .05$, with a large effect size (r =.62). The pre-test median score (Md = 2) increased from to post-test median score (Md = 11) on PNMCT. When the statistical results are evaluated, it is revealed that argumentation instruction effectively increases students' conceptual understanding of the particulate nature of matter and dissolution.

The fourth sub-question of the second main research question is "Is there a statistically significant difference between the post-test of the particulate nature of matter and dissolution concepts scores of the comparison group receiving curriculum-based instruction and the experimental group receiving argumentation instruction?". Mann- Whitney U Test was used to investigate this fourth sub-question. The findings regarding the test results of the Mann- Whitney U test of the particulate nature of matter concept post-test scores of the experimental and comparison groups are presented in Table 4.62. Moreover, both groups' related median values are presented in Table 4.63.

Table 4. 62 Results of the Mann- Whitney U Test of Particulate Nature of Matter Concept Post-Test Scores of the Experimental and Comparison Group

	Ranks			Test Statistics		
Group	N	Mean Rank	Sum of Ranks	U	z	p
Experimental	19	25.76	489.50	4.500	-.4.91	.000
Comparison	16	8.78	140.50			

Table 4. 63 Results of the Particulate Nature of Matter Concept Post-Test Median Values for Experimental and Comparison Groups

Group	N	Median
Experimental	19	11
Comparison	16	1

When the analysis results given in Table 4.62 and Table 4.63 are evaluated, A Mann-Whitney U Test showed that there is a statistically significant difference between the post-test of the PNMCT scores of the comparison group receiving curriculum-based instruction (*Md* =1, *n* =16) and the experimental group receiving argumentation-based instruction (*Md* =11, *n* =19), *U* = 4.500, *z* = –4.91, *p* = .00 (p< .05), with large effect size *r* =.82. When the mean rank data of the experimental group (25.76) and the mean rank data of the comparison group (8.78) are taken into consideration, it is revealed that the statistically significant difference is in favor of the experimental group. In line with these results, argumentation instruction is more effective than curriculum-based instruction in increasing students' conceptual understanding of the particulate structure of matter and dissolution.

4.4 Results of Ontological Categorizations of Misconceptions

The third main research question of the study is “What is the effect of argumentation instruction compared to curriculum-based teaching in eliminating ontologically evaluated misconceptions of 7th-grade students regarding the particulate nature of matter and dissolution concepts?". To find an answer to the stated question, the distribution percentages of the misconceptions detected in the research groups before and after the instruction (see Table 4.53) were noted by placing them in the categories they belong to, based on the ontological categories suggested by Chi and Slotaa (1993). Thus, in each question, the ontological category to which the misconceptions detected regarding various concepts belonged and the correct ontological category shown in **bold type** to which the idea should belong were determined, and the ontological reasons for the misconceptions were determined for each group.

4.4.1 Ontological Analysis for Question 1st of PNMCT

In the 1st question of PNMCT, the reasons for the students' misconceptions about atoms being alive were investigated from an ontology perspective. Figure 4.3. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.4. presents the ontological examination of the misconceptions detected in the experimental group for the 1st question.

In the first question of PNMCT, it is seen that students who placed the concept that atoms are not alive in the microscopic particle category, which is one of the subcategories of the non-living category, gave the correct answer. According to Figure 4.3, while this rate was 6.25% in the comparison group in the pre-test, no student could place the concept in the correct ontological category in the post-test. According to Figure 4.4, while this rate was 21.05% in the experimental group in the pre-test, it increased significantly in the post-test and rose to 94.74%. Two different sources of the misconceptions detected regarding the relevant concept were determined based on ontology. First, it stems from the idea that the microscopic particle category should be placed in the macroscopic matter category, which is its lateral category. Under this category, according to Figure 4.3, the misconception frequently encountered in the comparison group is that the living properties of atoms will change according to the entity they belong to. While this rate was 37.5% in the pre-test, it remained constant in the post-test. A similar misconception was frequently encountered in the experimental group under the macroscopic matter category. According to Figure 4.4, this rate decreased from 47.4% in the pre-test to 5.26% in the post-test. The second source determined based on ontology is due to placing the concept under the non-living category in its lateral category of living. The misconception frequently encountered in the comparison and experimental groups under this category is that all atoms are alive. For the comparison group, this rate increased from 12.5% in the pre-test to 25.0% in the post-test, so the frequency of the stated misconception increased after curriculum-based instruction. The stated misconception was completely eliminated in the experimental group through argumentation instruction, decreasing from 15.8% in the pre-test to 0.0% in the post-test.

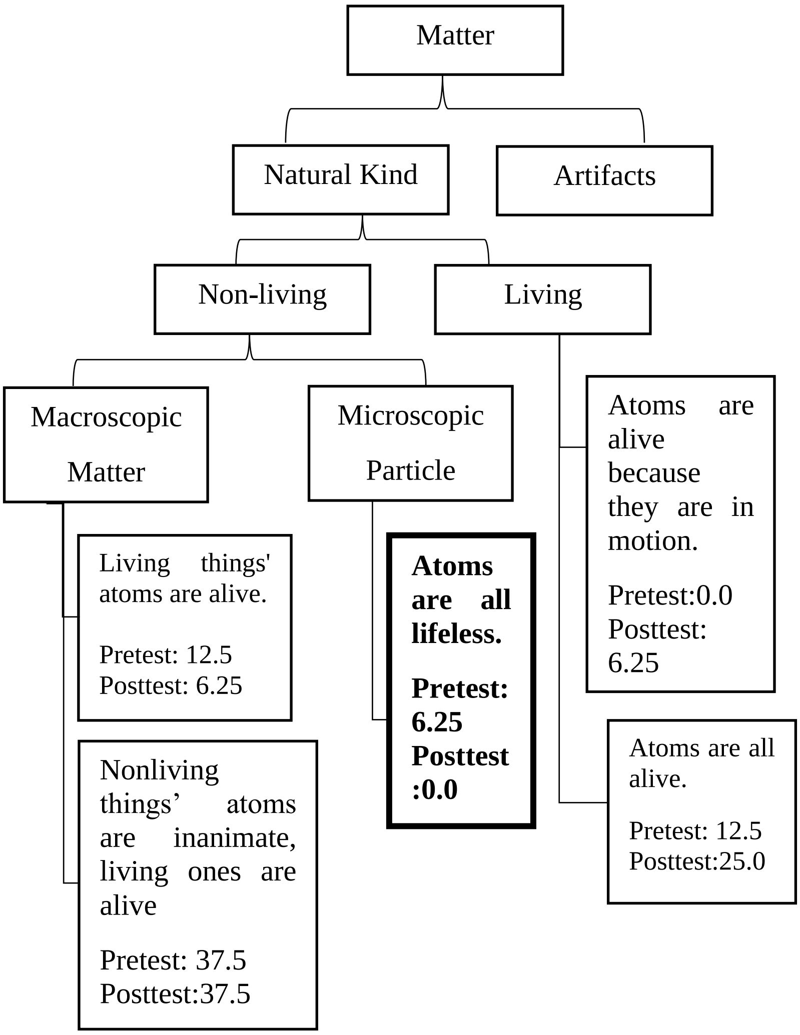


Figure 4. 3 Percentages of Comparison Group Misconceptions in Ontological Analysis of the First Question of the Particulate Nature of Matter Concept Test

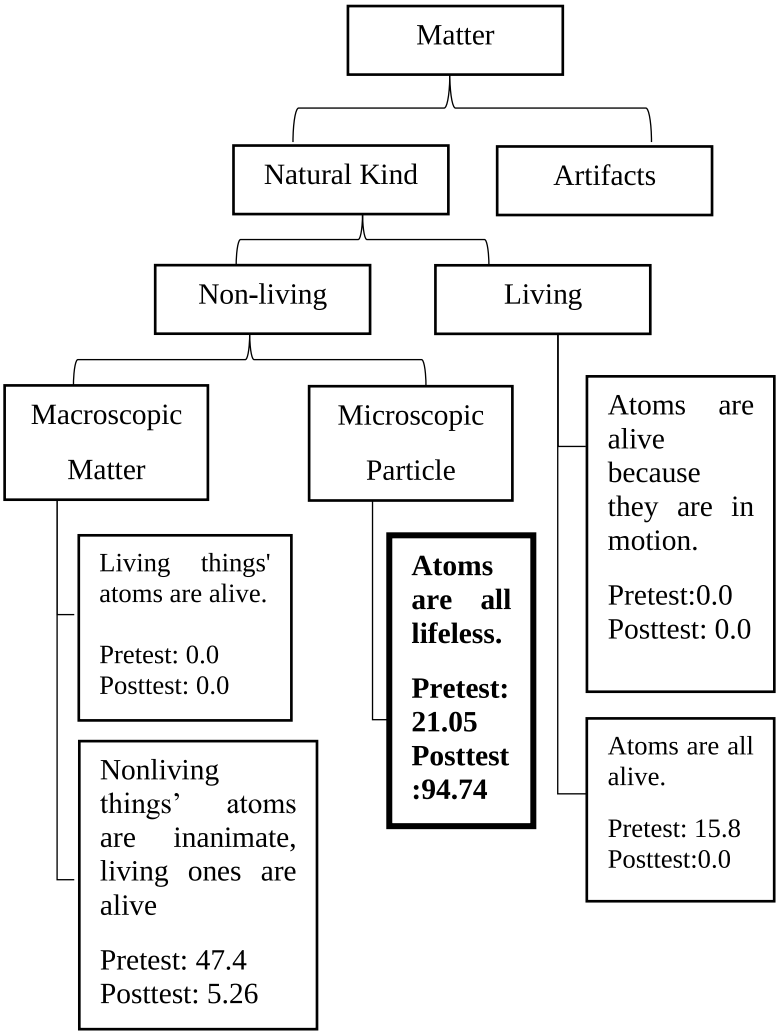


Figure 4. 4 Percentages of Experimental Group Misconceptions in Ontological Analysis of the First Question of the Particulate Nature of Matter Concept Test

4.4.2 Ontological Analysis for Question 2nd of PNMCT

In the 2nd question of PNMCT, the ontological reasons for the misconceptions about the atom were examined through the properties of the gold atom. Figure 4.5. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.6. presents the ontological examination of the misconceptions detected in the experimental group for the 2nd question. In this question, students evaluated the concept that a considerable part of the atom's volume is space at the micro level, placed it in the microscopic particle category, and gave the correct answer. According to Figure 4.5, in the comparison group, no students provided correct answers in the pre-test, but this increased to 6.25% in the post-test. According to Figure 4.6, no students in the experimental group placed the relevant concept in the correct ontological category on the pre-test; however, this percentage rose significantly to 73.69% in the post-test. For study groups, a single source of the misconceptions determined regarding the relevant concept was found based on ontology. This is because the idea that should be included in the microscopic particle category is included in its lateral category, the macroscopic matter category. One frequently encountered misconception under the macroscopic matter category is the misconception that students evaluate the atom at the macro level and that physical interventions applied to the matter will also exist in atoms. According to Figure 4.5., this rate is 50% in the comparison group and 25.0% in the post-test. A similar misconception in the experimental group decreased from 52.62% in the pre-test to 0% in the post-test, demonstrating that argumentation instruction successfully eliminated this misconception. Another misconception frequently encountered in the study groups in the macroscopic matter category is that the properties of matter (color, brightness) are also present in their atoms. According to Figure 4.5, the rate of this misconception in the comparison group pre-test and post-test was 25.0%. No positive effect of curriculum-based instruction on this misconception could be determined. According to Figure 4.6, while this rate was 10.52% in the experimental group’s pre-test, it was completely eliminated after argumentation instruction.

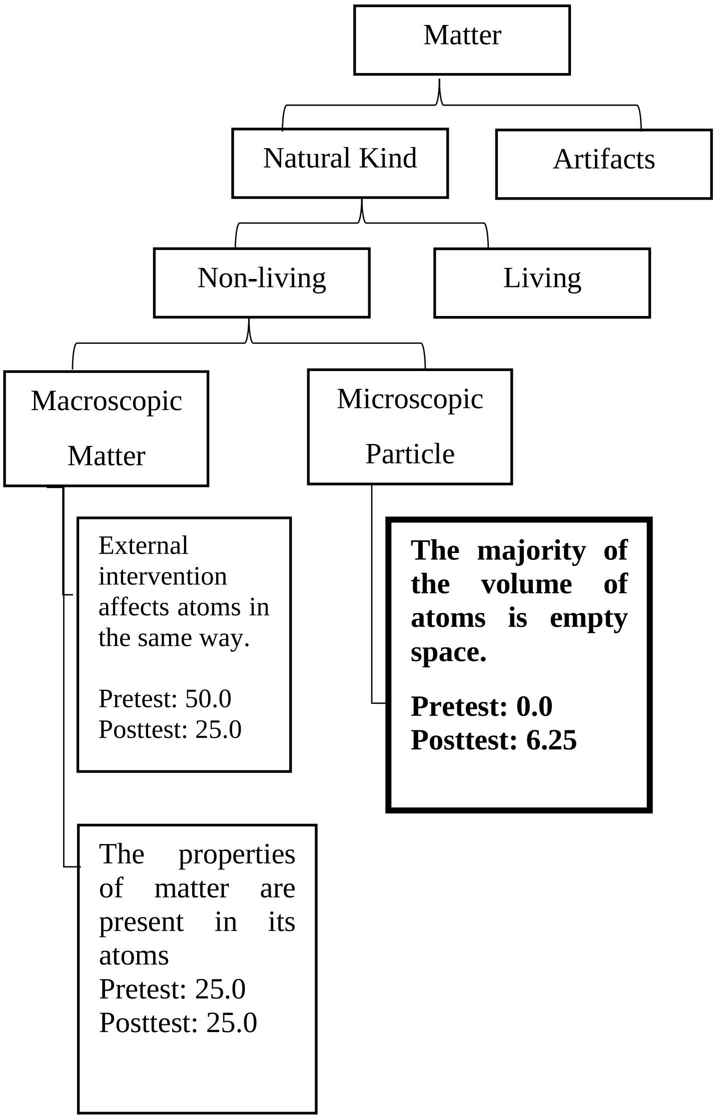


Figure 4. 5 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Second Question of the Particulate Nature of Matter Concept Test

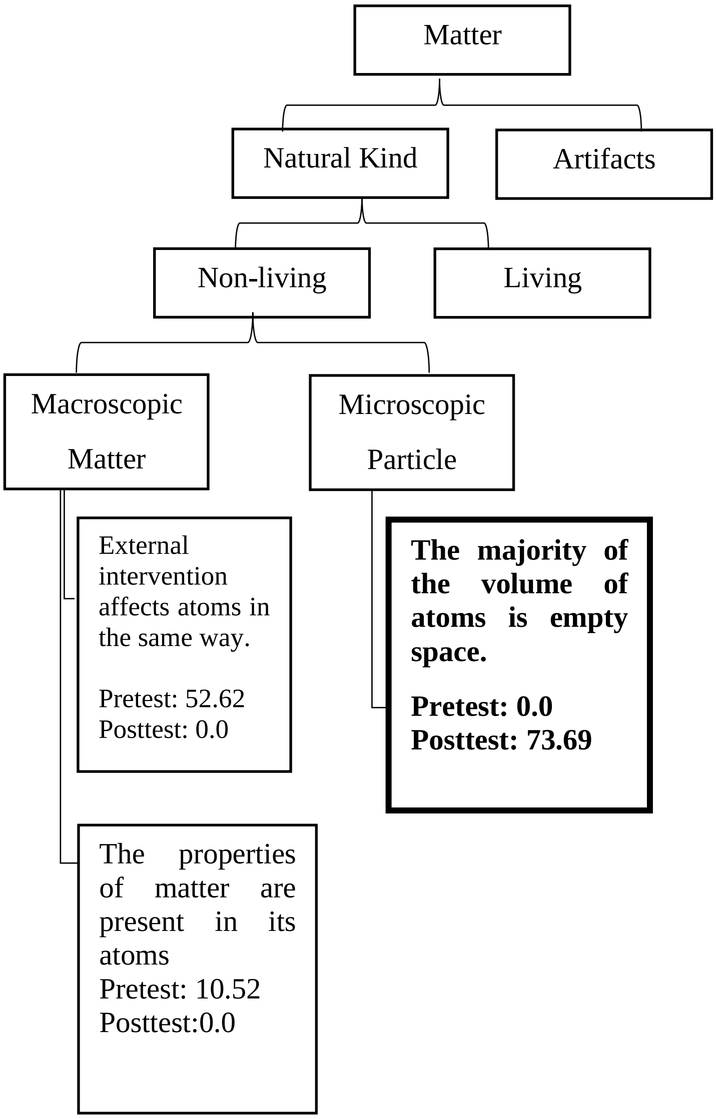


Figure 4. 6 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Second Question of the Particulate Nature of Matter Concept Test

4.4.3 Ontological Analysis for Question 3rd of PNMCT

In the 3rd question of PNMCT, the reasons for students' misconceptions about dissolution were examined from an ontological perspective through the sugar-water example. Figure 4.7. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.8. presents the ontological examination of the misconceptions detected in the experimental group for the 3rd question. In the 3rd question of PNMCT, it is seen that the students who separated the concept related to sugar-water interaction from the chemical event and placed it in the dissolution category, one of the subcategories of the physical event category, gave the correct answer. According to Figure 4.7, while this rate was 6.25% in the pre-test in the comparison group, it remained constant in the post-test. According to Figure 4.8, while this rate was 10.53% in the pre-test in the experimental group, it increased in the post-test and rose to 68.43%. Two different sources of misconceptions regarding the relevant concept determined in the study groups were encountered based on ontology. The first is due to placing the sugar-water interaction, which should be in the dissolution category, in the melting category, which is its lateral category. The rate of comparison group students who had misconceptions due to evaluating the concept of dissolution under the melting category was 43.75% in the pre-test and decreased to 25.0% in the post-test; in other words, it could not be eliminated. While the pre-test rate of the experimental group students who had misconceptions due to assigning to a similar incorrect ontological category was 42.08%, any misconceptions due to the stated reason were detected in the post-test. The second source detected from the ontology basis was due to the students placing the concept of dissolution in the chemical event category, which is its superordinate category. The first of the misconceptions detected due to the assignment of dissolution, a physical event, to the chemical event category was that the students thought a new compound was formed after dissolution. While the rate of the comparison group students who had misconceptions due to the stated ontological reason was 12.5% in the pre-test, it increased to 25.0% in the post-test.

While this rate was 10.52% in the experimental group, it decreased to 0% after the argumentation instruction. Another misconception in the chemical event category was that the students thought that sugar would turn into water. While the rate of the comparison group students who had misconceptions due to the stated ontological reason was 12.5% in the pre-test, it was 0% in the post-test. In the experimental group, this rate started at 15.79% in the pre-test but increased to 21.04% in the post-test. This result highlights the effectiveness of curriculum-based instruction in eliminating misconceptions within the chemical event category.

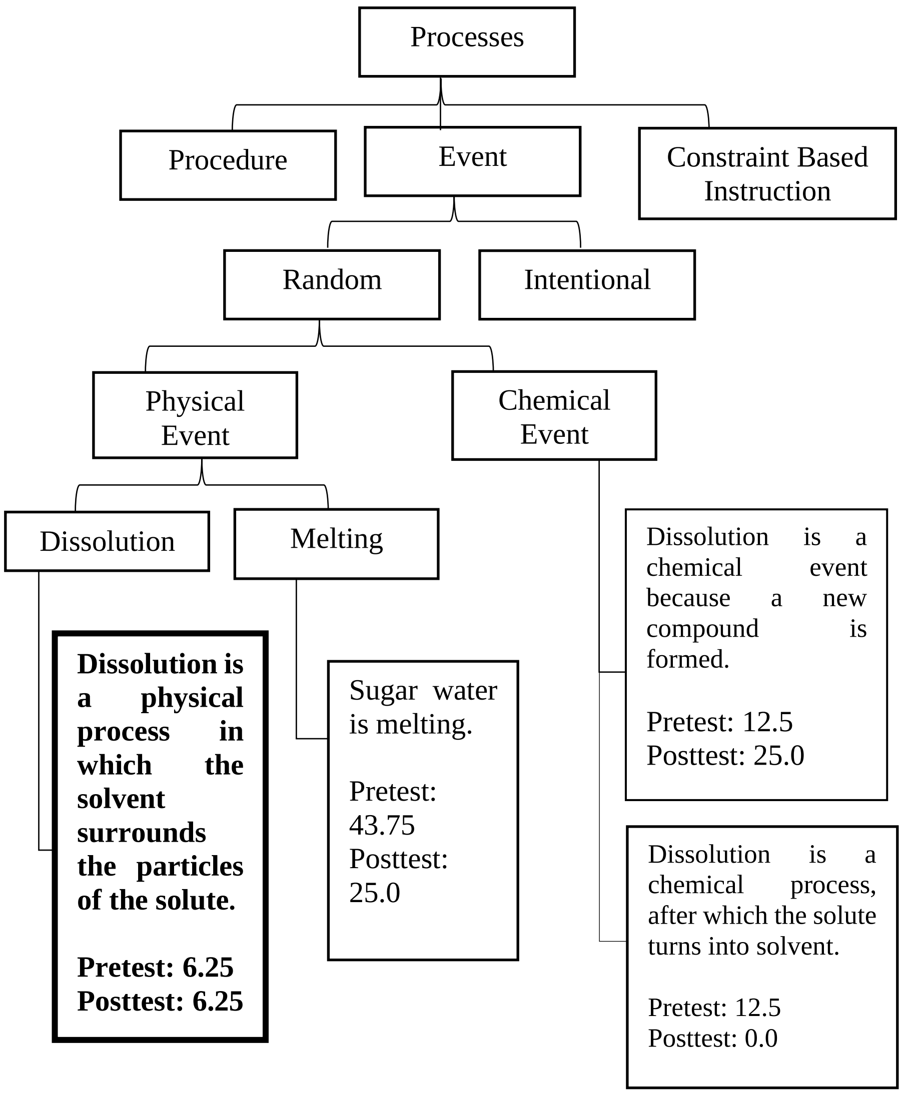


Figure 4. 7 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Third Question of the Particulate Nature of Matter Concept Test

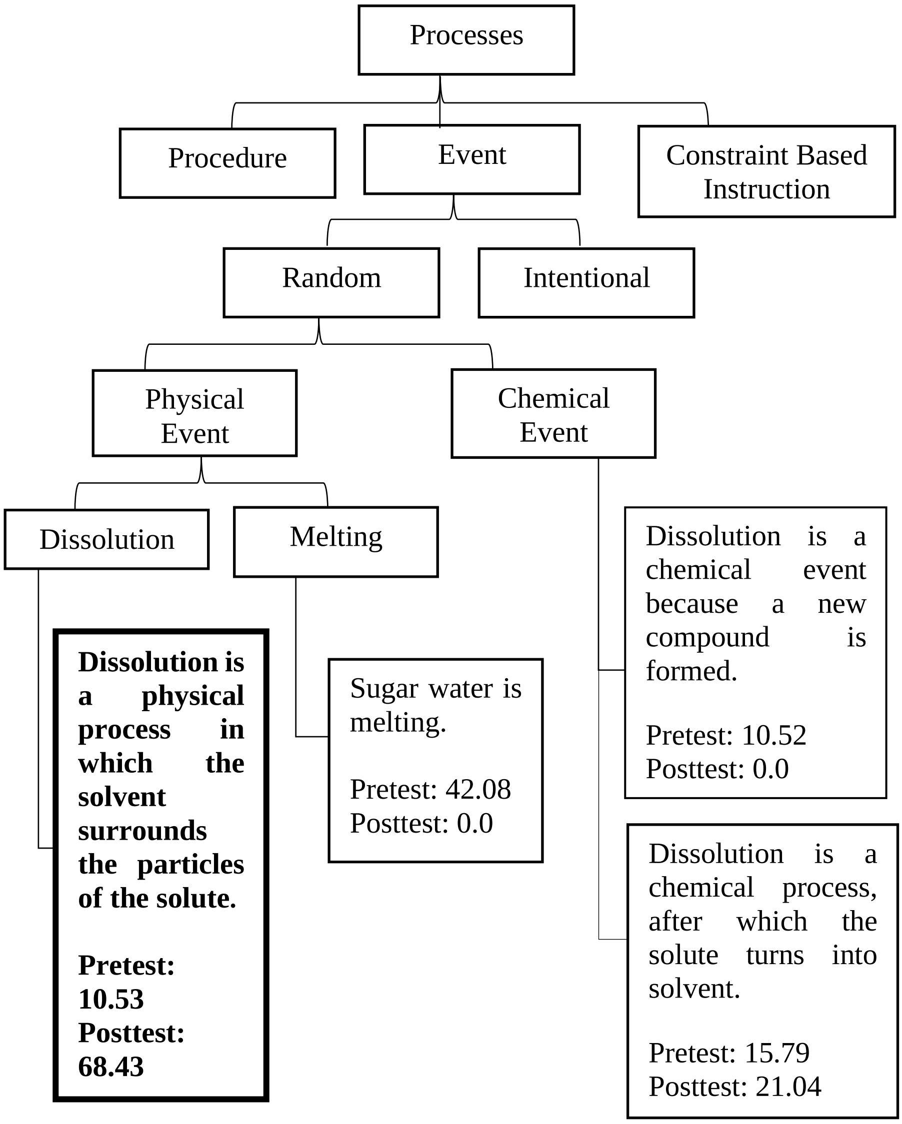


Figure 4. 8 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Third Question of the Particulate Nature of Matter Concept Test

4.4.4 Ontological Analysis for Question 4th of PNMCT

In the 4th question of PNMCT, the reasons for the misconceptions regarding evaluating expressions related to water molecules were examined from an ontological perspective. Figure 4.9. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.10. presents the ontological examination of the misconceptions detected in the experimental group for the 4th question. It is seen that students who evaluated the volumes of water molecules during phase change at the micro level and placed the concept that the volume change due to the phase transition of the matter will not be observed in its molecules in the microscopic matter category, which is a sub-category of the non-living category, gave the correct answer. According to Figure 4.9, this rate increased slightly from 18.75% in the comparison group pre-test to 25.0% in the post-test. According to Figure 4.10, the rate of students in the experimental group who placed the relevant concept in the correct ontological category was 31.58% in the pre-test and 89.48% in the post-test. A single source of misconceptions regarding the relevant concept detected in the study groups was found based on ontology. It stems from incorrectly placing the idea that the microscopic particle category should be in its sub-category, the macroscopic matter category. One of the misconceptions that students concentrated on in the macroscopic matter category is the increase in the volume of the molecule when it passes from the solid to the gas phase. The rate of comparison group students having this misconception increased from 18.75% in the pre-test to 25% in the post-test. A similar misconception decreased from 36.82% in the pre-test to 5.26% in the post-test in the experimental group. Another misconception students had was the belief that the volume of the molecule decreases when it passes from a solid to a gas phase. In the comparison group, the rate of this misconception remained constant at 31.25% from the pre-test to the post-test. In the experimental group, the rate was 31.56% in the pre-test, but this misconception was eliminated in the post-test.

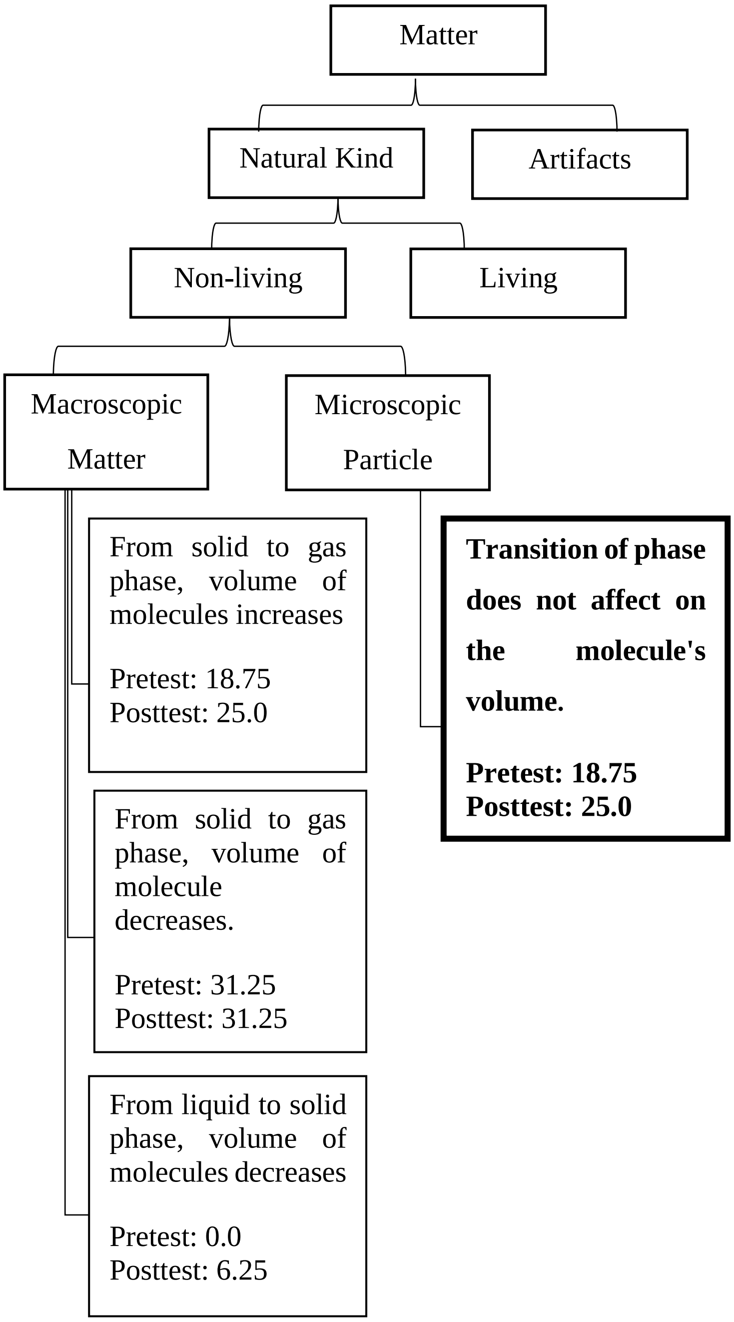


Figure 4. 9 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fourth Question of the Particulate Nature of Matter Concept Test

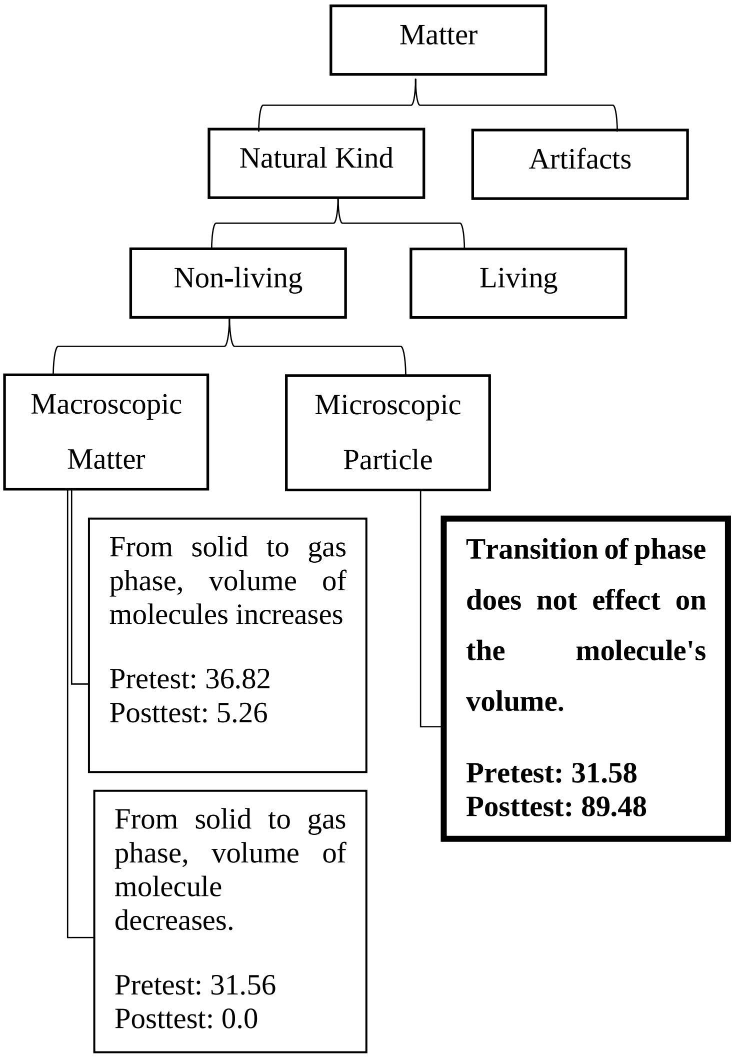


Figure 4. 10 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fourth Question of the Particulate Nature of Matter Concept Test

4.4.5 Ontological Analysis for Question 5th of PNMCT

In the 5th question of PNMCT, the reasons for the misconceptions detected regarding the movement of particles of solid matter, focusing on the iron example, were examined based on ontology. Figure 4.11. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.12. presents the ontological examination of the misconceptions detected in the experimental group for the 5th question. It is seen that the students who separated the concept related to the particles of solid matter being in vibration state through the iron example from the macroscopic dimension and placed it in the microscopic particle category, which is one of the subcategories of the non-living category, were evaluated in the correct ontological category. As indicated in Figure 4.11, this rate was 37.5% in the pre-test and decreased to 18.75% in the post-test for the comparison group. While 47.37% of the experimental group placed the relevant concept in the correct ontological category, this rate reached 100.0% in the post-test. A single source of the misconceptions developed by the study groups regarding the relevant concept has been identified based on ontology. Specifically, these misconceptions arise from the placement of particle motion, which should be evaluated within the microscopic particle category as belonging to the macroscopic matter category, which is a lateral category of the microscopic particle category. The first of the misconceptions detected regarding the statement that particles do not move due to their placement in the macroscopic matter category is that it is because the space between particles in the solid state is almost non-existent. In the comparison group, this misconception was present in 42.08% of students in the pre-test, but it was not observed in the post-test. Another misconception that the students concentrated on was the thought of the particle's movement under the macroscopic matter category by attributing the regularity of solids to particle immobility. Before the instruction, 12.5% of the comparison group and 5.26% of the experimental group had this misconception. It is a remarkable finding that both groups eliminated this misconception after the instructions.

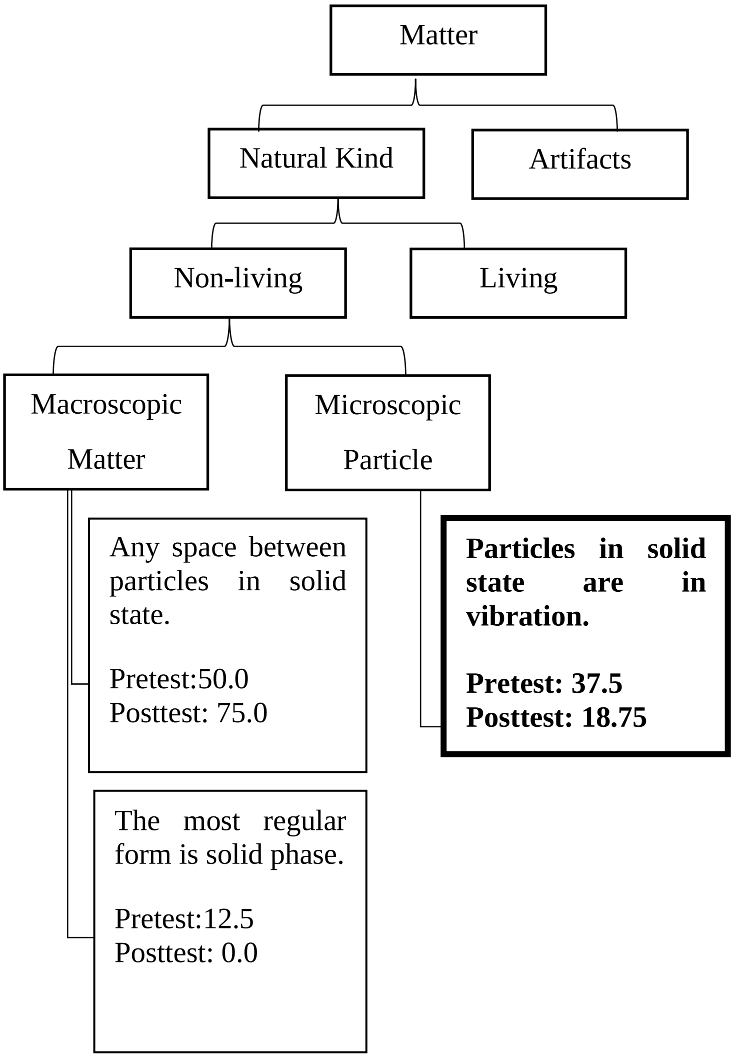


Figure 4. 11 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fifth Question of the Particulate Nature of Matter Concept Test

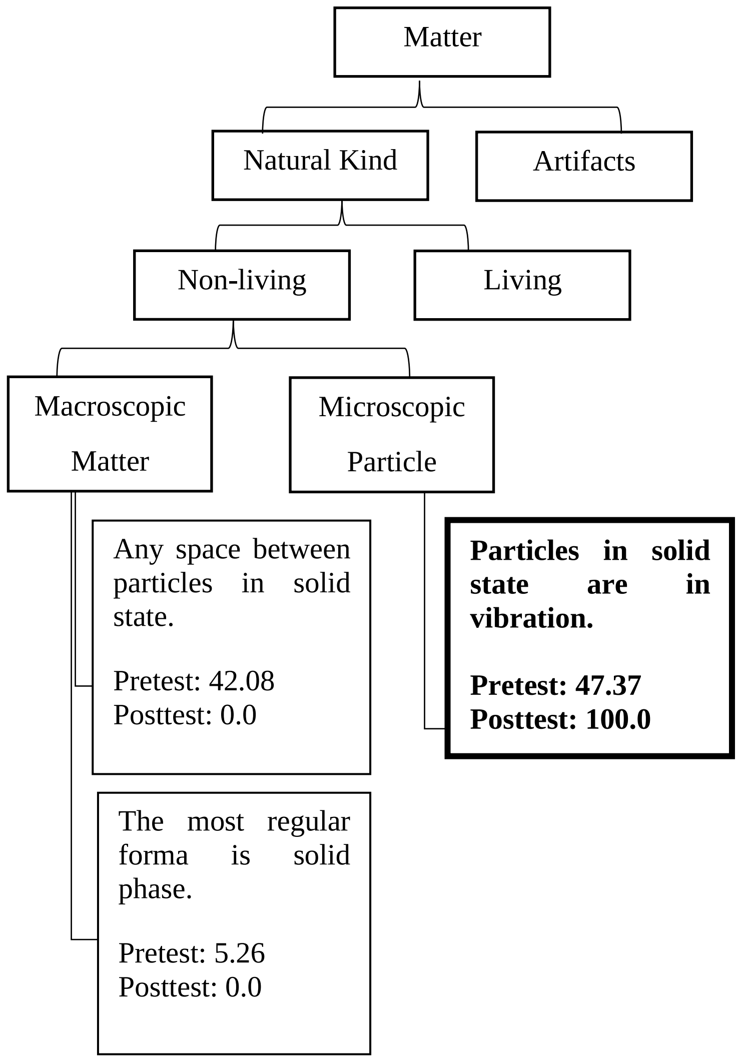


Figure 4. 12 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fifth Question of the Particulate Nature of Matter Concept Test

4.4.6 Ontological Analysis for Question 6th of PNMCT

In the 6th question of PNMCT, the students' misconceptions about whether there is any relationship between the fluidity property of liquids and their molecules were examined based on ontology.

Figure 4.13. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.14. presents the ontological examination of the misconceptions detected in the experimental group for the 6th question on water molecules. It is seen that the students who stated that the fluidity property of liquids is not related to the shape of molecules and placed the concept related to water molecules in the microscopic particle category by separating it from the macroscopic level assigned the relevant concept to the correct ontological category. According to Figure 4.13, this rate was 18.75% in the pre-test in the comparison group and 18.75% in the post-test. According to Figure 4.14, while 36.84% of the comparison group placed the concept in the correct ontological category in the pre-test, this rate increased to 78.95% in the post-test. In the related question, the only source of the misconceptions detected in the students before and after the instruction was based on ontology. This is due to the placement of the related concept in the macroscopic matter category, a lateral category of the microscopic particle category. One of the most common misconceptions about macroscopic matter is that molecules have physical states. The rate of comparison group students with this misconception was 18.75% in the pre-test and 12.5% in the post-test. This rate was 10.53% in the experimental group pre-test, while a similar rate was found in the post-test. Notably, the related misconception could not be minimized in either group. Another misconception within the macroscopic matter category is the attribution of flexibility property to water molecules. However, flexibility is specific to matter and is included in the macroscopic matter category, and flexibility cannot be attributed to an example in the microscopic matter category. The rate of this misconception was 18.75% in the comparison group pre-test and increased to 31.25% in the post-test. This rate was 26.32% in the pre-test and 5.26% in the post-test for the experimental group. Another

misconception detected under the same ontological category is the attribution of macroscopic properties to water molecules, thinking that the shapes of water molecules are the minor form of water that can be seen with the naked eye. The rate of comparison group students holding this misconception was 6.25% in the pre-test, which increased to 25.0% in the post-test. Conversely, in the experimental group, this rate was 15.79% in the pre-test and decreased to 5.26% in the post-test. In addition, the misconceptions stated by the students in the "None. According to me, the reason..." section were also detected. The ontological reason for the students' misconceptions stems from assigning the concept of the molecule, which should be evaluated within the microscopic particle category, to its lateral category, the macroscopic matter category. This led students to believe that the properties of water, such as fluidity, interparticle space, and physical phase, also exist in water molecules. The rate of this misconception in the pre-test was 18.75% in the comparison group and 5.26% in the experimental group. After the instruction, the stated misconception was eliminated in both groups.

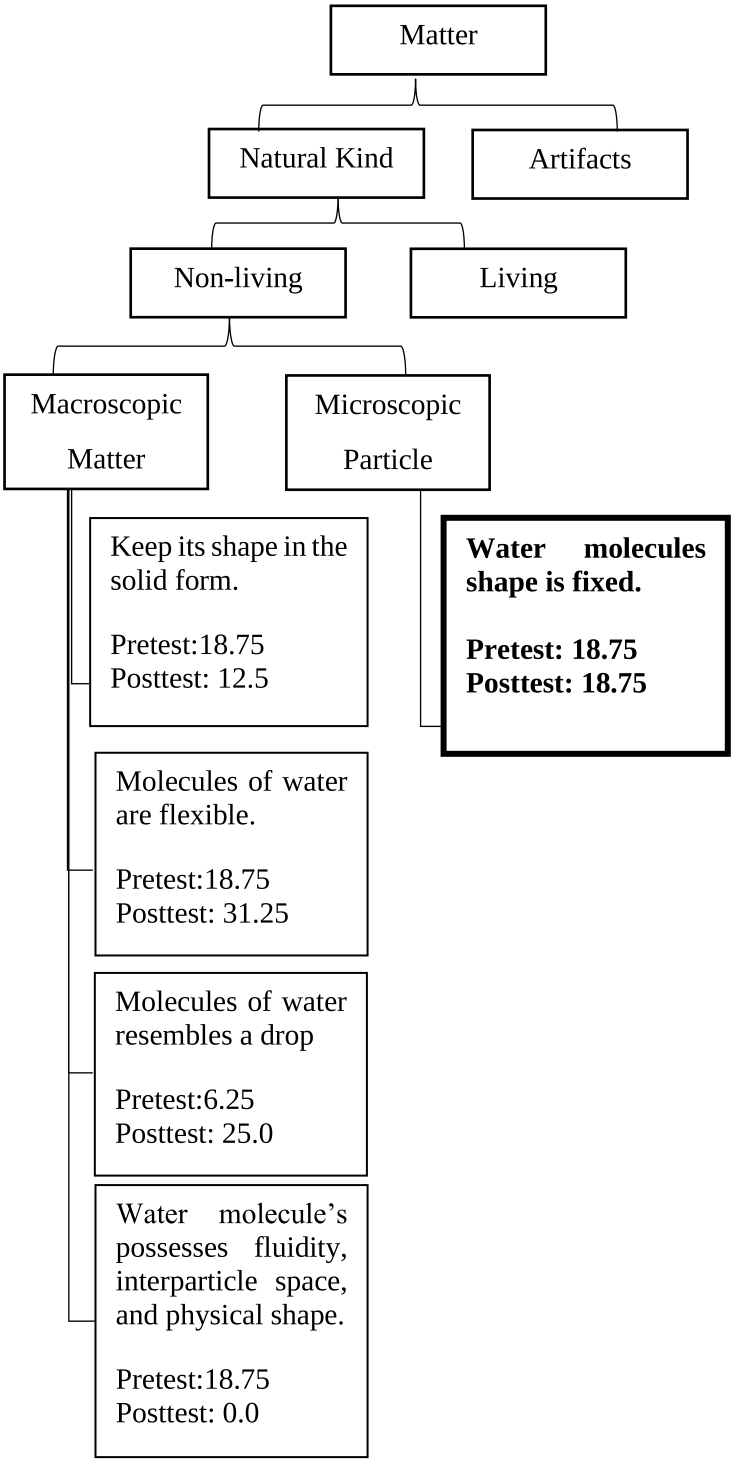


Figure 4. 13 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Sixth Question of the Particulate Nature of Matter Concept Test

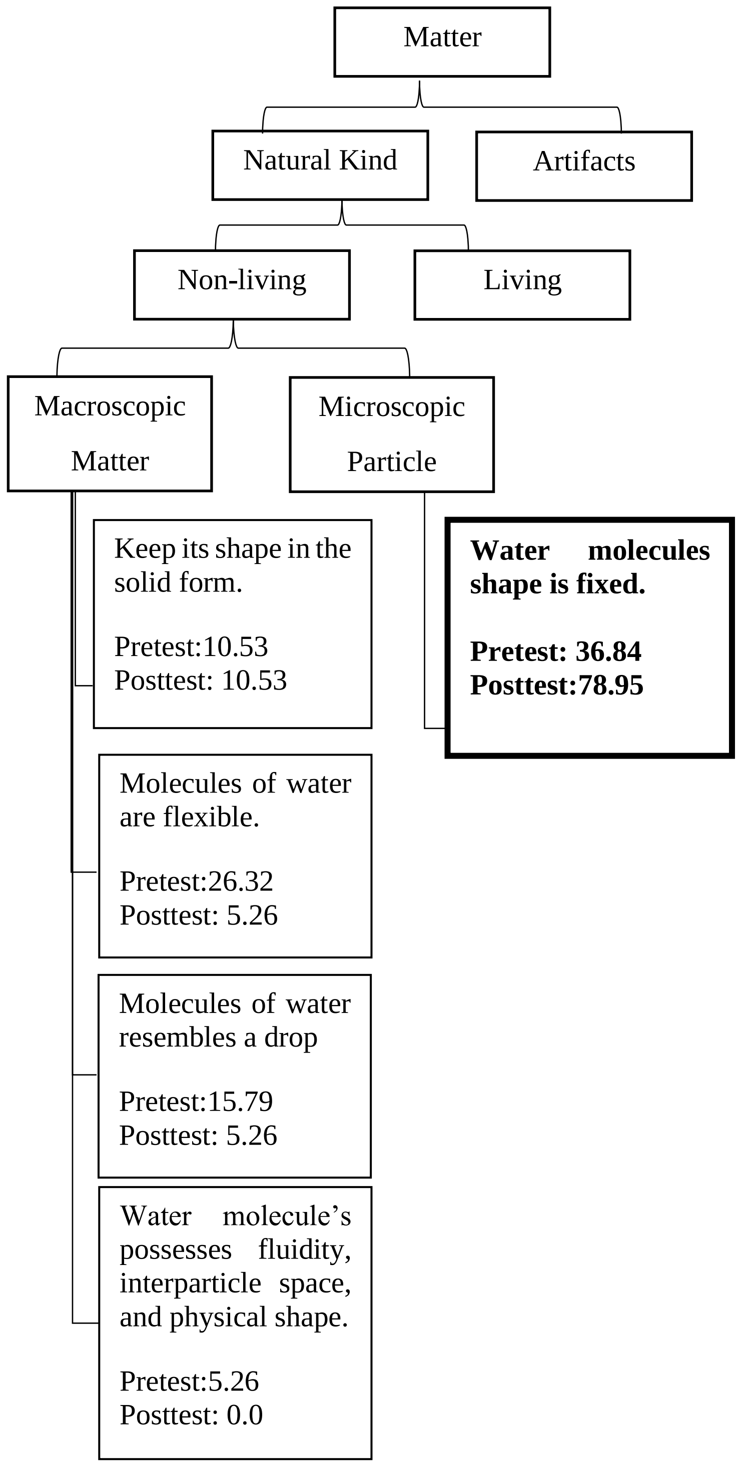


Figure 4. 14 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Sixth Question of the Particulate Nature of Matter Concept Test

4.4.7 Ontological Analysis for Question 7th of PNMCT

In the 7th question of PNMCT, the misconceptions detected in the students regarding the information that the reason for the three primary states of matter, solid, liquid, and gas, is the interaction between particles were examined from an ontological perspective.

Figure 4.15. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.16. presents the ontological examination of the misconceptions detected in the experimental group for the 7th question on water and ice molecules. It was observed that students who stated that molecules do not have physical states to answer the information in the question correctly separated ice and water molecules from the macroscopic dimension and placed them in the microscopic particle category. The rate of comparison group students who gave correct answers decreased from 12.5% in the pre-test to 6.25% in the post-test. In the experimental group, this rate was 5.26% in the pre-test and increased to 47.37% in the post-test, showing substantial progress. The only source of the misconceptions detected on an ontology basis was determined. This is because the expressions related to water and ice molecules, which should be under the microscopic particle category, were placed in its lateral category, the macroscopic matter category. The most common misconception among students in the lateral category is that the physical forms of ice and water molecules are similar to the substances they belong to. According to Figure 4.15, the rate of comparison group students with this misconception was 37.5% in the pre-test and 37.5% in the post-test. According to Figure 4.16, the rate of the specified misconception was 57.9% in the pre-test in the experimental group while it decreased to 5.26% in the post-test. This indicates that, although significantly reduced, the misconception was not completely eliminated. The second misconception frequently seen in students under the category of microscopic matter is the idea that molecules are always in the solid phase, independent of the substance they belong to. While the rate of this misconception in the comparison group in the pre-test was 18.75%, it increased to 25.0% in the post-

test. In the experimental group, the rates were 21.06% and 15.80%, respectively. Notably, the stated misconception was not completely eliminated in either group despite the type of instruction received. The misconception that occurred in both groups after instruction was the idea that molecules are always in the liquid phase, independent of the substance they belong to, contrary to the previous misconception. While the rate of this misconception in the comparison group post-test was 6.25%, it was 10.53% in the experimental group. A remarkable result is that students who received argumentation instruction formed this misconception at a higher rate.

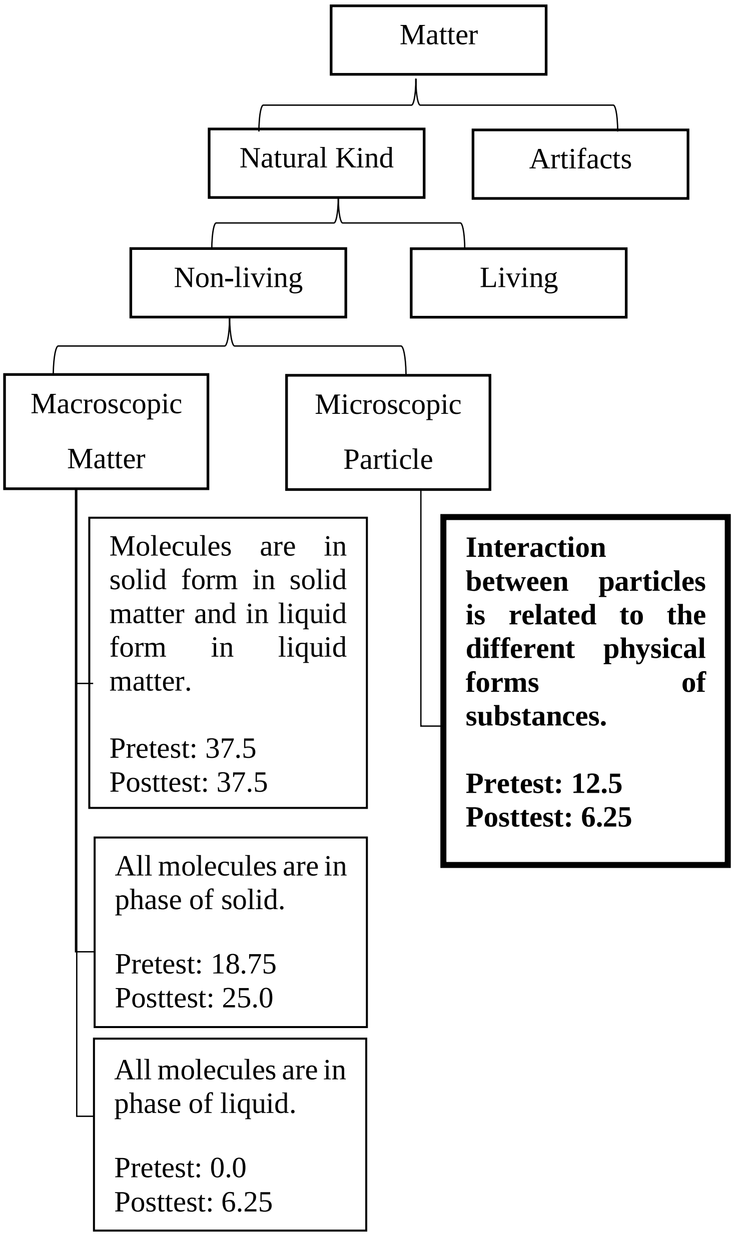


Figure 4. 15 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Seventh Question of the Particulate Nature of Matter Concept Test

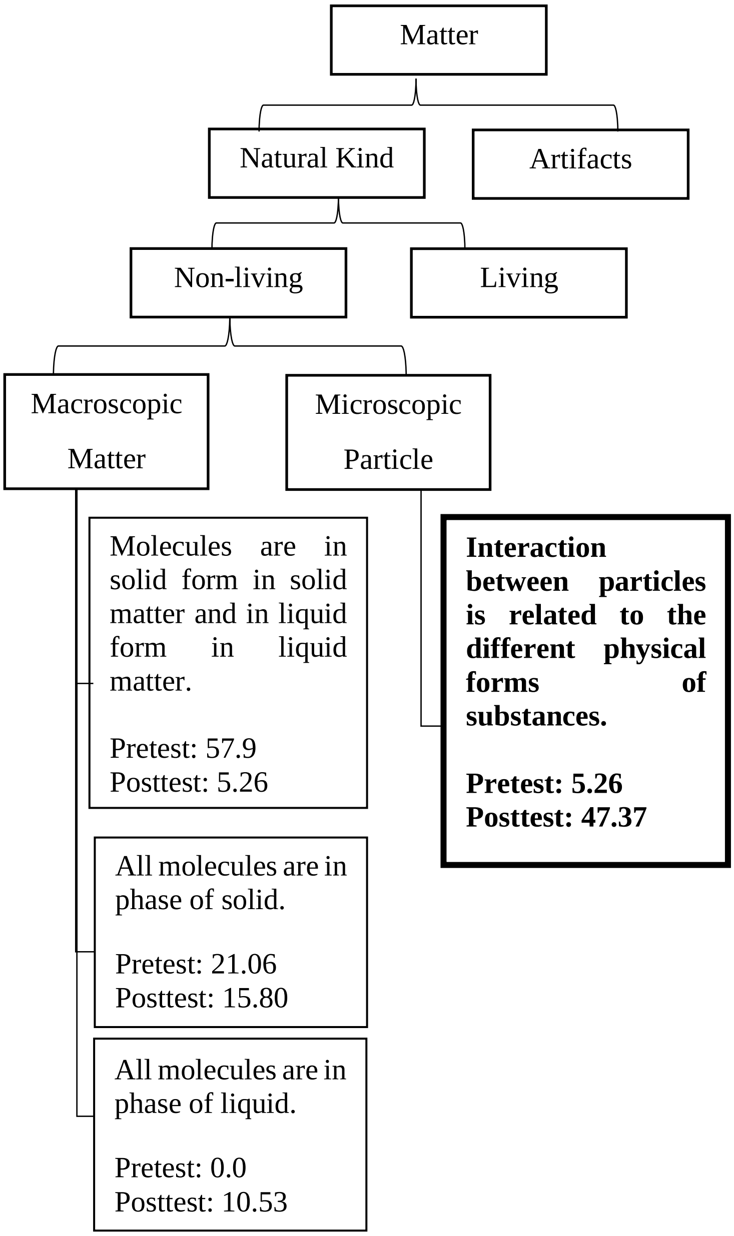


Figure 4. 16 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Seventh Question of the Particulate Nature of Matter Concept Test

4.4.8 Ontological Analysis for Question 8th of PNMCT

In the 8th question of PNMCT, the misconceptions detected by the students regarding the knowledge that the smallest particle of alcohol and sugar that shows their chemical properties is in the form of a molecule were determined and examined based on ontology, as shown in Figure 4.17. for the comparison group, and Figure 4.18. for the experimental group. Students who evaluated within the microscopic category gave the correct answer by stating that since alcohol and sugar are compounds, molecules are minor structural units that carry their chemical properties. According to Figure 4.17, while this rate was 37.5% in the comparison group pre-test, it decreased to 25.0% in the post-test. As stated in Figure 4.18. for the experimental group, the rates were 31.58% and 78.35%, respectively. It is seen that the students who received argumentation instruction gave a higher rate of correct answers to the question. In the relevant question, the only source of the reasons for the misconceptions determined in the students was found based on ontology. This is to make evaluations on a macro scale by placing the concept related to the smallest structural unit that carries the substance's chemical properties, which should be placed in the microscopic particle category, in its lateral category, the macroscopic matter category. One of the misconceptions frequently encountered by students within the macroscopic matter category is not knowing that different substances are composed of distinct particles. While the rate of comparison group students having this misconception was 12.5% in the pre-test, it increased to 31.25% in the post-test. In the experimental group, this rate was 5.26% in the pre-test, but the stated misconception was not encountered in any student in the post-test. Another misconception within the macroscopic matter category is that particles are expressed with visible shapes because they attribute macro properties to them. While the stated misconception was 18.75% in the pre-test of the comparison group, it decreased to 6.25% in the post-test. This rate was 31.58% in the experimental group and 5.26% in the post-test, respectively. It is a remarkable finding that this misconception was still observed in both groups after the study.

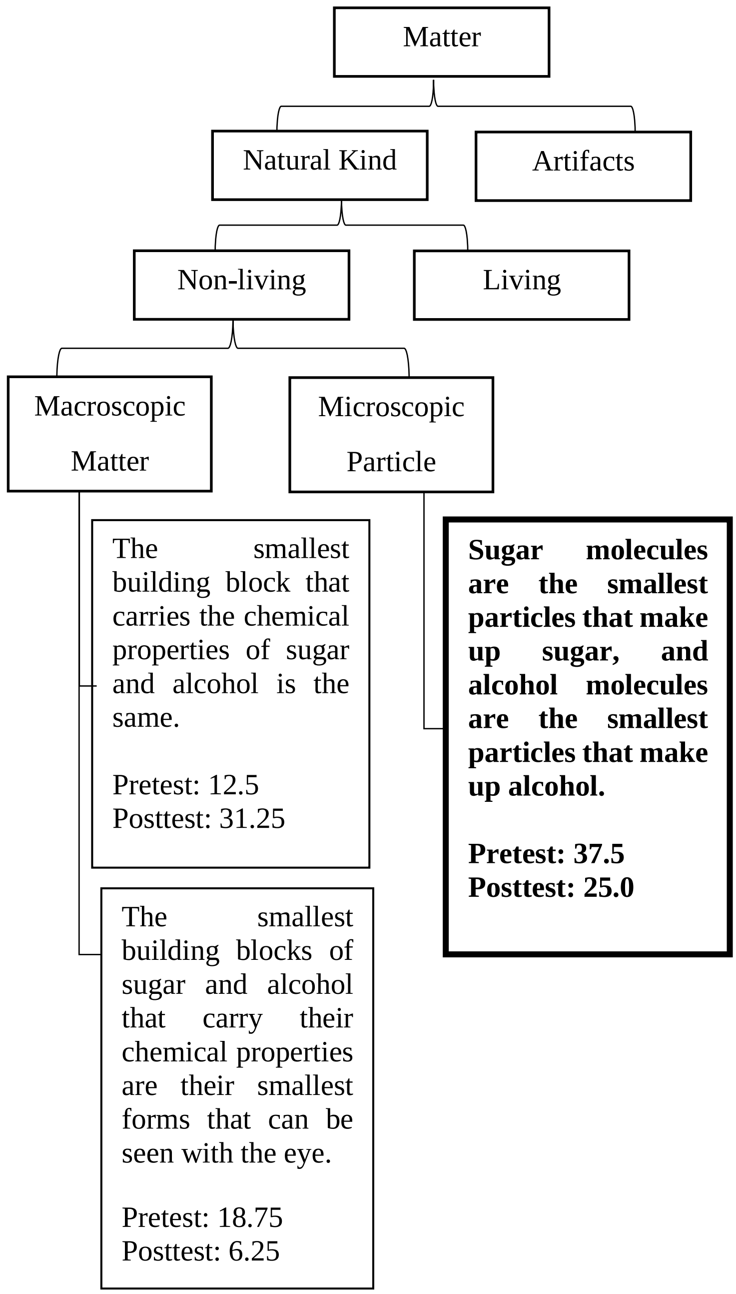


Figure 4. 17 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Eighth Question of the Particulate Nature of Matter Concept Test

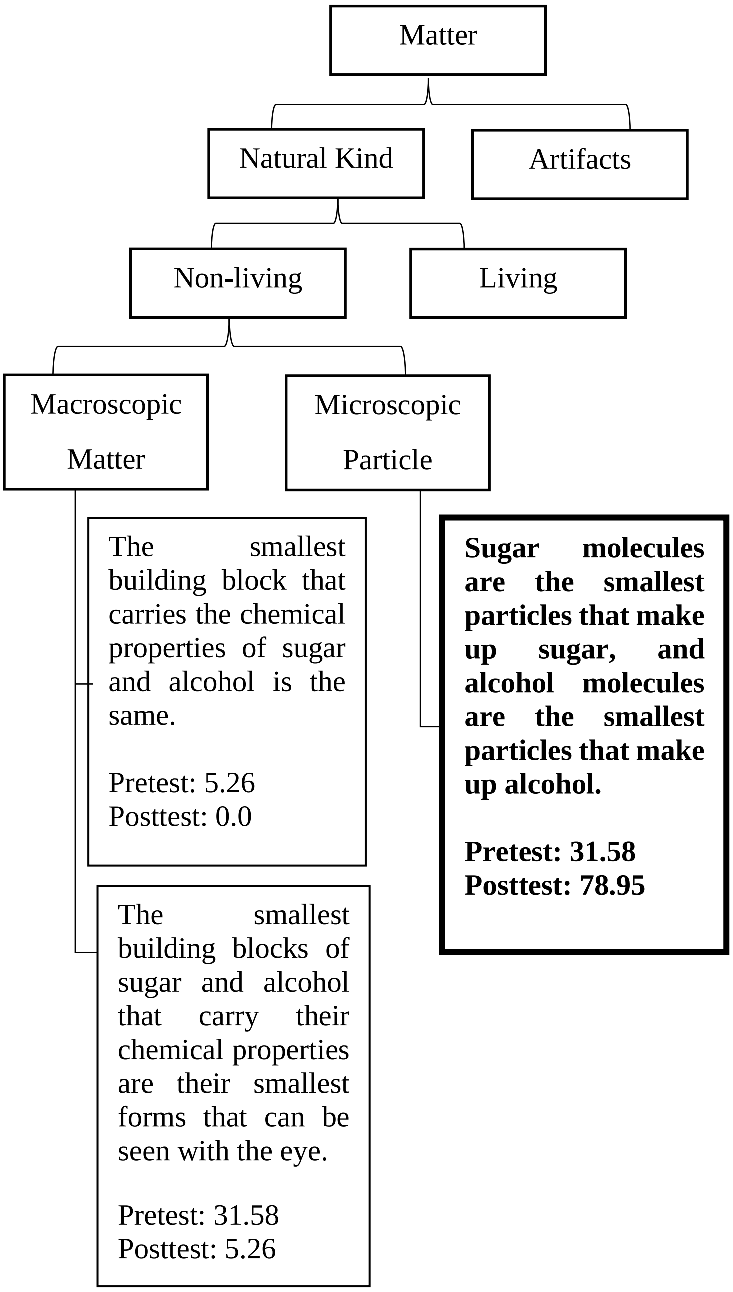


Figure 4. 18 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Eighth Question of the Particulate Nature of Matter Concept Test

4.4.9 Ontological Analysis for Question 9^{th} of PNMCT

In the 9th question of PNMCT, the students' misconceptions about the expressions regarding the volumes, temperatures, and physical states of water molecules during freezing were examined from an ontological perspective.

Figure 4.19. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.20. presents the ontological examination of the misconceptions detected in the experimental group regarding the changes in water molecules during water freezing. It is seen that the students who evaluated the temperature and volume decrease observed in water during the freezing event and the transition to the solid phase in a macroscopic dimension stated that it does not exist in water molecules and answered the question correctly by placing the water molecules in the microscopic particle category. According to Figure 4.19, while the comparison group of students who responded to the question correctly was 12.5% in the pre-test, it remained at a similar rate in the post-test. While this rate was 5.26% in the experimental group pre-test, it increased and reached 68.42% in the post-test. The only source of the misconceptions detected in the relevant question was found on an ontology basis. Students presented different reasons and evaluated the concept that there would be no change in molecules during freezing, which should be in the microscopic matter category, in its lateral category, the macroscopic matter category, and transferred the properties observed in water during freezing to its particles. One misconception in the macroscopic matter category is that freezing will reduce the temperature of water molecules and make them solid. The rate of comparison group students with this misconception remained constant in the pre-test and post-test and was 31.25%. This rate was 47.4% in the pre-test results of the experimental group, while it was 0% in the post-test. In other words, students who received environment argumentation instruction completely eliminated the stated misconception. Another misconception placed in the macroscopic matter category is the idea that water molecules will decrease in volume during freezing, in addition to the previous misconception. The rate of comparison group students with this misconception was

37.5% in the pre-test and 25.0% in the post-test. In the experimental group, the rates were 15.78% and 10.52%, respectively. Unlike the previous misconception, the rate of thinking that water molecules will increase was 6.25% in the comparison group pre-test, while it increased to 12.5% in the post-test. In the experimental group, it was 15.78% in the pre-test and 5.26% in the post-test. It is seen that the stated misconceptions were not eliminated despite the different types of instruction provided. A student in the experimental group stated his/her reasoning both before and after the instruction, noting that since s/he believed that water shrinks when it freezes, its molecules will shrink as well. The ontological reason for this misconception is that the student attributes macroscopic properties to water molecules and assigns the concept to the macroscopic matter category.

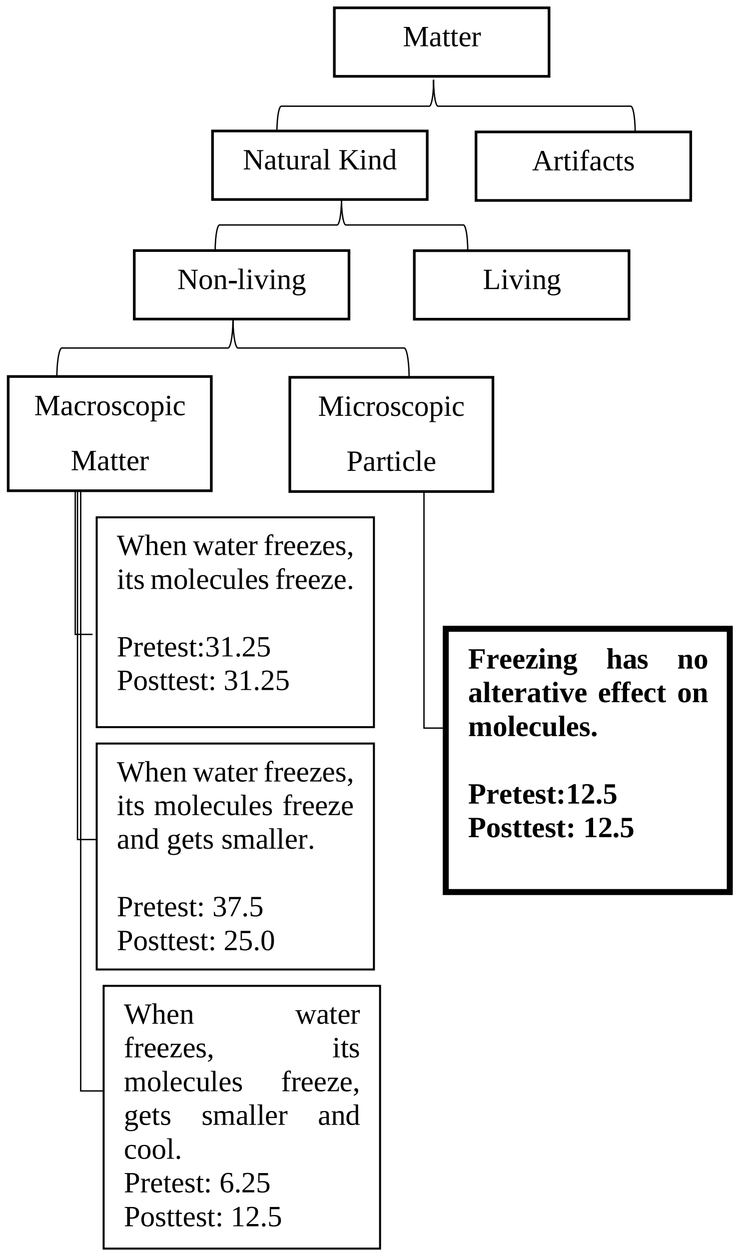


Figure 4. 19 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Ninth Question of the Particulate Nature of Matter Concept Test

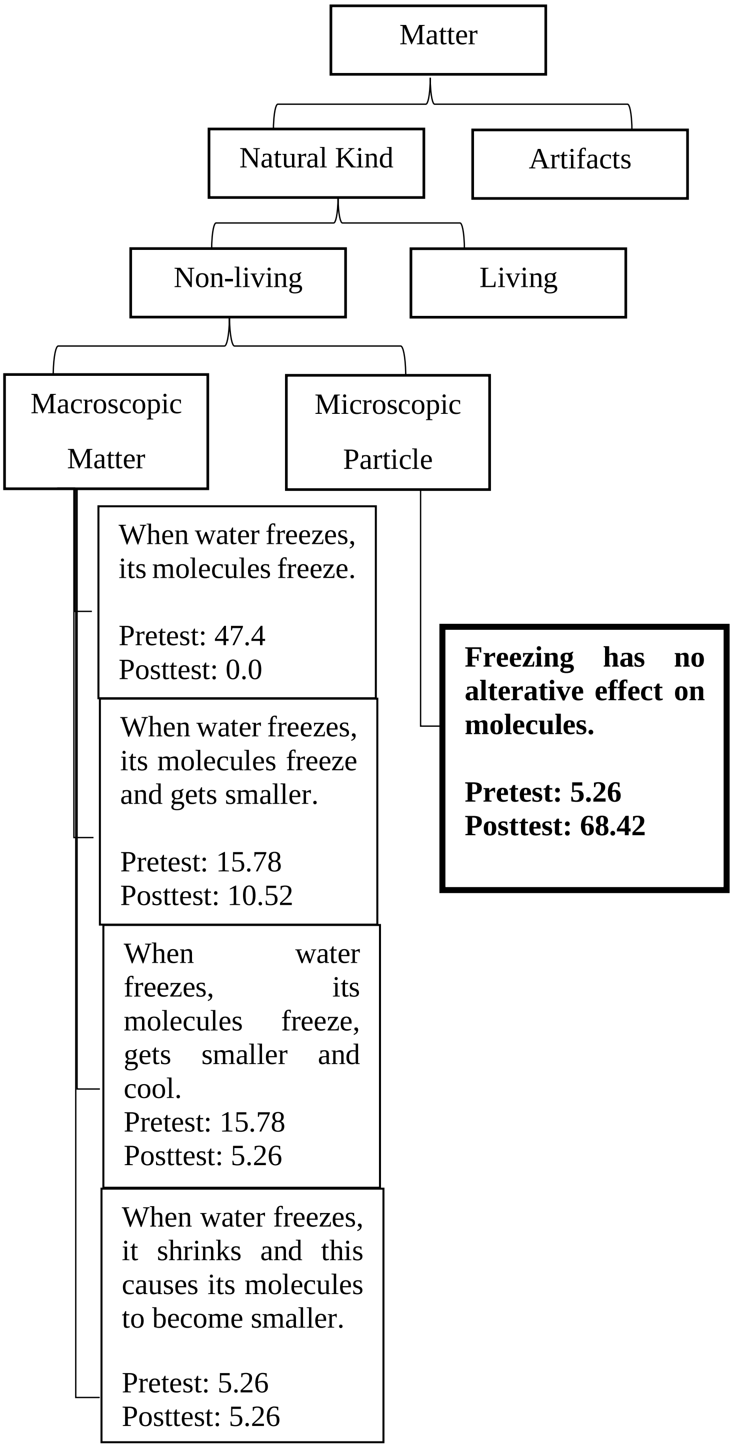


Figure 4. 20 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Ninth Question of the Particulate Nature of Matter Concept Test

4.4.10 Ontological Analysis for Question 10th of PNMCT

In the 10th question of PNMCT, the ontological reasons for the misconceptions detected by the students regarding the different changes that occur in the iron atoms during the melting of iron were examined.

Figure 4.21. presents the ontological examination of the misconceptions detected in the comparison group, while Figure 4.22. presents the ontological examination of the misconceptions detected in the experimental group regarding the changes in iron atoms during the melting process of iron. It is seen that the students who focused only on melting affected matter at the macroscopic level and thought that the specified physical event would not affect the particles answered the question correctly by placing the iron atoms in the microscopic particle category, which is one of the subcategories of the matter category. According to Figure 4.21, while this rate was 18.75% in the comparison group pre-test, it decreased and became 12.5% in the post-test. As shown in Figure 4.22, while the rate of the experimental group students who answered the question correctly was 10.53% in the pre-test, it increased and became 63.16% in the post-test. The only source of the misconceptions detected regarding the relevant question was based on ontology. This is because iron atoms, which are members of the microscopic matter category, were placed in the macroscopic matter category, which is its lateral category, due to the idea that melting, which is a physical event, will affect the atoms of the solid. The first of the misconceptions observed in the macroscopic matter category was the students' idea that melting would also reduce the atom's volume. The rate of the comparison group students who had this misconception in the pre-test and post-test was 31.25% and 18.75%, respectively. In the experimental group, it was 5.26% in the pre-test and remained the same in the post-test. It was concluded that the stated misconception was not eliminated in both study groups. The other misconception was that the volume of iron atoms would increase during melting, in addition to the previous misconception. According to Figure 4.21, while the rate of this misconception in the comparison group was 6.25%, it increased in the post-test and became 25.0%. As

shown in Figure 4.22, 47.37% of the experimental group had this misconception in the pre-test, but it was eliminated after the instruction. The students stated that melting will not affect the temperature of the atoms but will melt them and increase their volume, which is another misconception in the macroscopic matter category. While 25.0% of the comparison group had this misconception in the pre-test, it decreased to 18.75% in the post-test. While only one student in the experimental group had this misconception, the misconception was eliminated after the instruction. The misconception that both study groups concentrated on was that melting heats and melts the atoms but does not affect their volume. The percentage of students in the comparison group who held this misconception remained constant at 12.5% in both the pre-test and post-test. This rate was 26.32% in the pre-test and 15.78% in the post-test in the experimental group. Although a decrease was observed in the experimental group, it was observed that the stated misconception was not eliminated.

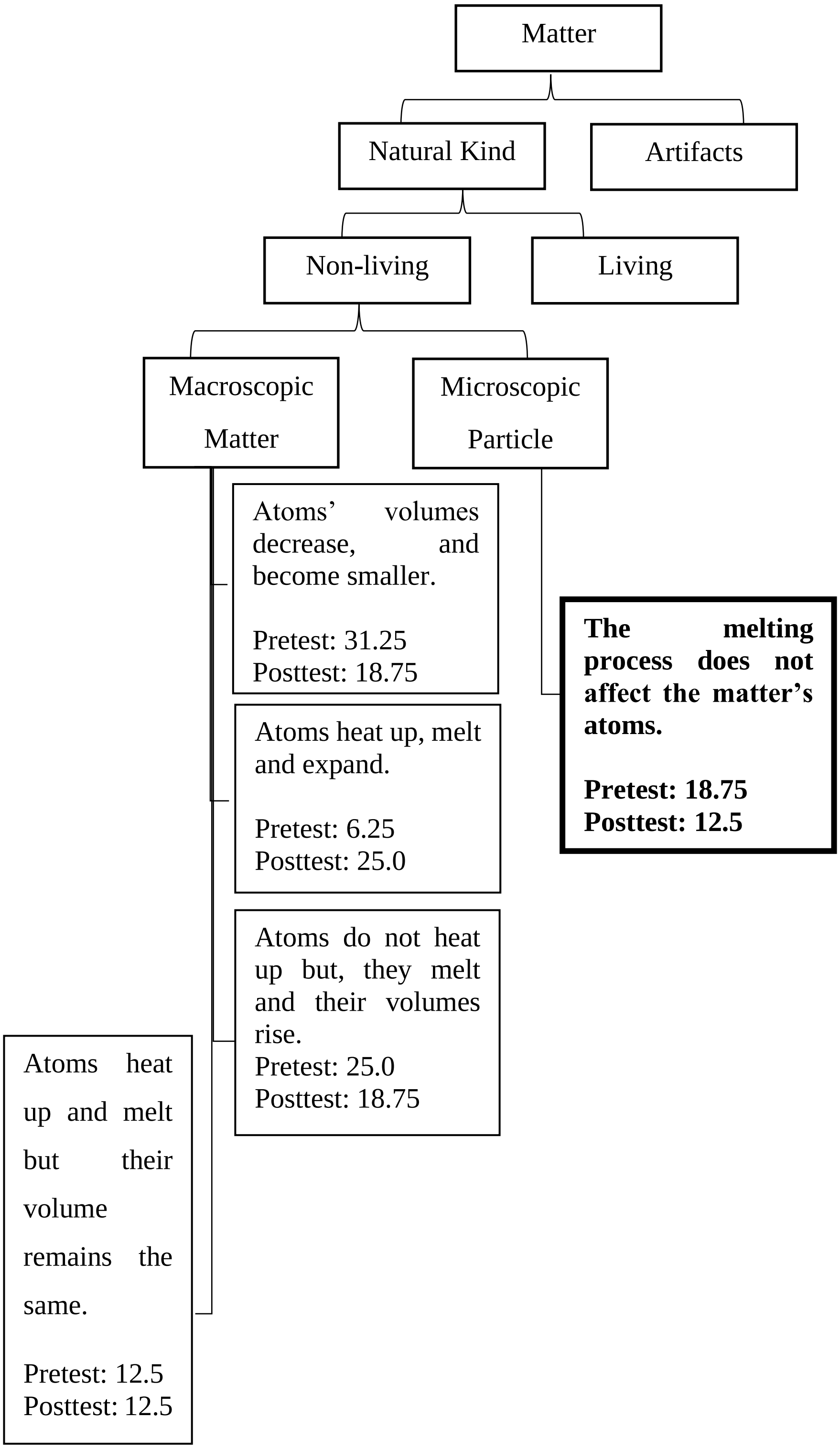


Figure 4. 21 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Tenth Question of the Particulate Nature of Matter Concept Test

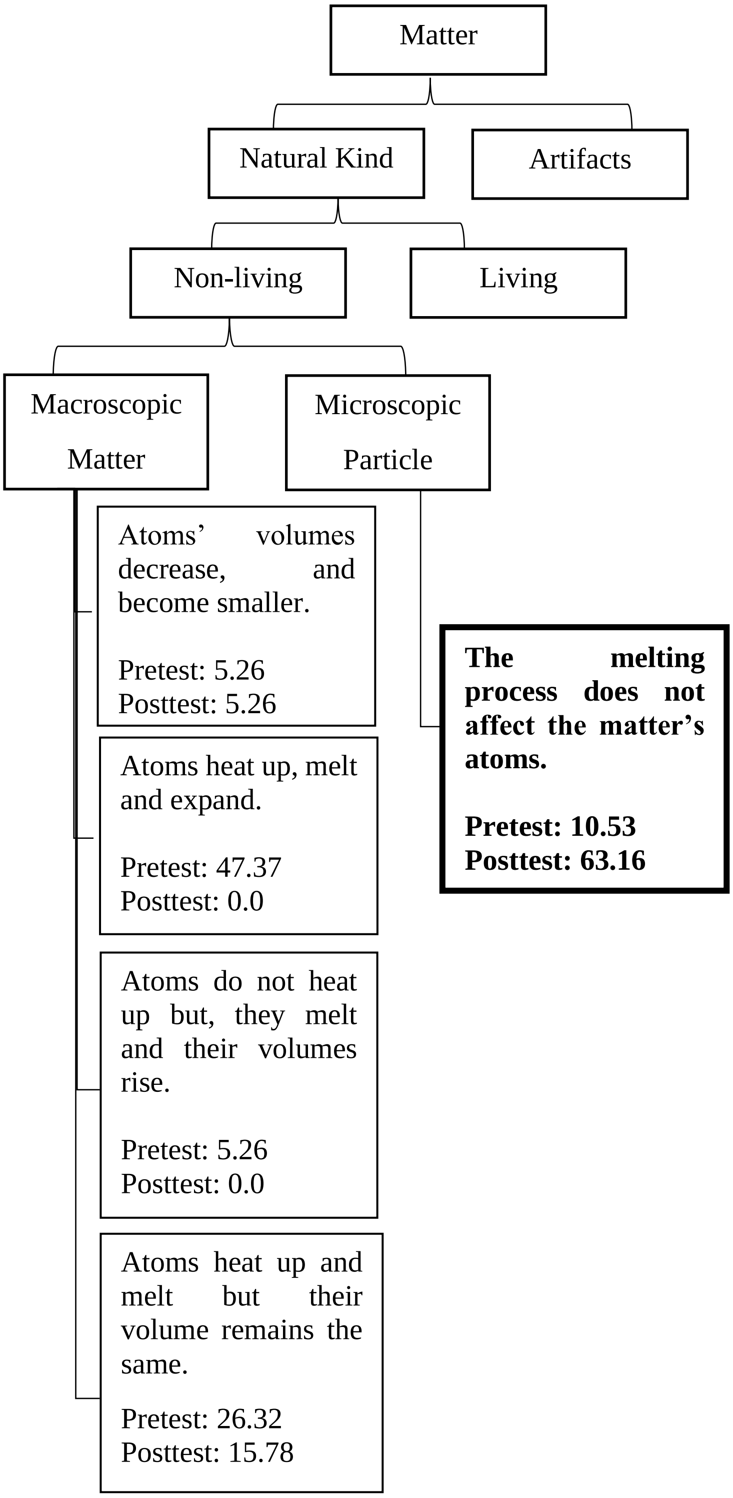


Figure 4. 22 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Tenth Question of the Particulate Nature of Matter Concept Test

4.4.11 Ontological Analysis for Question 11th of PNMCT

In the 11th question of PNMCT, the reasons for the misconceptions detected by the students regarding the statement that sugar thrown into a container full of water becomes invisible after a certain period and sweetens the water were analyzed based on ontology.

Figure 4.23. shows the ontological analysis of the misconceptions found in the comparison group, while Figure 4.24. shows the ontological analyses of the misconceptions found in the experimental group. Students believed that the presented statement was true. They separated the concept of solution, which is a physical event, from the chemical event and melting and placed it in the dissolution category, one of the subcategories of the process category, and responded to the question accurately. As shown in Figure 4.23. while this rate was 6.25% in the pre-test in the comparison group, it increased in the post-test and became 18.75%. As shown in Figure 4.24., in the experimental group, while 5.26% of correct answers were detected in the pre-test, it increased slightly in the post-test and rose to 26.31%. It is seen that they did not provide sufficient conceptual understanding after both instructions. Three kinds of sources of the misconceptions detected in the relevant question have been examined through ontology. First, it is due to placing the concept of dissolution in its lateral melting category. It is seen that students with this misconception define the event of sugar becoming invisible as it melts by taking heat from the outside. While the rate of comparison group students with this misconception was 50.0% in the pre-test, it showed a minimal reduction in the post-test and became 31.25%. In contrast, the rate of the experimental group was 47.37% in the pre-test and became 5.26% after argumentation instruction. Another reason is that the concept of dissolution, which should be evaluated under the sub-category of the physical event category, was incorrectly placed in the chemical event category, which is the lateral category of the physical event category. In other words, the correct expression that should be in the dissolution category was placed in its superordinate category, the chemical event category. It was determined that students

with this ontological reason for the misconception explained the invisibility of sugar in water by using the expressions of disappearing or vanishing. While the rate of comparison group students with this misconception was 6.25% in the pre-test, it increased in the post-test and rose to 18.75%. Curriculum-based instruction caused this misconception to increase. These rates were 15.78% and 52.64% in the experimental group, respectively. The increase in the stated misconception after argumentation instruction is a remarkable finding. The reason for placing the last ontologically incorrect category is that the concept of dissolution, a subcategory of the event category, was placed in the procedure category, a lateral category of the event category. It was determined that students with this misconception believed sugar would become invisible in water and would give its taste to water only as a result of external intervention (such as stirring). While the rate of comparison group students with this misconception was 37.5% in the pre-test, it decreased to 12.5% in the post-test. In the experimental group, this rate was 26.32% in the pre-test, showing only a slight decrease to 15.79% in the post-test. In this question of PNMCT, argumentation instruction could not dispel the mentioned misconceptions.

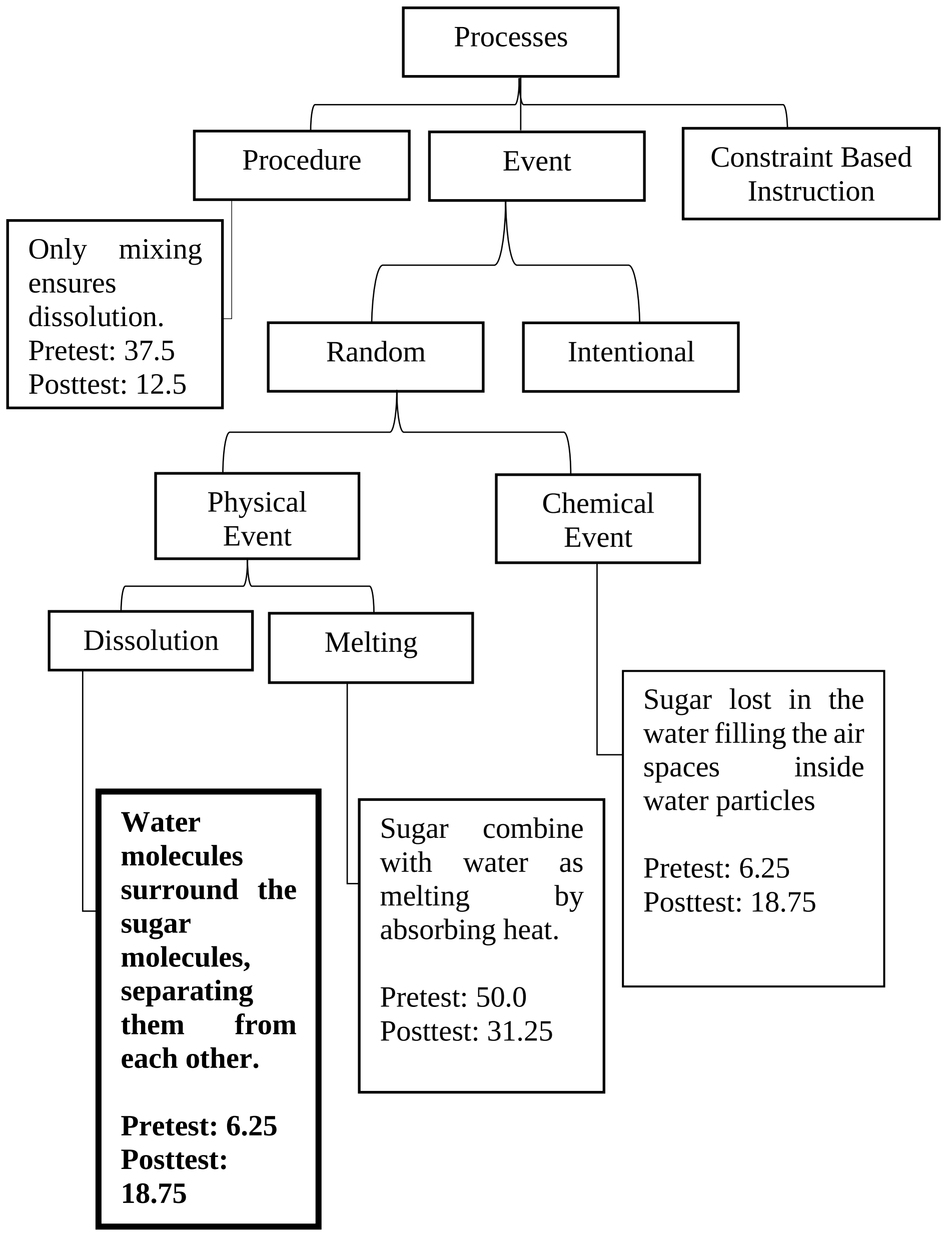


Figure 4. 23 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Eleventh Question of the Particulate Nature of Matter Concept Test

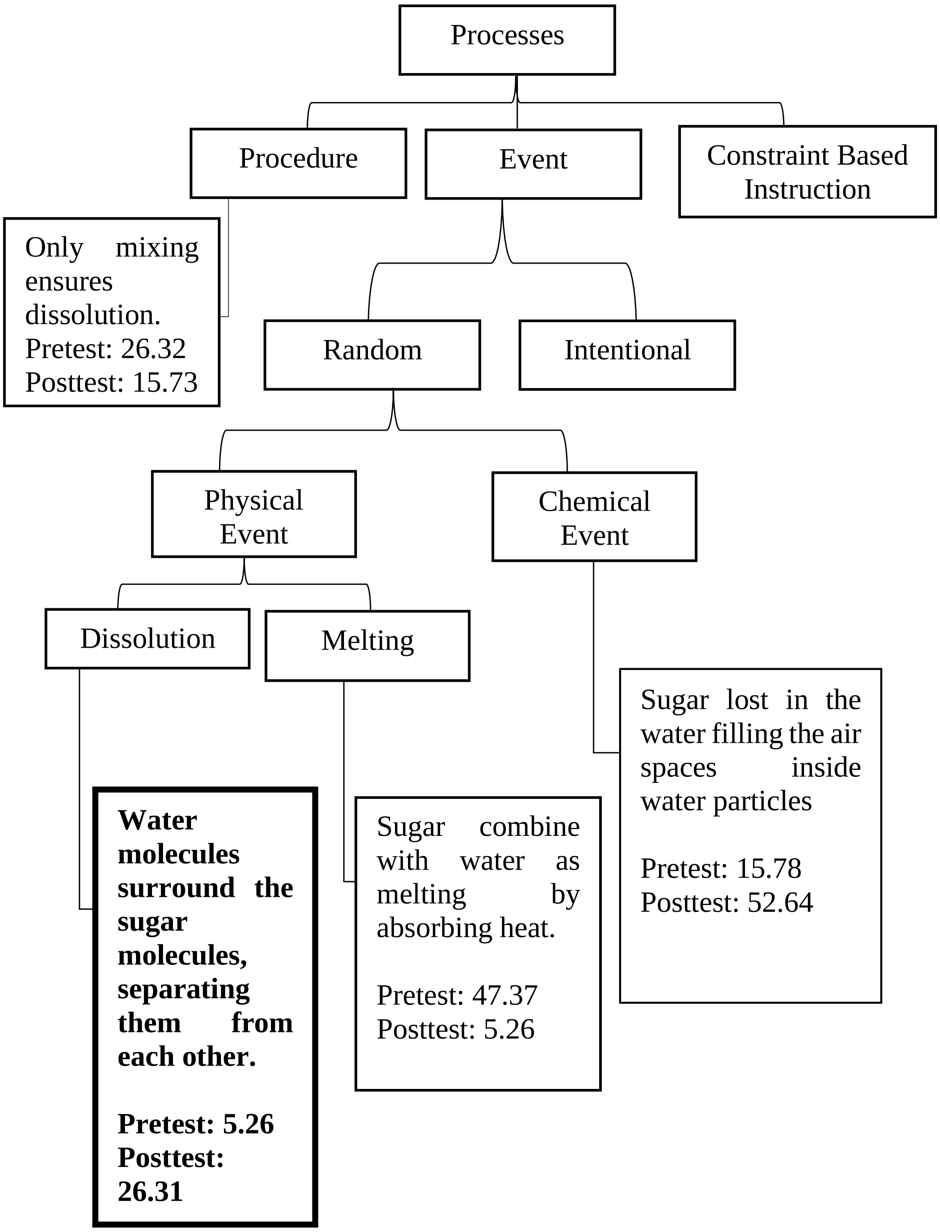


Figure 4. 24 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Eleventh Question of the Particulate Nature of Matter Concept Test

4.4.12 Ontological Analysis for Question 12th of PNMCT

In the 12th question of PNMCT, the misconceptions detected by the students regarding the distinctive properties of sulfur due to the interaction of atoms were determined, and their causes were analyzed from an ontological perspective. Figure 4.25. shows the ontological analysis of the misconceptions found in the comparison group, while Figure 4.26. for the experimental group. Students consider the observable distinctive properties of matter at a macroscopic level and do not include them in the properties of its particles to give the correct answer. This means that students provide the correct answer and reach a sufficient conceptual understanding of particle theory. During the study, none of the students in the comparison group were able to answer the question correctly. However, 15.78% of the students in the experimental group answered correctly on the pre-test, and this percentage increased to 26.32% on the post-test. Despite this increase, it is evident that the argumentation instruction did not lead to sufficient conceptual understanding. A single source of the misconceptions detected in the relevant question was observed based on ontology. This is due to placing the distinctive properties of matter, which should be in the macroscopic matter category, in the microscopic particle category where particle properties are located. Under this ontological category, two different misconceptions that students focused on were identified. The first one is the evaluation of the atom as the smallest structural unit that carries all of a substance's physical and chemical properties. While the rate of comparison group students having this misconception was 25.0% in the pre-test, it became 31.25% in the post-test. In the experimental group, it was 5.26% and increased to 31.58%. It was determined that both instructional methods increased the stated misconception. The other is the students' belief that only physical properties can be seen in particles. While the rate of this misconception in the comparison group was 37.5% in the pre-test, it increased to 50.0% in the post-test. In the experimental group, it was 68.38% in the pre-test and decreased to 36.83% in the post-test.

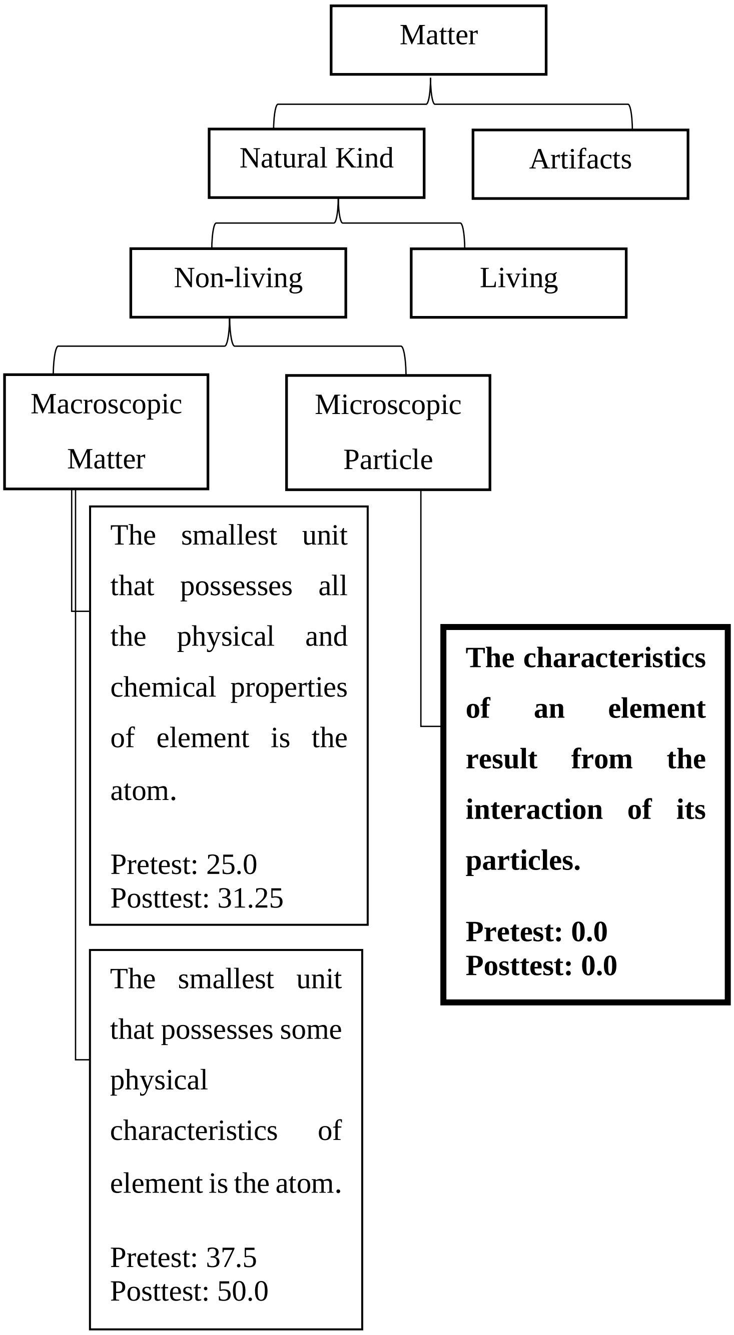


Figure 4. 25 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Twelfth Question of the Particulate Nature of Matter Concept Test

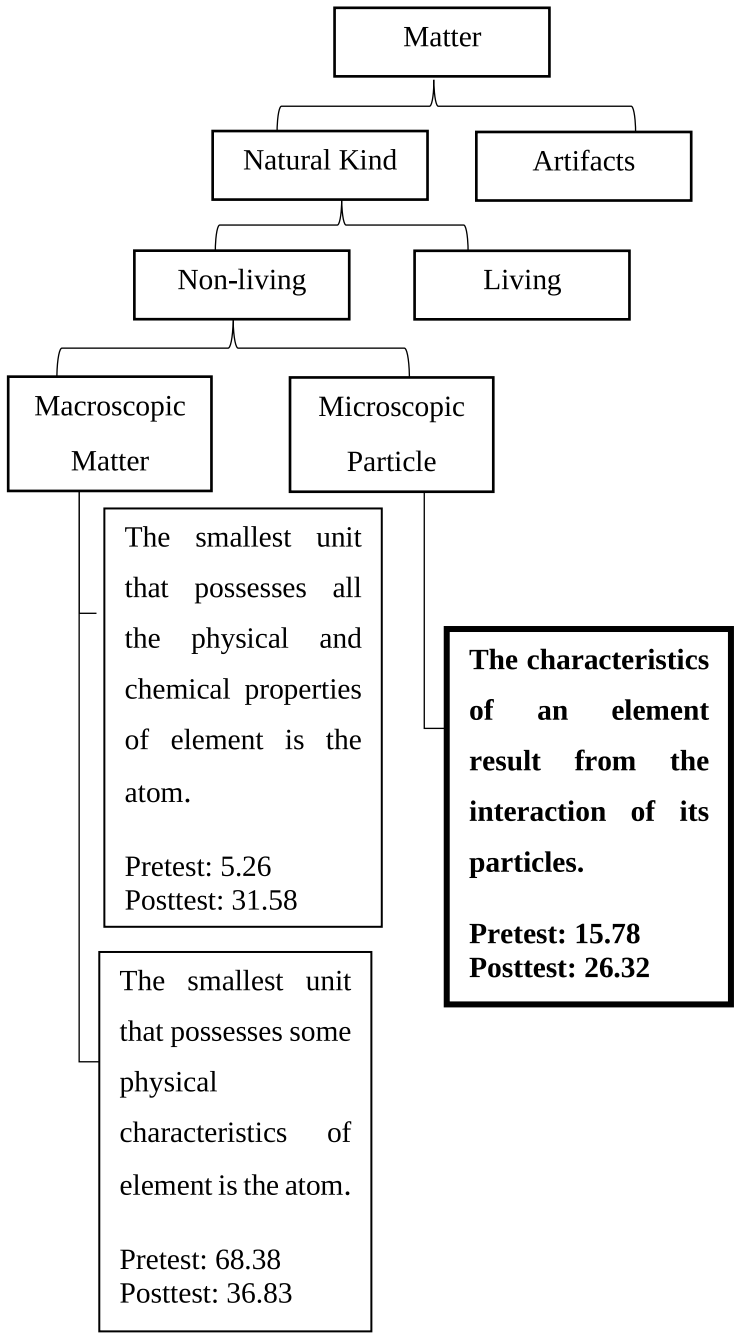


Figure 4. 26 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Twelfth Question of the Particulate Nature of Matter Concept Test

4.4.13 Ontological Analysis for Question 13th of PNMCT

In the 13th question of PCT, the students' misconceptions about the pure nature of the mixtures were determined, and their reasons were evaluated based on ontology.

Figure 4.27. presents the ontological analysis of the misconceptions found in the comparison group, while Figure 4.28. presents the ontological analyses of the misconceptions found in the experimental group. Students who correctly answered the question recognized that there were different particles in the sugar-water mixture and that the mixtures were not pure substances. They assigned the sugar-water mix to the dissolution branch of the psychical event category, which is one of the subcategories of the event category, as a result of thinking that the chemical properties of sugar and water remain the same in the sugar-water mix, which is a homogeneous mixture (solution). As shown in Figure 4.27, the rate of the comparison group students who gave the correct answer was only 6.25%, while no one gave the correct answer after the curriculum-based instruction. According to Figure 4.28, this rate was 31.58% in the pre-test in the experimental group and rose to 67.37% in the post-test. The misconception regarding the impurity of the sugar-water mixture arises from two different sources, as identified through an ontological approach. The first originates from students' tendency to place the concept in the chemical category, a lateral category of the physical category. This led to the misconception that the sugar-water mixture would form a new matter. While the rate of comparison group students having this misconception was 31.25% in the pre-test, it increased in the post-test and became 43.75%. For the experimental group, the rates are 31.58% and 26.32%, respectively. It is seen that the effect of argumentation instruction in eliminating the stated misconception is not at a satisfactory level. The other is that the sugar-water mixture cannot protect the properties of sugar and water during the formation. While the rate of comparison group students having this misconception was 6.25% in the pre-test, it rose to the post-test and became 25.0%. These rates were 10.50% in the experimental group and decreased in the post-test and became 5.26%, respectively. The other ontological reason is the categorization

of the solution as melting. The rate of comparison group students who had this misconception was 43.75% in the pre-test. Although this decreased to 18.75% in the post-test, the misconception was not fully eliminated. In the experimental group, the rate of 21.06% remained constant throughout the study, and no effect of argumentation instruction could be determined. In this question, a student in the comparison group stated, "The color of sugar molecules in sugar water mixtures will change, and this means mixtures are not pure substances." Student evaluated the sugar water mixtures by assigning them to the chemical event category. In other words, a misconception resulting from incorrectly placing the relevant concept in its lateral category was detected. After the curriculum-based instruction, this misconception was eliminated, and the student provided the correct answer in the post-test.

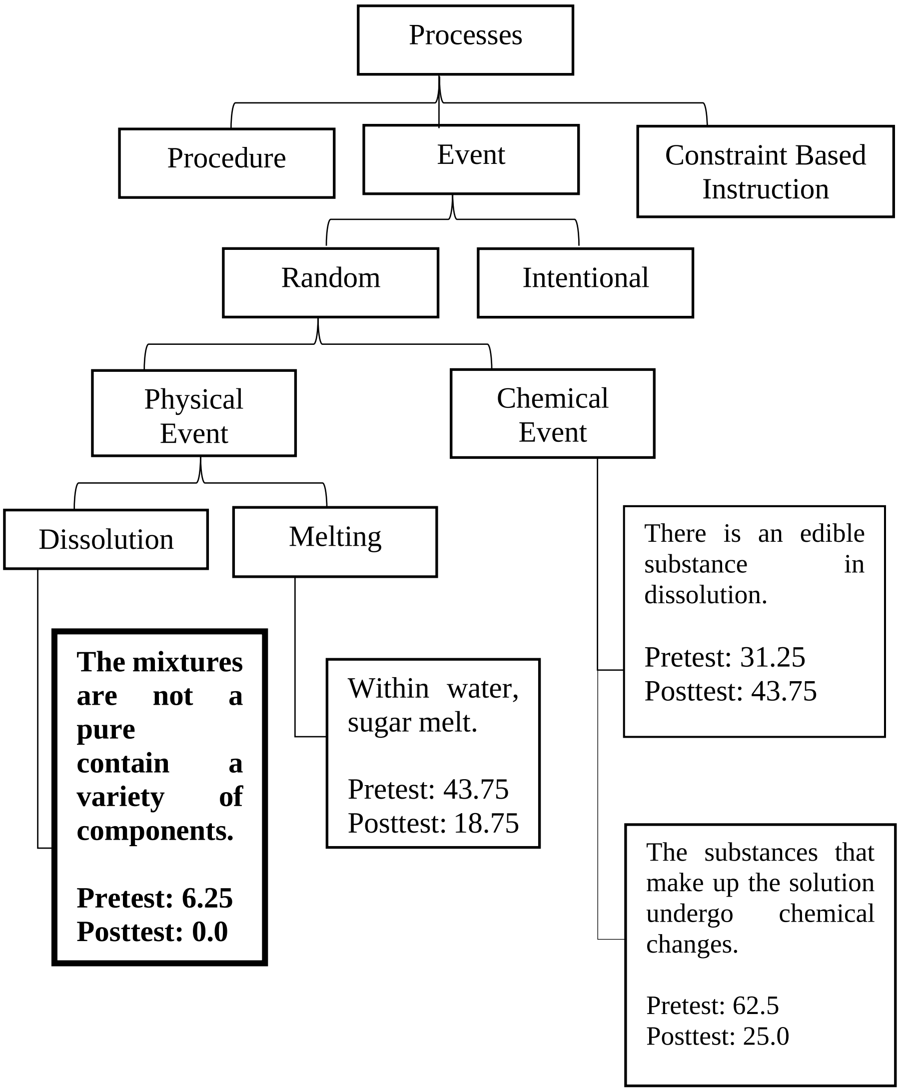


Figure 4. 27 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Thirteenth Question of the Particulate Nature of Matter Concept Test

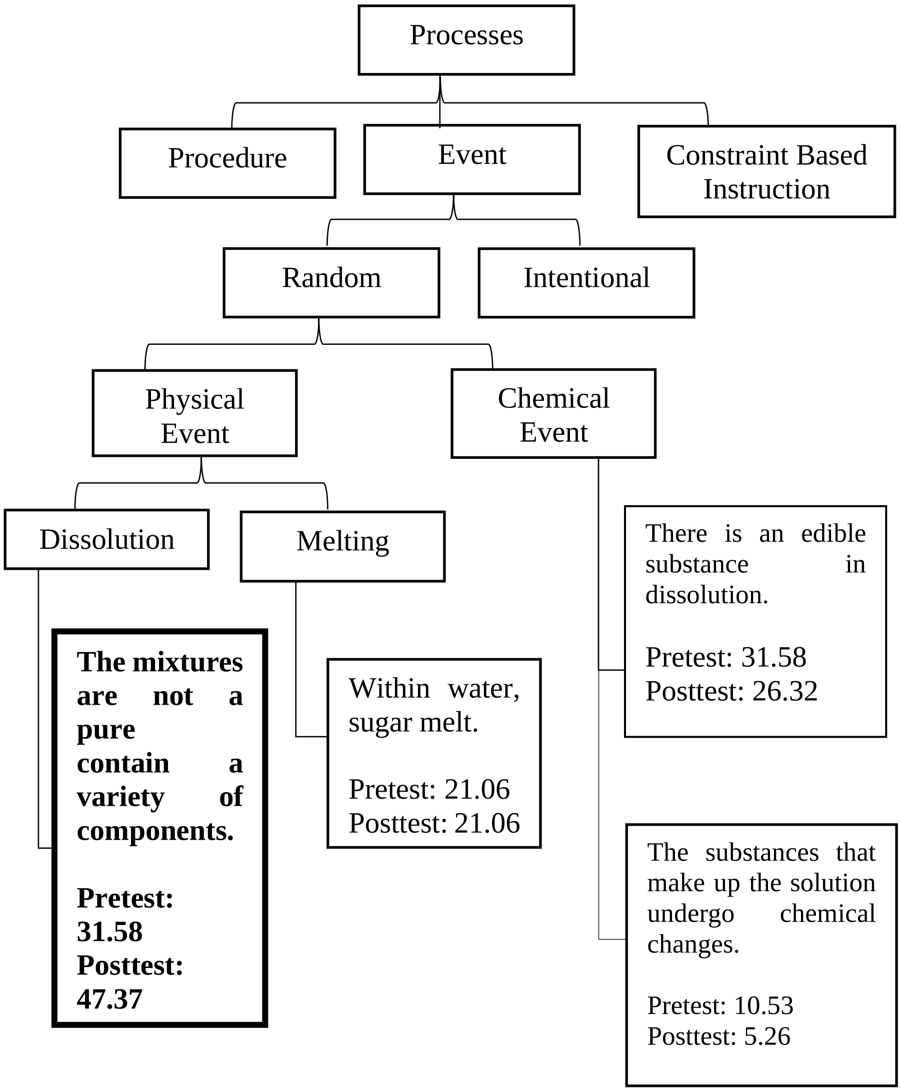


Figure 4. 28 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Thirteenth Question of the Particulate Nature of Matter Concept Test

4.4.14 Ontological Analysis for Question 14th of PNMCT

In the 14th question of PNMCT, misconceptions regarding the change in the size of particles when a solid is heated were determined, and their reasons were investigated based on ontology. Students who evaluated the transformation of solid matter into liquid state on a microscopic scale indicated that heating does not cause any change in the particles of the solid and only affects the distance between particles and provided the correct answer to the question. This means that by separating the particles from the macroscopic matter category and placing them correctly in its lateral category, the microscopic particle category, they did not create a misconception based on ontology. The ontological analyses of the misconceptions discovered in the comparison group are shown in Figure 4.29, and the experimental group' is shown in Figure 4.30. In line with Figure 4.29., the rate of comparison group students who assigned the relevant answer to the correct ontological category was 37.5% in the pre-test, while it decreased to 18.75% in the post-test. In line with Figure 4.30., in the experimental group, while it was 26.32% in the pre-test, it showed a high increase in the post-test and became 73.69%. The misconceptions detected in the question have a single ontology-based source with distinct ideas. The rate of comparison group students who considered particles within the macroscopic matter category, stating that the particles of the heated substance also heat up in the same way, was 37.5% in the pre-test. In comparison, it decreased to 18.75% in the post-test. The experimental group's rate remained at 5.26% in the pre-test and post-test. It was observed that curriculum-based instruction was more effective in eliminating the stated misconception than argumentation. Another misconception in the macroscopic matter category was that particles would expand with heat intake. While the rate of comparison group students with this misconception was 25.0% in the pre-test, it doubled to 50.0% in the post-test. These rates were 52.63% and 5.26% in the experimental group, respectively. Argumentation instruction was more successful than curriculum-based instruction in dispelling the misconception regarding heat causing particles to get bigger.

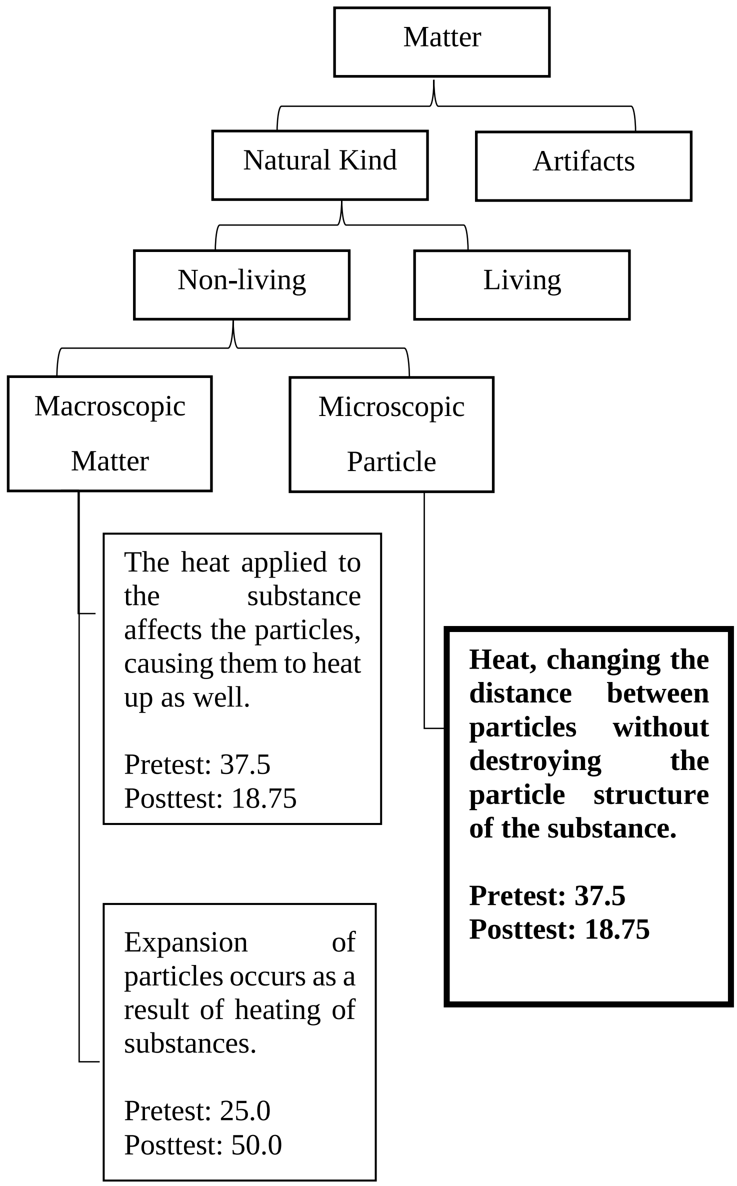


Figure 4. 29 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fourteenth Question of the Particulate Nature of Matter Concept Test

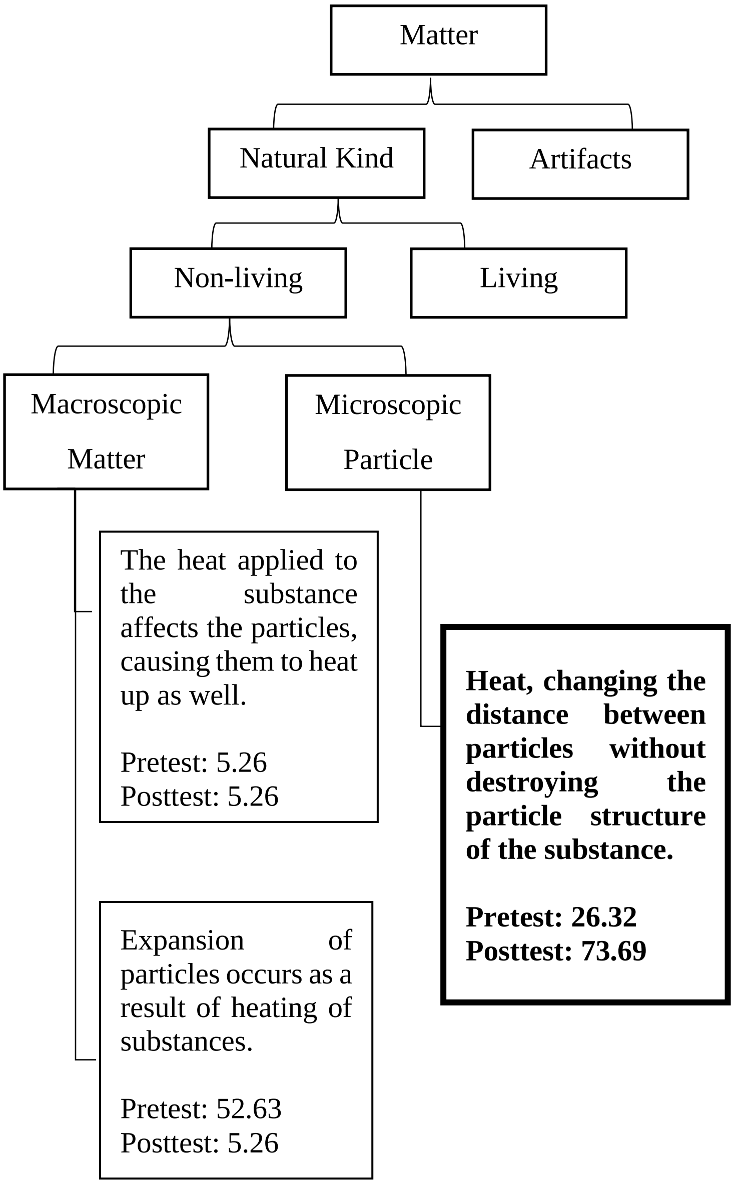


Figure 4. 30 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fourteenth Question of the Particulate Nature of Matter Concept Test

4.4.15 Ontological Analysis for Question 15th of PNMCT

In the 15th question of PNMCT, students' misconceptions about the structure of NaCI (table salt) and the smallest structural unit carrying its chemical properties were determined, and their reasons were analyzed from an ontological perspective.

Figure 4.31. illustrates the ontological analyses of the misconceptions discovered in the comparison group and Figure 4.32. illustrates analyses of the ontological perspective of the experimental group's misconceptions. Students who placed NaCI in the ion category, one of the subcategories of the microscopic particle category, stated that the reason is that NaCI is an ionic compound and that the smallest structural unit carrying its chemical properties is not in the form of an atom or molecule, answered the question correctly. While this rate was 12.5% in the comparison group pre-test, no student could provide the correct content and reason combination in the post-test, as indicated in Figure 4.31. In the experimental group, it increased from 21.05% in the pre-test to 78.95% in the post-test, as shown in Figure 4.32. This result indicates that the argumentation instruction effectively fostered a satisfactory conceptual understanding of the relevant question. As a result of the ontological analysis of the misconceptions detected in the groups, three different sources of misconceptions were determined. The first is due to the assignment of the smallest structural unit of NaCI, which should be evaluated in the microscopic particle category, to the macroscopic matter category, which is its lateral category. The misconception in this category is that the grain of salt is a tiny piece of salt that can be seen with the eye. While the rate of comparison group students with this misconception was 37.5% in the pre-test, it only slightly decreased to 31.25% in the post-test. In contrast, the rates in the experimental group were 10.53% in the pre-test and dropped to 0.0% in the post-test. This indicates that the argumentation instruction contributed to a reduction in the related misconception. The second ontological source is the misconception that arises from assigning the concept of NaCI's smallest structural block to the molecule category, which is its lateral category, rather than to the ion category. Since table salt is an ionic compound, its

smallest particle is an ion cluster. Therefore, NaCI should be evaluated more specifically in the ion category, a sub-category of the microscopic particle category. It was determined that students with misconceptions stemming from assigning it to the molecule category thought that salt was made up of molecules due to its molecular structure. While the rate of this misconception was 12.5% in the comparison group pre-test, it increased to 43.75% in the post-test. Although it decreased from 15.79% to 10.53% in the experimental group, it could not be eliminated. The last ontological reason is due to assigning the NaCl particle to its lateral category, the atom category, instead of the ion category. The misconception in the atom category is that since salt is an element, its smallest structural unit is in the atomic form. While the rate of comparison group students who had this misconception was 12.5% in the pre-test, it increased to 18.75% in the post-test. Although it decreased from 42.08 % to 10.53% in the experimental group, it could not be eliminated.

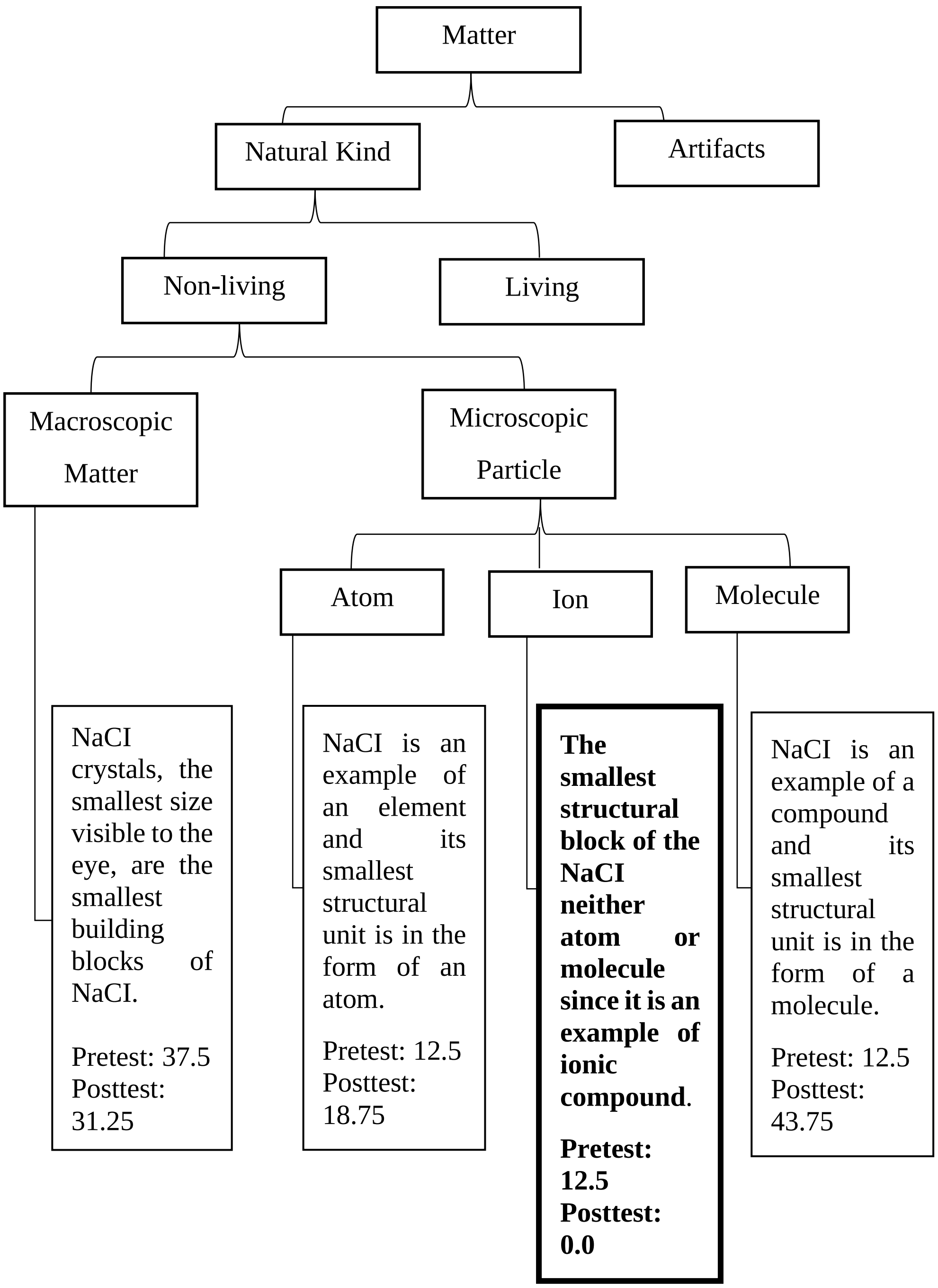


Figure 4. 31 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Fifteenth Question of the Particulate Nature of Matter Concept Test

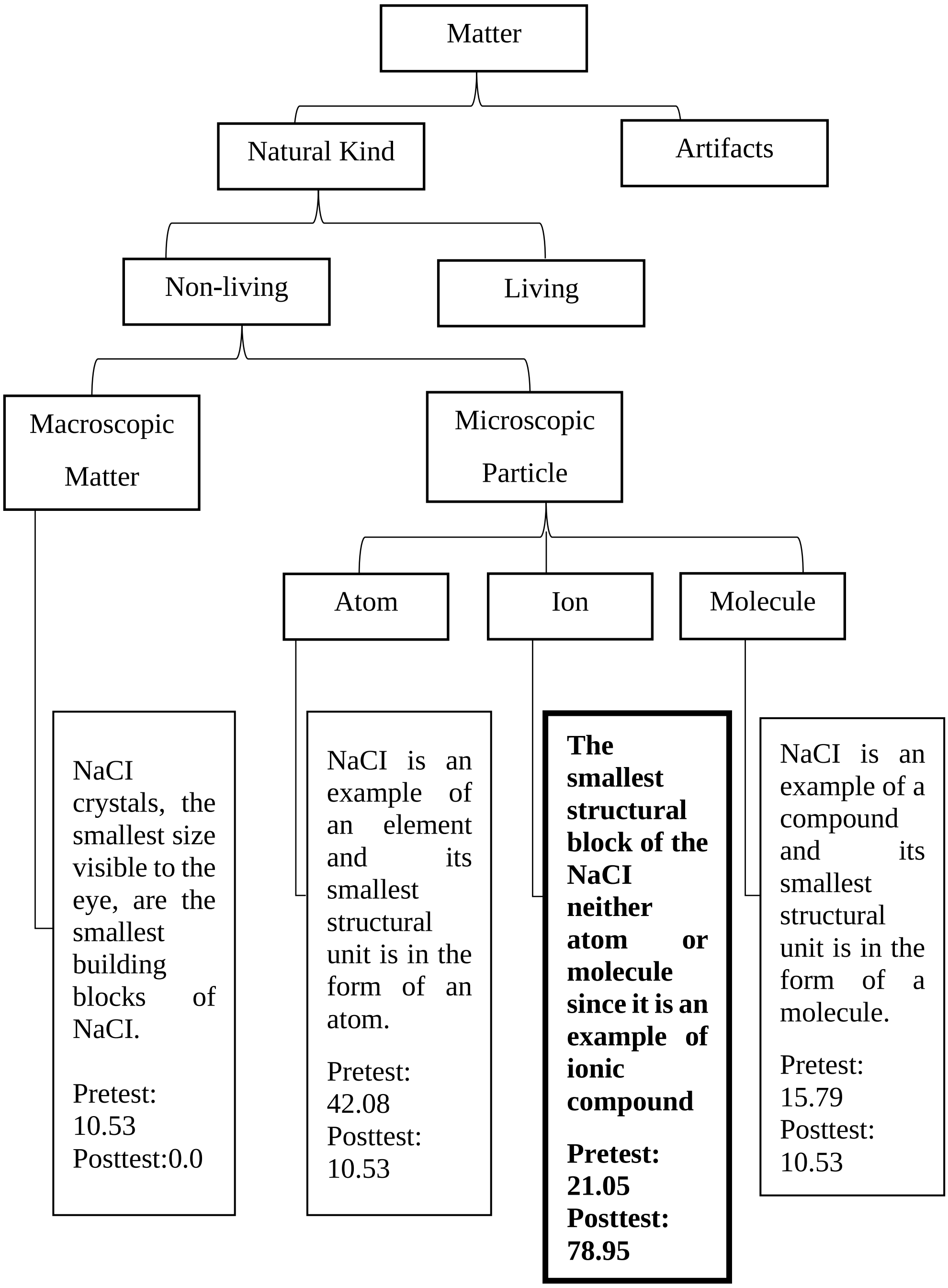


Figure 4. 32 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Fifteenth Question of the Particulate Nature of Matter Concept Test

4.4.16 Ontological Analysis for Question 16th of PNMCT

In the 16th question of PNMCT, the misconceptions among students regarding the structural unit of mercury were determined, and their reasons were explained based on ontology. Figure 4.33. illustrates the ontological analyses of the misconceptions discovered in the comparison group and Figure 4.34. illustrates analyses of the ontological perspective of the experimental group's misconceptions. In this question, the students are expected to know that mercury is an example of an element, and therefore identify the atom as its smallest structural unit. In other words, the smallest structural unit of mercury is the atom, which belongs to the microscopic particle category ontologically. While the rate of comparison group students who did not attribute macroscopic properties to the particle of mercury by considering it at a microscopic level was 12.5% in the pre-test, no student could provide the correct content-reason combination in the post-test. These rates were 26.32% and 68.42% in the experimental group, respectively. It is seen that the students who received the instruction equipped with activities that provided an argumentation environment had higher rates of evaluating the mercury atom at a micro level. In the specified question, two different sources of the misconceptions detected in the research groups were found based on ontology. The first is due to placing the mercury atom, which should be in the microscopic particle category, in its lateral category, the macroscopic matter category. It was determined that the students with this misconception attributed macroscopic properties to the atom and thought that a particle was the most minor form that could be seen with the eye. While the rate of the comparison group students with this misconception was 0.0% in the pre-test, it increased to 37.5% in the post-test, as shown in Figure 4.33. It is a remarkable finding that this misconception occurred in the students' minds after the curriculum-based instruction. In the experimental group, it was eliminated by decreasing from 10.53% in the pre-test to 0.0% in the post-test, as shown in Figure 4.34. The second ontological reason determined is the placement of the concept of the atom, which should be in the sub-category of the microscopic particle category, in its lateral category, the molecule category. The first misconception in the molecule category is that the smallest structural unit of mercury is thought to be in the form of a molecule because it is a compound. The percentage of students in the comparison group who held this misconception decreased from 37.5% in the pre-test to 18.75% in the post-test. In the experimental group, this rate dropped from 31.56% to 10.53%. The second misconception was that students stated that the smallest structural unit was a molecule because mercury was an element. The percentage of comparison group students who had this misconception decreased from 25.0% in the pre-test to 18.75% in the post-test. These rates were 26.32% and 10.53% for the experimental group, respectively. Neither teaching method could effectively eliminate these misconceptions that existed due to incorrect placement in the molecule category.

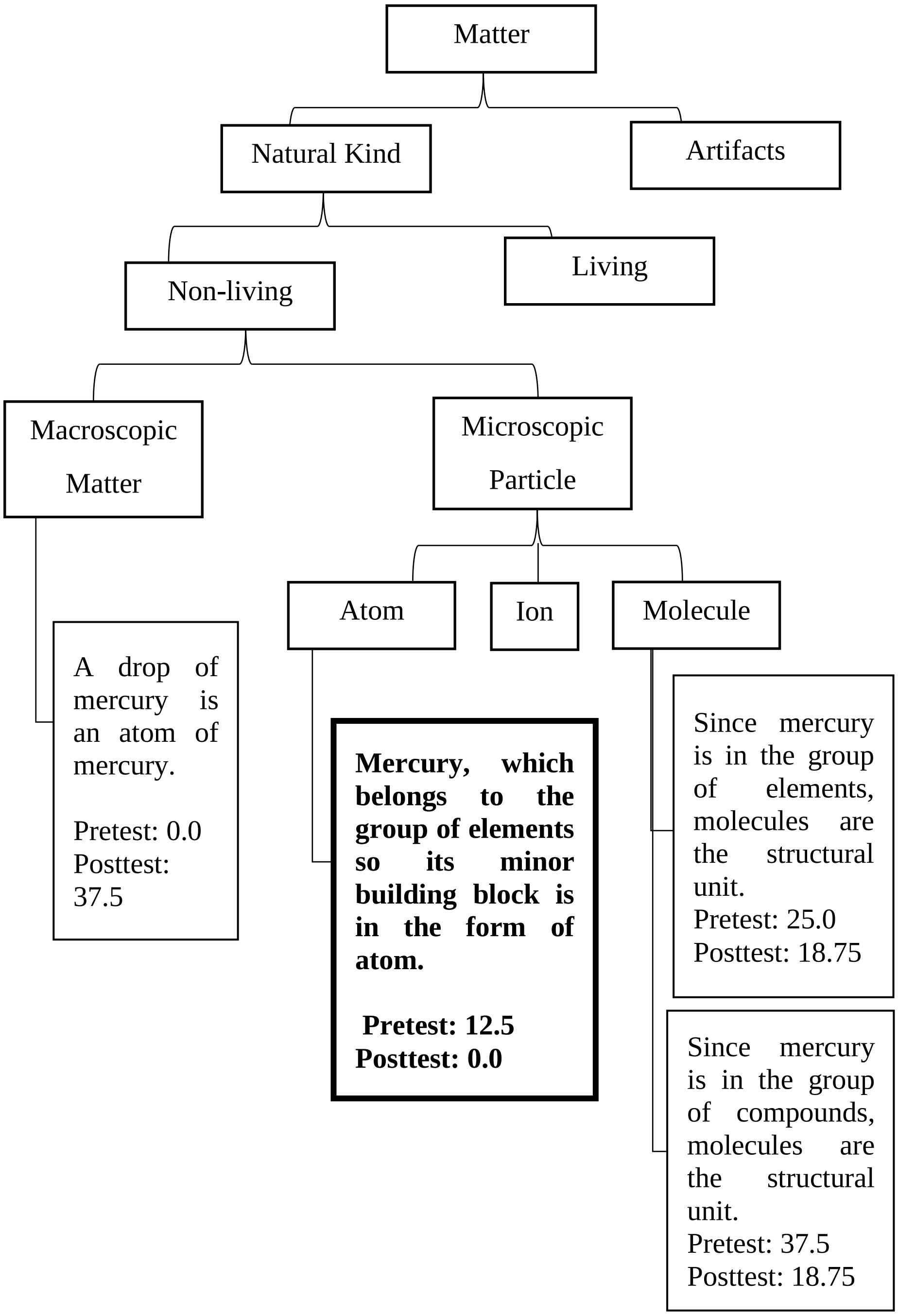


Figure 4. 33 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Sixteenth Question of the Particulate Nature of Matter Concept Test

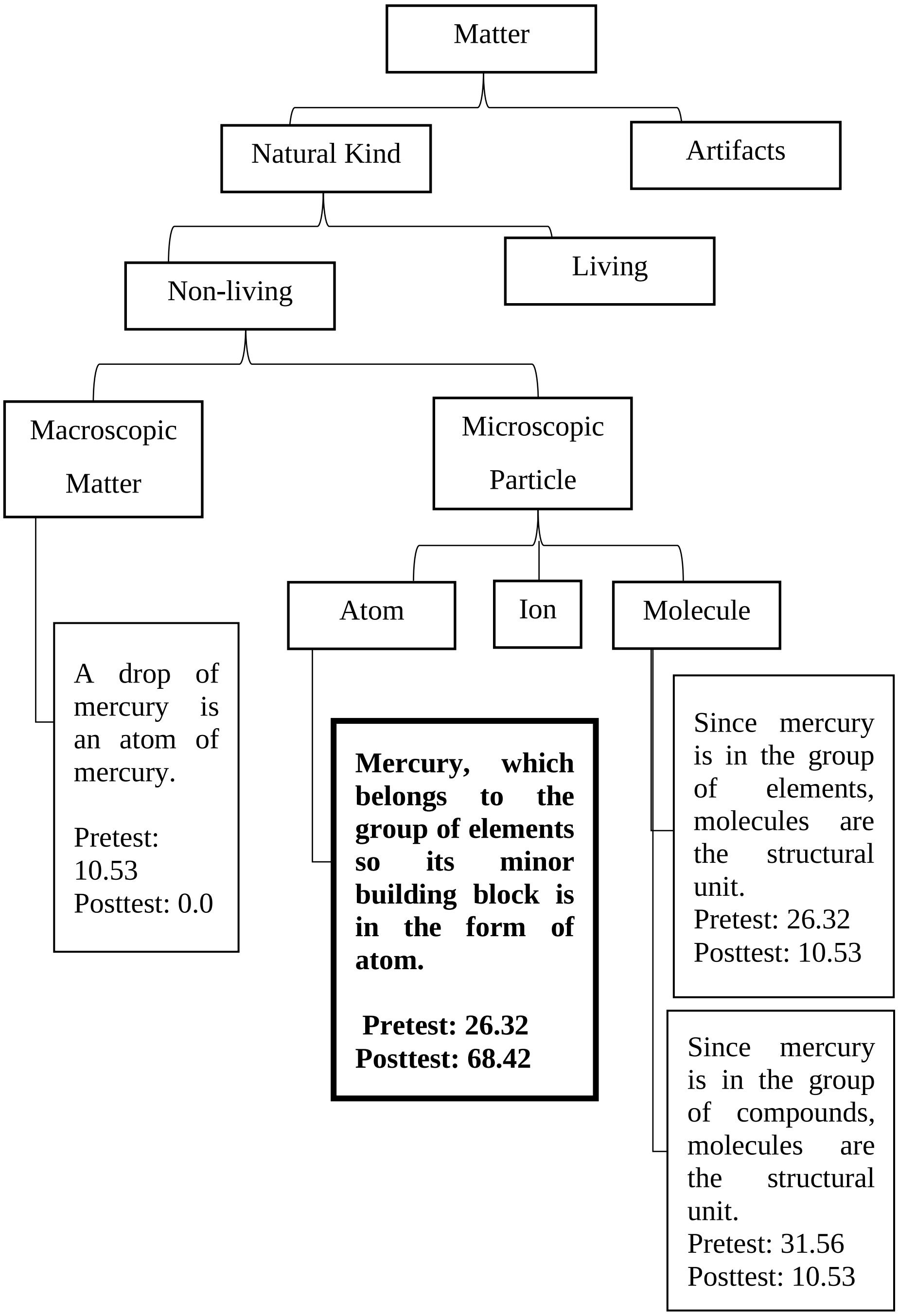


Figure 4. 34 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Sixteenth Question of the Particulate Nature of Matter Concept Test

4.4.17 Ontological Analysis for Question 17th of PNMCT

In the 17th question of PNMCT, the students' misconceptions about microscopic particles being alive were determined through the sodium chloride example, and their reasons were examined from an ontological perspective.

The ontological analyses of the misconceptions discovered in the comparison group are presented in Figure 4. 35. The ontological analyses of the misconceptions found in the experimental group are presented in Figure 4. 36. Sodium chloride is an ionic compound solid at room temperature. Therefore, the expected answer is that the question statement given by placing sodium chloride in the ion category, one of the subordinate categories of the microscopic particle category, is incorrect. The rate of the comparison group students who assigned NaCl to the ion category and stated that it was not in the molecule form at room conditions was 6.25% in the pre-test and 12.5% in the post-test. These rates increased from 15.80% to 63.16% in the experimental group. It is seen that argumentation instruction is more effective in assigning the relevant concept to the ontological category it belongs to. Two different sources of the misconceptions detected in the study groups were determined from an ontological perspective. The first source is due to assigning NaCI to its lateral category, the molecule category, instead of the ion category. It was determined that students with this misconception stated that NaCI is in the form of molecules under room conditions. While this rate was 56.25% in the pre-test of the comparison group, it decreased to 37.5% in the post-test. While this rate was 47.37% in the pre-test of the experimental group, it decreased to 26.32%. It is seen that the misconception that the students concentrated on the most is due to assigning the concept to the lateral category, which is the molecule category. Another source determined from an ontological perspective is the placement of NaCI, which should be evaluated under the ion category (member of the non-living category) in its superordinate category, which is the living things category. The first misconception detected in the residing things category is that the sodium atom wants to give electrons. Still, statements expressing actions or movement are in the living things category. While the rate of comparison group students with this misconception was 6.25% in the pre-test, it remained constant in the post-test. Although this misconception was initially absent in the experimental group (0.0%), it was identified in one student in the post-test. Another misconception resulting from placing in the living category is the idea that there is a physical rope, a structure that sense organs can perceive as being between sodium and chlorine. While no students in the comparison group had this misconception in the pre-test (0.0%), it increased to 12.5% in the post-test. In the experimental group, the rate of this misconception was 21.06% in the pre-test and decreased to 5.26% in the post-test, but it was not fully eliminated.

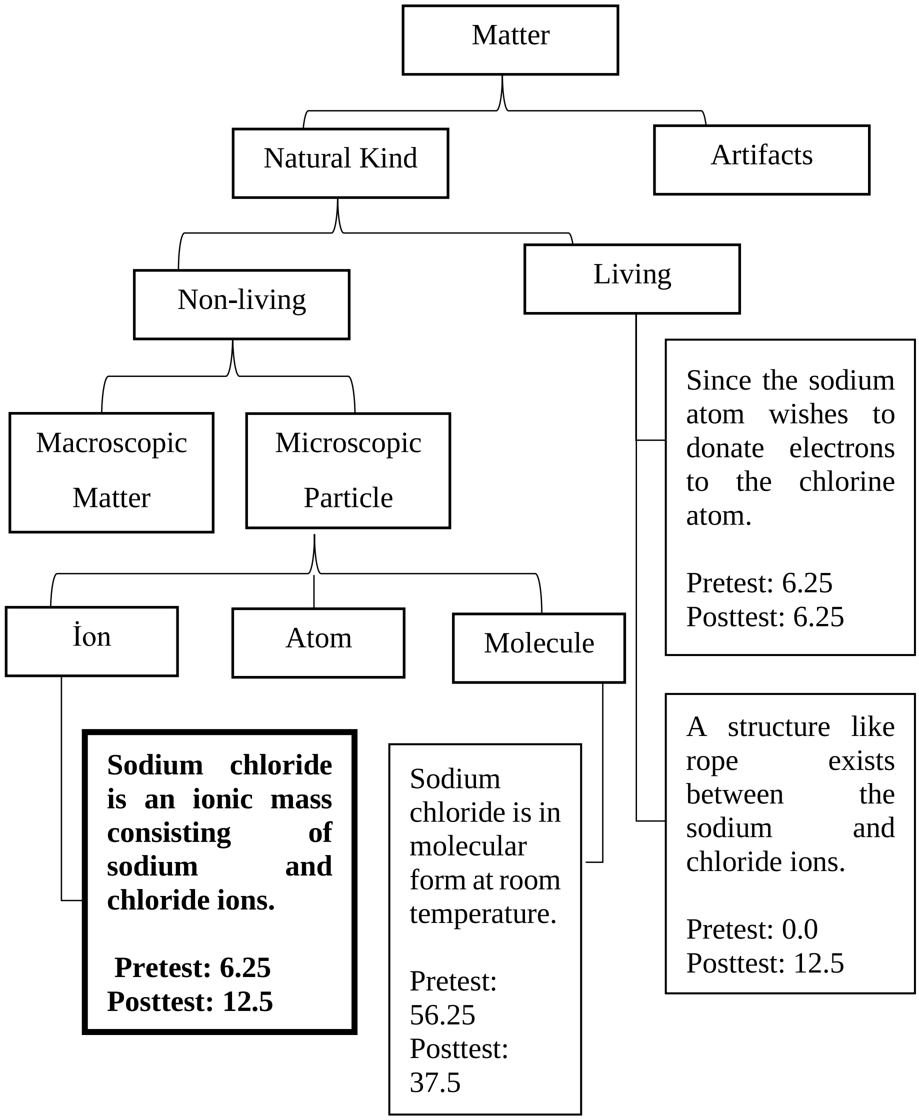


Figure 4. 35 Percentages of Comparison Group Misconceptions in Ontological Analysis of the Seventeenth Question of the Particulate Nature of Matter Concept Test

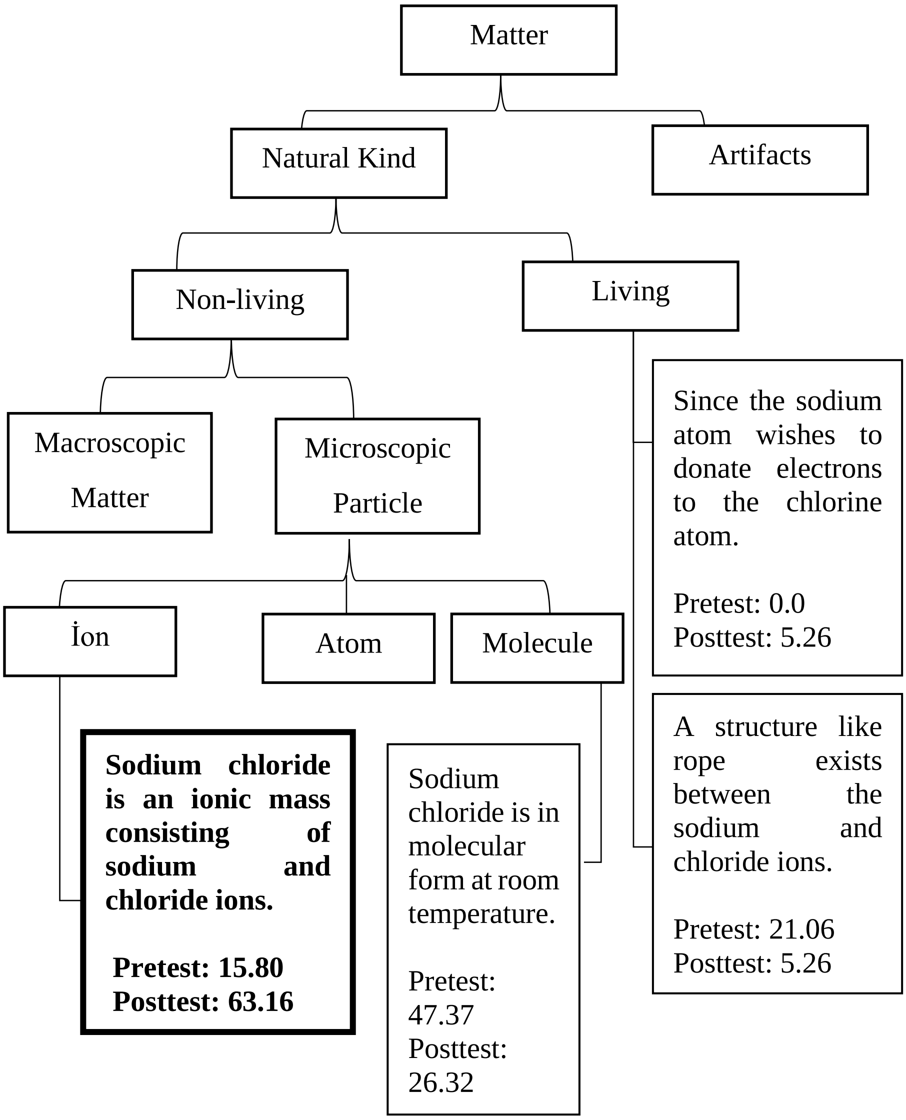
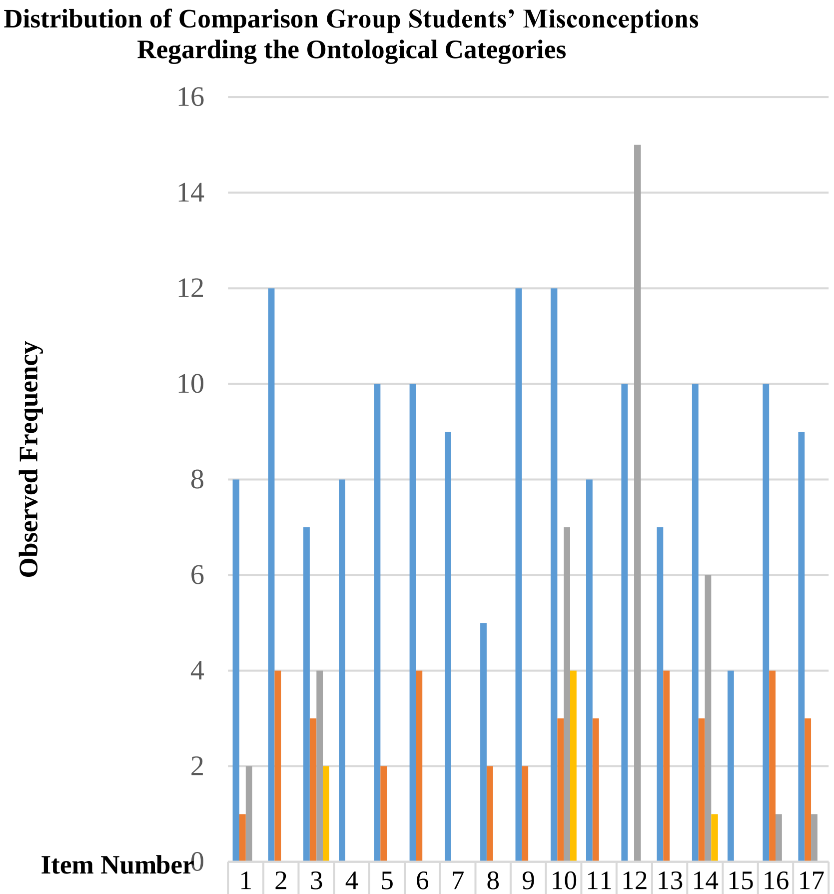


Figure 4. 36 Percentages of Experimental Group Misconceptions in Ontological Analysis of the Seventeenth Question of the Particulate Nature of Matter Concept Test

4.4.18 Distribution of Misconceptions According to the Upper and Superordinate Categories

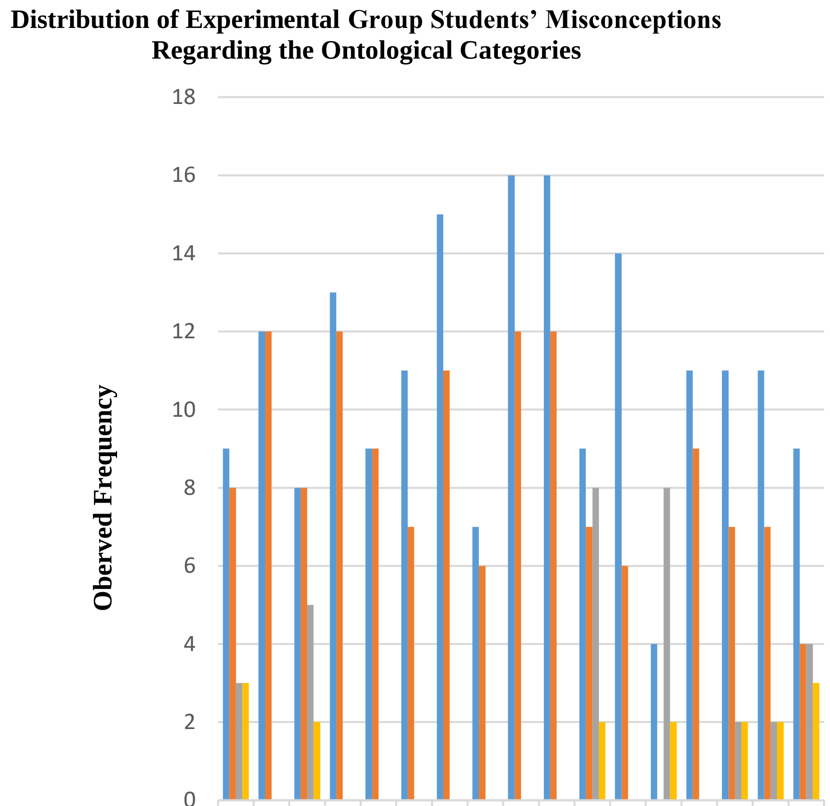
As a result of the ontological examination of the misconceptions detected in the study groups before and after the instruction, it is seen that the misconceptions arise from two main reasons. These are due to assigning the concept to the lateral category of the ontological category or assigning the idea to the superordinate category (not in a hierarchical relationship) of the ontological category it belongs to. In this direction, the focus was on the sub-questions of the third main research question that needs to be investigated. The sub-problems of the third main research question are "How does argumentation instruction impact eliminating 7th-grade students' misconceptions caused by incorrectly placing the concepts of the particulate structure of matter and dissolution into lateral and superordinate ontological categories?" and "How does curriculum-based instruction impact eliminating 7th-grade students' misconceptions caused by incorrectly placing the concepts of the particulate structure of matter and dissolution into lateral and superordinate ontological categories?".

To find answers to the specified sub-research questions, the distributions of students who placed the concept in the lateral and superordinate category before the instruction and those who put the same idea in the lateral and superordinate categories after the instruction were reported in Figure 4.37. for the comparison group, and in Figure 4.38. for the experimental group, the findings were evaluated in terms of the effect of the instruction, using the student percentage rates in the ontological category to which the misconceptions found during the ontological analysis of each question belonged.



Item Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Detected Misconceptions Before the Instruction in Lateral Category	8	12	7	8	10	10	9	5	12	12	8	10	7	10	4	10	9
Elimanating Misconceptions in Lateral Category	1	4	3	0	2	4	0	2	2	3	3	0	4	3	0	4	3
Detected Misconception Before the Instruction in Superordinate Category	2	0	4	0	0	0	0	0	0	7	0	15	0	6	0	1	1
Eliminating Misconceptions in Superordinate Category	0	0	2	0	0	0	0	0	0	4	0	0	0	1	0	0	0

Figure 4. 37 Total Frequencies of Comparison Group Misconceptions Based on Ontological Categories



Item Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Detected Misconceptions Before the Instruction in Lateral Category	9	12	8	13	9	11	15	7	16	16	9	14	4	11	11	11	9
Elimanating Misconceptions in Lateral Category	8	12	8	12	9	7	11	6	12	12	7	6	0	9	7	7	4
Detected Misconception Before the Instruction in Superordinate Category	3	0	5	0	0	0	0	0	0	0	8	0	8	0	2	2	4
Eliminating Misconceptions in Superordinate Category	3	0	2	0	0	0	0	0	0	0	2	0	2	0	2	2	3

Figure 4. 38 Total Frequencies of Experimental Group Misconceptions Based on Ontological Categories

As indicated in Figure 4.37, while the number of misconceptions placed in the lateral category by the comparison group students (N=16) before the instruction was 151, the number of misconceptions placed in the superordinate category was 35. After the curriculum-based instruction, 38 misconceptions were eliminated in the lateral category and seven in the superordinate category. In other words, 25.16% of the misconceptions resulting from placing in the lateral category were eliminated, while 20% of the misconceptions resulting from putting in the superordinate category were eliminated. In addition, it was determined that none of the misconceptions originating from placing in the lateral category detected in items 4, 7, 12, and 15 could be eliminated. Item 4 tested that the sizes of water molecules are not dependent on phase change, while item 7 tested that ice and water molecules are not in any physical phase. Item 12 tested the definition that an atom is the smallest structural unit that carries the chemical properties of a substance, and item 15 tested that table salt is an ionic compound and, therefore, the smallest structural unit is an ion cluster. According to Figure 4.38, while the total number of misconceptions in the lateral category of the experimental group students (N=19) before the instruction was 184, the total number of misconceptions in the superordinate category was 32. After argumentation instruction, 28 misconceptions were eliminated in the lateral category and 15 in the cross-higher category. In other words, 69.57% of the misconceptions resulting from the lateral category were eliminated, while 46.88% of those resulting from being placed in the superordinate category were eliminated. In addition, none of the misconceptions resulting from placing the lateral category identified in item 13 could be eliminated for the experimental group. In item 13, the information that the sugar-water mixture is not in the category of pure substances and is an example of a solution is tested. To interpret the effect of argumentation and curriculum-based instruction in eliminating misconceptions due to assignment to lateral and superordinate categories, Figure 4.39 presents a bar graph displaying the percentage of misconceptions eliminated in each category, as reported in Figures 4.37 and 4.38.

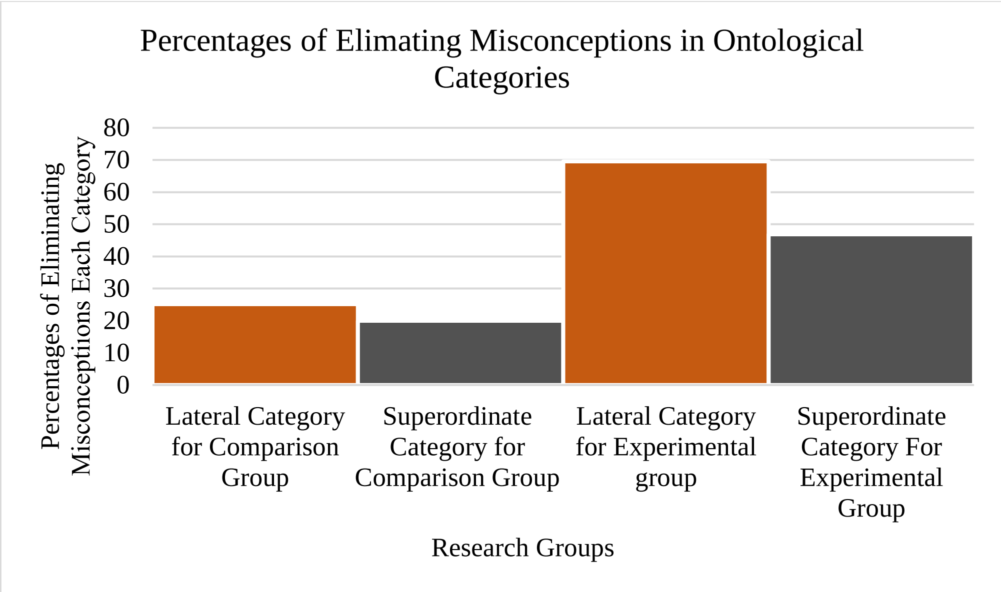


Figure 4. 39 Distribution Percentages of Elimination Rates of Misconceptions

When the data in Figure 4.39 are evaluated, the effectiveness percentage of curriculum-based instruction in eliminating misconceptions originating from the incorrect assignment of the concepts of the particulate structure of matter and dissolution to the lateral and superordinate categories is 25.16% (*f=38*) and 20.0% (*f=35*), respectively. In comparison, the effectiveness percentage of argumentation instruction is 69.57% (*f=128*) and 46.88% (*f=15*), respectively. This indicates that argumentation instruction is generally more effective than curriculum-based instruction in eliminating misconceptions on the particulate nature of matter and dissolution concepts, particularly those resulting from incorrect placement of the concepts to the superordinate and lateral ontological categories.

4.5 Summary of the Study Results

Students come to school with unscientific prior knowledge about the particulate nature of matter and dissolution. Before and after the instruction, 53 misconceptions regarding the particulate nature of matter, pure substances, and mixture topic areas were identified at different rates in the study groups.

The general frameworks of the misconceptions detected within the scope of the particulate nature of matter topic are animism (particles being alive), attributing macroscopic properties to the particles, the changes of volumes, physical states, and movements of particles in conditions such as heat, temperature, melting and freezing. The topic of pure substances includes misconceptions such as believing that particles are identical across different substances, assuming that all physical properties of matter exist within individual atoms, confusing the relationships between elements and atoms, compounds and molecules, and compounds and ions, and thinking that particles are the most miniature form of matter that can be seen with the eye. Misconceptions found with mixtures are as follows: confusing melting with dissolving, evaluating melting and dissolving as chemical events, and stating that the mixtures are pure.

Another result obtained from the two-tier diagnostic test PNMCT was that the conceptual understanding levels of the comparison group students regarding the particulate structure of matter, pure substances, and mixtures were insufficient (the desired content-reason combination rate was below 49% for each question item). In contrast, the experimental group demonstrated satisfactory conceptual understanding for six specific questions (items 1, 4, 5, 6, 8, and 15) (the desired content-reason combination rate was above 75%). Their conceptual understanding was successful for most items, except for items 11, 12, and 13, where the desired content-reasoning combination rate remained above 49%.

The general frameworks of the results obtained from the quantitative analysis findings of the research are as follows: the Mann-Whitney U Test showed that the conceptual understanding of the experimental and comparison group students regarding the particulate structure of matter and dissolutions concepts was equal before the study, with the test statistic result of U = 136.00, z = -.541, p = .612 ($p>0.05$). The Wilcoxon Signed Rank test results showed that curriculum-based instruction had a negative medium effect size on students' conceptual understanding of the particulate nature of matter and dissolution topics with the test statistics result of z = –2.03, p < .05, r = .36. The Wilcoxon Signed Rank test results showed that argumentation instruction significantly increased students' conceptual understanding of the particulate nature of matter and dissolution topics with the test statistics result of z = –3.83, p < .05, r = .62 with large effect size. The Mann-Whitney U test results showed that argumentation instruction more effectively increased students' conceptual understanding of the particulate nature of matter and dissolution topics than curriculum-based instruction with the test statistics results of U = –4.500, z = –4.91, p = .00 (p< .05), with large effect size r =.82.

The results obtained from the ontological analysis of misconceptions are as follows: ontological categories in which the misconceptions detected in the study groups are most concentrated are macroscopic matter-microscopic particle, melting-dissolution, physical event-chemical event, ion-atom-molecule, and process-procedure categories. In other words, the ontological reasons for the misconceptions detected in the study groups are due to evaluating the concept in the lateral category instead of the category it belongs to or assessing the idea in the superordinate category instead of the category it belongs to. Also, argumentation instruction is more effective in eliminating misconceptions caused by being assigned to the lateral and superordinate categories (rate of 46.88% in lateral and 69.57% in superordinate) than curriculum-based instruction (rate of 25.16% in lateral and 20.0% in superordinate).

A misconception not included in the concept test content was identified among the open-ended answers in the "*None. In my opinion, ...*" section. This is the misconception of students that the color of sugar molecules will change when they are transferred to a container full of water.

CHAPTER 5

CONCLUSION

This chapter discusses the study's main results within the context of the relevant science education literature. At the end of the section, important implications and recommendations for future studies are included.

5.1 Discussion

This study had two main aims. The first was to identify the misconceptions of 7th-grade students about the particulate nature of matter and dissolution and to examine the effect of argumentation instruction compared to curriculum-based instruction in eliminating these misconceptions. The second objective was to analyze these misconceptions from an ontological perspective. This involved determining the source of students' misconceptions from an ontological perspective and assessing the effectiveness of argumentation and curriculum-based instruction in eliminating misconceptions resulting from incorrect placement in the ontological category. The results obtained from the three main research questions are discussed below.

5.1.1 Discussion of Misconceptions Identified Regarding the Particulate Nature of Matter and Dissolution

The first research question is: What are the misconceptions of 7th-grade students about the particulate structure of matter and dissolution? This section presents a discussion of the findings related to this question.

Analysis of the content-reason combinations of PNMCT provided by the participant groups both before and after the instruction revealed that the students held various misconceptions about specific topics.

Misconceptions about the animism of atoms were detected in both the pre-test and post-test, with students believing that atoms are alive due to their qualities, such as being able to move and their presence in both living and non-living matter. These findings align with research by Griffiths and Preston (1992), Harrison and Treagust (1996), Pideci (2002), and Salmaz (2002). Furthermore, these misconceptions were identified through the combinations of responses given to the first question of the PNMCT (see Table 4.1, Table 4.2, and Table 4.3). In the pre-test, 25.0% of the comparison group chose the "b3" combination as content, “iron atoms are alive” as reason, and “the atoms are alive because the leaf is alive.” However, since this response does not contain a logical relationship, so this combination is a sign of a lack of conception rather than a misconception. This finding aligns with the results from Daniel Tan et al. (2001).

Misconceptions regarding particle size were detected in the pre-test and post-test results of research groups. Students believed that the size of water molecules decreases from solid to liquid and increases from liquid to solid. Similarly, they thought that the size of water molecules decreases when changing from liquid to gas. Students also assumed that the volume of particles of the substance decreases when a substance's temperature decreases (the frozen substance), and conversely, it increases when a substance's temperature increases (the melted substance). They associated particle expansion directly with heat. Additionally, they believed that particles as the smallest visible forms of substances, for instance, seeing a water molecule as the size of a water droplet, mercury as the size of a mercury droplet, and particles of alcohol, salt, or sugar as their smallest visible forms. These misconceptions align with the findings of Griffiths and Preston (1992), Kind (2004), Lee et al. (1993), Kokkotas and Vlachos (1998), and Renström et al. (1990).

Pre-test and post-test responses from the research group revealed several misconceptions about particle phase and form during change of state. Students believed that when a substance freezes, the molecules freeze due to decreased temperature, and when a substance melts, the atoms melt due to increased temperature. Some also thought that the atoms melt without a temperature increase during melting. Additional misconceptions included the belief that ice molecules are solid, water molecules are liquid, and the molecules are always solid or liquid. These identified misconceptions are similar to the results of research conducted by Andersson (1992), Boz (2006), Brook et al. (1984), Koulaidis and Hatzinikita (1966), and Lee et al. (1993). The pre-test and post-test responses detected misconceptions about structure, interparticle gaps, and particle movement. Some students believed solid-state atoms do not move because there is no space between them to allow them to move, aligning with findings from Adbo and Taber (2009), Boz (2006), Griffiths and Preston (1992), Lee et al. (1993), and Renstrom et al. (1990). Additional misconceptions included beliefs that table salt is an example of a compound with a molecular structure whose smallest particle is a molecule, that salt is an example of an element, and its smallest particle is an atom, and that in the formation of NaCI, electron sharing occurs between the Chlorine atom and the Sodium atom, or the Chlorine atom takes an electron from the Sodium atom. Some students also thought that in salt formation, there is a physical structure similar to a rope between its atoms and that there is air in the space between particles. These misconceptions are consistent with studies by Butts and Smith (1987), Coll and Treagust (2003), Griffiths and Preston (1992), Othman et al. (2008), Sarı (2014), and Taber (1998).

Misconceptions were identified in the study groups' pre-test and post-test on attributing the properties of particles to their matters. For example, students believed that all external changes to a gold atom (such as shaping) are also reflected in its atoms. Additionally, they assumed that since gold atoms are shiny and hard, their atoms are also glossy and stiff. Another misconception was that an atom is the smallest structural unit that carries an element's physical and chemical properties. Similar misconceptions were documented in the study by Othman et al. (2008). Researchers applied a two-tier diagnostic test consisting of 10 items to a total sample of 260 9th and 10th-grade students (15 to 16 years old) to determine the students' naive beliefs on the particulate nature of matter and chemical bonding. In the reason-content combinations obtained, it was determined that more than 50% of the classes had the misconception that the atom has some properties of the element it belongs to, while 25% of the 10^{th} graders and 34% of the 9^{th} grades had the misconception that the atom has all the physical and chemical properties of an element. One of the reasons why similar misconceptions about the atom, one of the basic terms of chemistry, are detected in both middle and high school levels is the strong resistance of these misconceptions to change (Griffiths, 1998).

Misconceptions about dissolution are identified in research groups' pre-test and post-test results. Some students believed that sugar dissolution in water is a chemical reaction that forms a new substance and causes solutes to lose their properties. Other misconceptions included that sugar melts in water, turns into water, and disappears, or requires external intervention (e.g., mixing) to break down and dissolve. Other misconceptions included beliefs that mixtures are not included in the category of pure substances, that sugar molecules melt if they receive heat from outside in the water, and that they change color when dissolved. These misconceptions align with findings from studies by Abraham et al. (1992), Griffiths and Preston (1992), Fellow (1994), Lee et al. (1993), Othman et al. (2008), Prieto et al. (1989).

Additionally, the misconceptions determined in different subject areas above mainly relate to attributing macroscopic properties (color, volume, phase change, conductivity, etc.) to particles (atoms, molecules, and ions) except dissolution. This tendency arises because students find understanding and reasoning about macroscopic properties easier. For this reason, their understanding of chemistry concepts often remains at a macroscopic level (Stavridou & Solomonidou, 1998). Many studies in the literature support this situation. For example, Franco and Taber (2009), Adadan, Trundle, and Irving (2010), and also Karaçöp and Doymuş (2012) found that students could not fully relate the micro dimension to the macro dimension, resulting in difficulties in understanding the micro level.

Last but not least, students' misconception about dissolution is the interchangeable use of the terms "melting" and "dissolution." This confusion likely arises because these concepts are often conflated in everyday language (Çalık et al., 2006). In addition, many studies have emphasized that the prior knowledge students acquire from their social environment, especially before teaching, is not scientific and prevents the correct learning of concepts (Abdullah et al., 2017; Hewson, 1992; Posner et al., 1982). Similarly, in this study, misconceptions about "melting" versus "dissolving" persisted in both the experimental and control groups even after different instructional methods were applied, indicating that misconceptions learned from the social environment can significantly hinder effective learning (see Table 4.53).

5.1.2 Discussion on the Effect of Argumentation Instruction in Conceptual Understanding

The second research question is: What is the effect of argumentation instruction compared to curriculum–based instruction on 7th-grade students' conceptual understanding of the particulate nature of matter and dissolution concepts?

The results of the first sub-question of the 2nd question indicated that no statistically significant mean difference was found between the conceptual understanding levels of the experimental and comparison group students regarding the concepts of the particulate nature of matter and dissolution before the instructions. The mean rank values for the experimental group (*M=18.84)* and the comparison group *(M=17.00)* showed that both groups had similar levels of conceptual understanding of this topic. Considering the max= 17 and min= 0 scores obtained from PNMCT, the median value of = 2 for both study groups showed that the students in both groups held misconceptions and lacked scientific knowledge on this topic. Previous studies have documented similar misconceptions about the particulate nature of matter and dissolution (Pideci, 2000; Salmaz, 2002; Özalp, 2008; Valanides, 2000). Additionally, comprehensive literature examples about misconceptions are presented in section **5.1.1.**

The results of the second sub-question of the 2nd question revealed a statistically significant difference between the pre-and post-test PNMCT score averages for the comparison group regarding conceptual understanding. The pre-test average score (M = 2) compared to the post-test average score (M = 1) indicates that this difference favors the pre-test. In other words, curriculum-based instruction appears to have a significant negative impact on students’ conceptual understanding of the particulate nature of matter and dissolution concepts. Studies have found that curriculum-based instruction does not positively impact students' conceptual understanding of the particulate nature of matter and dissolution (Güler, 2023; Kaya, 2005; Kapıcı & Akçay, 2016). For example, Güler (2023) investigated the effects of argumentation, collaborative argumentation, and curriculum-based instruction on the conceptual understanding of the 7th-grade students on the unit of pure substances and mixtures. The study was designed using a mixed-method research design. The study lasted 6 weeks and included three groups: Experimental Group 1, which received argumentation instruction; Experimental Group 2, which received collaborative instruction; and Control Group, which received curriculum-based instruction, totaling 90 participants. The two-tier “*Misconception Determination Concepts Test*” was administered to all groups as a pre-test and post-test. The statistical analysis conducted after the study revealed a significant improvement in conceptual understanding among the experimental group compared to the comparison group.

The failure of curriculum-based instruction to improve students' conceptual understanding may stem from its lack of alignment with constructivist learning principles. Many researchers have emphasized that students have difficulty learning concepts when teaching methods are not aligned with constructivist approaches (Brooks& Brooks, 1994; Beothel &Dimock, 2000). In this study, the comparison group's class environment lacked constructivist principles: the students tried to learn the subject in an environment where information was directly transferred from the teacher to the student, the student's prior ideas were not taken into account, group work was not carried out, activities were limited to the textbook, based on question-answer dialogues and stayed within the curriculum boundaries.

Lastly, analysis of the response combinations given by the comparison group students in the two-tier PNMCT revealed a significant decrease in the rates of correct content-reason combinations after the instruction (see Table 4.53). This suggests that curriculum-based instruction negatively affected the students' conceptual understanding of the particulate nature of matter and dissolution, indicating that their understanding did not reach the "sound understanding" level. According to Abraham et al. (1992), achieving a sound understanding requires correct responses in both content and reasoning tiers. Previous studies also found that curriculum-based instruction does not positively affect the conceptual understanding levels of students (Özalp, 2008; Sarı, 2014; Bayram, 2020; Kocakülah, 2006).

The results of the third sub-question of the 2nd question indicated a statistically significant difference between the pre-and post-test PNMCT score averages for the experimental group's conceptual understandings. When the pre-test average score (*M=2)* and post-test average score *(M=11)* of the students are taken into consideration, it is seen that the statistical difference is in favor of the post-test. It was revealed that argumentation instruction effectively increases students' conceptual understanding of the particulate nature of matter and dissolution. Similarly, the results of the last sub-questions of the 2nd question indicated that a statistically significant mean difference was found between the conceptual understanding levels of the experimental and comparison group students regarding the concepts of the particulate nature of matter and dissolution after the instructions. The mean rank values of the experimental group and the comparison group showed that the students in the experimental groups had higher conceptual understanding levels. Considering the max= 17 and min= 0 scores obtained from PNMCT, the median value of = 11 for the experimental group and the median value of = 1 for the comparison group showed that the students in the experimental group have fewer misconceptions regarding the relevant topic rather than the comparison group. In short, in this study, argumentation instruction improved students' conceptual understanding of the particulate structure of matter and dissolution, but it could not eliminate all identified misconceptions.

One reason argumentation instruction enhanced conceptual understanding in this study may be the constructivist classroom environment provided to the experimental group. Lessons for this group included activities designed to foster in-class argumentation, as recommended by Osborne et al. (2004b). These argumentation activities allowed students to reveal their prejudices, evaluate different opinions, provide evidence for their thoughts, seek evidence while accepting information, and actively participate in group and class discussions in the current study. As Newton et al. (1999) emphasized, constructivist classrooms should incorporate argumentation activities that engage students in discussions and encourage the development of conceptual understanding through the active use of writing and speaking skills. In order to create a constructivist classroom environment for this study, students were made to feel that their initial thoughts were vulnerable. Before starting the lesson, the teacher asked questions such as "*What do you think about ...? and "Have you ever heard of ... before?*" to determine the students' prior knowledge. The students were constantly considered thinkers from the beginning to the end of the lesson. This situation may have positively affected the students' conceptual understanding. Venville and Dawson (2010) emphasized that students can produce more comprehensive information in argumentation environments where they are active thinkers. In contrast, the comparison group's classroom environment was traditional, lacking the opportunities offered by the constructivist approach.

Another reason for the improvement in the experimental group’s conceptual understanding may be the effective integration of argumentation into the classroom. Simon et al. (2006) identified key requirements for successfully incorporating argumentation into instruction. The first requirement pertains to the role of teachers, which undergoes a significant change during the argumentation process. To facilitate this change effectively, teachers must possess a strong understanding of argumentation principles. In the present study, a "Teacher Information Form (see Appendix E)" was prepared for the teacher before the study. This form included the definition of argument and argumentation, the Toulmin Argumentation Pattern, and basic information about in-class activities. Another requirement is providing teachers with appropriate materials to effectively support and facilitate the argumentation process. In this study, various activities were designed using the frameworks recommended by Osborne et al. (2004b). The Toulmin Argumentation Pattern was used as the basis for the design of the activities. Section *"3.3.2.1"* of the study presented strategies to overcome the pattern's limitations. Furthermore, lesson plans were prepared to facilitate the teacher's argumentation process in this study. The content of the lesson plans included question patterns aimed at attracting the students' attention to the lesson. For example, "*What do you remember about the subject of ...?", "Have you heard of ... before?"*. In addition, the lesson plans included questions that enabled students to structure their arguments and produce various ideas. For example, *"Why do you claim this claim is scientifically true/false? What evidence do you have to support this claim? What would you say to your groupmate who disagrees with your claim that you marked as ... in order to defend your claim?"*. The last requirement related to teachers is providing consistent feedback. In this study, the "Lesson Observation Form (see Appendix F)" results were shared with the teachers every week. In summary, the requirements regarding the teacher are essential for effective argumentation instruction because, as Simon et al. (2006) also stated, improvements in the teacher's knowledge and performance regarding argumentation will positively affect the argumentation process in the classroom. In addition, where all students engage in the argumentation process, the teachers' ability to develop students' ideas and effectively guide the process is closely tied to their instructional knowledge (Newton et al., 1999).

The second requirement is related to students. According to Simon et al. (2006), students need to know the rules of respect before the argumentation process starts. In this study, the teacher conveyed the classroom rules written in the lesson plans to the students before each activity and mentioned their importance to the students. Secondly, before the debate starts, students should know what argumentation and argument elements (data, claim, warrant ... etc.) are. In this study, the researcher held a preparation lesson to develop the students' adaptation skills and knowledge regarding the process. Informative materials and activities about argumentation were presented to the students in the lesson. Toulmin Argumentation Pattern has some limitations, especially in not drawing a clear boundary between the argument elements. This situation can be challenging for students (Simon et al., 2006; van Eemeren et al., 1996). In order to reduce the effect of this situation, the question patterns suggested by Toulmin (1958) were used in this study so that students could find the argument elements. For example, for the claim *"From the concept cartoons, whose answer do you think is completely correct?*"; for data, "*What makes you think your claim is correct?* In other words, on what data do you base your claim? Please explain". These questions remained similar in all activities and aimed to accelerate students' adaptation to the process. Finally, in this study, students were given some tasks, such as giving written answers to questions within a specific time limit, presenting evidence, and participating in intra-group and inter-group discussions with their friends. As a result, it was concluded that these requirements, whose successful effectiveness in the argumentation process was proven by Simon et al. (2006), also yielded successful results in this study.

In addition, the statistical analysis of the study revealed that argumentation instruction was more effective than curriculum-based instruction in improving students' conceptual understanding of the particulate nature of matter and dissolution. These results are consistent with many science education studies that examined the effects of argumentation on conceptual understanding across various grade levels and different contexts (Asterhan & Schwarz, 2007; Çelik & Kılıç, 2014demirel; Dawson & Venville, 2010; Demirel, 2016; Kaya, 2013; Niaz et al., 2002; Nussbaum & Sinatra, 2003; Özelma & Seyhan, 2022; Pabuçcu & Erduran, 2017; Riyanti, 2023; Teichert & Stacy, 2002; Uluçınar Sağır, 2008; Walker et al., 2012; Yalçın- Çelik, 2010; Zohar & Nemet, 2002). For example, Uluçınar Sağır (2008) examined the changes in academic success, attitudes towards science, understanding of concepts related to the nature of science, and willingness to participate in discussions of 7th-grade students in the unit "*Journey to the Internal*

Structure of Matter" with argumentation instruction. Students in the comparison group received curriculum-based, while students in the experimental group received argumentation instruction. The results of this study, conducted using a pre-test–post-test control group experimental design, indicated that the science class receiving argumentation instruction achieved higher levels of conceptual understanding. A similar study was conducted by Özelma and Seyhan (2022), employing a quasi-experimental design with a pre-test–post-test control group to examine the effect of argumentation instruction on 6th-grade students' conceptual understanding of the particulate nature of matter. The study found that the experimental group receiving argumentation instruction significantly increased conceptual understanding. In addition, some researchers have linked the existence of argumentation in the classroom with the achievement of conceptual understanding (Jiménez-Aleixandre, 2007).

Another possible explanation for the greater effectiveness of argumentation instruction in enhancing students' conceptual understanding, compared to curriculum-based instruction, is that the argumentation activities prepared for the experimental group are based on ontological reasons. For example, the aims of "*Activity-2: Finding the Smallest Unit “in* this study are to show that atoms are the smallest structural unit of all living and non-living entities and that they are not living. In the relevant literature review, it was determined that students believe that atoms are alive because they like them to cells (Harrison & Treagust, 1996), and also found that students think of atoms as macroscopic particles; therefore, they believed that the smallest structural unit of living entities is the cell, and the smallest structural unit of non-living entities is the atom because atoms take on the characteristics of the entities they belong to (Johnson and Driver, 1991). When these findings are evaluated from an ontological perspective, it was seen that students have misconceptions resulting from assigning the concept of atom laterally between the categories of *"Living - Non-living*" *and "Macroscopic matter - Microscopic particle."* In line with this inference, Activity 2 was created within the boundaries of the specified ontological categories to make students think more about the specified ontological categories and gain awareness. Thus, during the activity, students became aware of the subcategories of "*Living – Non-Living*" and "*Macroscopic matter - Microscopic particle*" and shaped their thoughts within the scope of the qualities of these ontological categories. After the instruction, it was determined that the students in the experimental group gave a higher rate of correct answers to the first question of the PNMCT regarding the relevant activity compared to the control group. In many previous studies in the science literature, it has been determined that instruction developed based on ontological reasons, as in this study, is more successful in developing students' conceptual understanding compared to curriculum-based instruction (Slotta & Chi, 2006; McLure et al., 2020). For example, Slotta and Chi (2006) found that the module containing clues that allowed students to evaluate electrical concepts in the "processes" category in developing university students' conceptual understanding of the subject of electricity yielded much more successful results than traditional instruction.

Although the study's analysis showed that argumentation instruction positively affected students' conceptual understanding of the particulate nature of matter and dissolution compared to curriculum-based instruction, the experimental group's misconceptions could not be eliminated entirely. This finding may be attributed to the fact that the experimental group of students have received education in a traditional classroom environment for six years. According to Confrey (1990), the students' naive beliefs often originate from formal education. Similarly, McNeil and Alibali (2005, p. 884) suggest that these naive beliefs can act as an obstacle and limit further learning.

Last but not least, the frequencies of misconceptions detected in the PNMCT and their correction (see Figure 4.37. and Figure 4.38.) showed that the comparison group students were more successful in the 13th item of the PNMCT. This item tested the understanding that sugar water is a solution, explaining its impurity. This finding indicated that curriculum-based instruction was more effective than argumentation in eliminating this misconception. Specifically, while the percentage of eliminating this misconception in the experimental group was 0%, it reached 57.14% in the comparison group. This result aligns with Çınar's (2013) study, where argumentation instruction did not significantly enhance 5th-grade students' conceptual understanding of "Change and Definition of Matter" in the experimental group. Although curriculum-based instruction has limitations in promoting conceptual learning, studies by Boumová (2008) and Schwerdt and Wuppermann (2009) acknowledge its effectiveness in specific contexts.

5.2 Discussion on the Effect of Argumentation Instruction on Eliminating Misconceptions in the Context of Ontology

The third research question is: What is the effect of argumentation instruction compared to curriculum-based instruction in eliminating ontologically evaluated misconceptions of 7th-grade students regarding the particulate nature of matter and dissolution concepts?

The findings regarding this research question are discussed in three dimensions: misconceptions are frequently caused by assignment to the lateral category, conceptual change occurs at a non-radical level, and instruction methods affect the elimination of misconceptions caused by incorrect placement in the lateral and superordinate categories.

At first, one of the findings from the analysis of the third research involved placing misconceptions into lateral and superordinate categories. A misconception classified in a lateral category was detected in all questions of the concept test. In a total of 6 items, a misconception due to assigning to a superordinate category in addition to the lateral category was detected (Items 3, 11, 13, 15, 16, and 17). The main reason for this situation is due to the structure of ontological categories (Chi, 2008). Lateral categories are defined as those that do not have any hierarchical relationship with each other and share standard features only in superordinate or higher superordinate categories. For example, the "Natural Kind" and "Artifacts" categories, which are subcategories of the matter category, are lateral because although they share the category of matter as a superordinate category, the concepts they contain are not valid for each other. In other words, they are different branches in the same tree (Chi, 2008; Thagard, 1990). In line with this definition, although the lateral categories contain different features, they also have many standard features. This situation supports the result that misconceptions may arise from assigning a concept to its lateral category (Chi & Slotta, 1993). Especially in a field where macroscopic and microscopic evaluations are involved, such as the particle structure of matter and the subject of dissolution (Gabel, 1999), it is supported that there are many misunderstandings resulting from the assignment of a concept in the microscopic particle category to the subcategory of macroscopic particles (Stavridou & Solomonidou, 1998).

Another reason for the high frequency of misconceptions resulting from assigning a concept to a lateral category may be that students often fail to recognize they need to reassign this concept to a different category before the study. According to Chi (2008), the need to reassign a concept to a lateral category is rare in daily routine. For example, students can easily distinguish a living cat (living category) from a plush cat (Non-Living Category) based on their outward perceptual features (artifacts- living things are lateral categories), and failure to distinguish is infrequent. This situation makes it difficult for students to realize that a concept is due to assigning it to a lateral category. In this study, students tended to focus on the macroscopic, i.e., outward perceptual features before instruction, even though the particulate structure of matter requires evaluation at the microscopic level. As a result, they did not realize that they needed to evaluate the concepts at the micro level. For example, since students know that gold is stiff and shiny, they thought that its atoms could also be hard and shiny. For these reasons, many of the misconceptions identified before this study resulted from assigning concepts to lateral categories, and conceptual change was often interpreted as a shift between lateral categories. Thus, the study's results were related to eliminating misconceptions from incorrect assignment to the lateral category. However, this situation shook the foundation of more resistant misconceptions that could have formed in the students' minds. According to Chi (2008), such category errors form the basis of deeply rooted misconceptions in science. Therefore, studies aimed at encouraging shifting between categories should focus on raising students' awareness of such category errors. In this study, the quantitative data after instruction showed that argumentation instruction enhances students' awareness of misconceptions originating from assigning to a lateral category.

Secondly, another finding within the scope of the research question for both study groups is that conceptual change occurs within different branches of the same tree. In other words, the conceptual changes detected are among the sub-branches of the same ontological category. Chi (1992) preferred to use "conceptual change or non-radical conceptual change" when defining conceptual change within the ontological category. Radical conceptual change did not occur in this study. However, this is a possible result and is consistent with the literature. According to Chi (1992), radical conceptual change is scarce and complicated. Because, even in our daily lives, it is not expected to assign a concept to a completely different place than it originally belonged to by attributing completely different characteristics to it.

Another finding of this study, supporting why radical conceptual changes rarely occur due to daily life experiences, is the detection of misconceptions in items 3, 11, and 13 of the PNMCT for both study groups. These misconceptions arose from placing the concept of dissolution in its lateral category of melting. One of the reasons for students' misconceptions about melting and dissolution is that the concepts are used interchangeably in daily language, such as sugar and salt melting in water (Lawson & Thomson, 1988).

Lastly, the results of the distribution of misconceptions of the comparison and experimental group students to ontological categories before and after the instruction showed that argumentation was more effective in eliminating misconceptions arising from placing the concepts of the particulate nature of matter and dissolution in lateral and superordinate categories. This finding parallels the results of the study conducted by Topalsan (2015). Topalsan (2015) examined the participants' misconceptions regarding "*Force and Motion*" through ontological categories in the study conducted with classroom teacher candidates. The findings of her study showed that argumentation instruction was more effective than curriculum-based instruction in eliminating misconceptions assigned to lateral and superordinate categories. Furthermore, the weakness of the effect of curriculum-based instruction in eliminating misconceptions assigned to lateral and superordinate categories is parallel to the results of the studies in the literature (Diyarbekir, 2020; Sarı, 2014). For example, Sarı (2014) examined the misconceptions of 7th-grade students on the subject of "*Structure and Properties of Matter*" through ontological categories. The results of her research show that curriculum-based instruction is less effective in eliminating misconceptions assigned to lateral and superordinate categories than computer and concept map-supported instruction. In another study, Diyarbekir (2020) examined the misconceptions of 7th-grade students on "*Force and Motion*" through ontological categories. The results of her research show that curriculum-based instruction is less effective in eliminating misconceptions assigned to lateral and superordinate categories than animation-supported instruction.

In addition, this study found that argumentation is more effective at eliminating misconceptions in lateral categories than curriculum-based instruction. The possible reason for this situation may be that argumentation instruction is more successful than curriculum-based instruction in learning concepts. According to (Chi, 1997, p. 220), assigning a concept from a different branch of the same tree to another branch (laterally) is a pretty reasonable situation that occurs when students thoroughly learn a limited number of correct attributes regarding the concept. As students learn more correct things about the concept, it also encourages them to make correct inferences about the lateral category of the concept.

5.3 Implications and Recommendations for Practitioners and Researchers

This study provides comprehensive information on determining students' misconceptions about the particulate nature of matter and dissolution. It examines the effect of argumentation instruction on conceptual understanding, identifies the leading causes of misconceptions by considering them on an ontological basis, and assesses how argumentation instruction can effectively eliminate them from an ontological perspective. In this respect, it has significant implications for teachers, curriculum developers, and science education researchers.

The study revealed that students had various misconceptions about the particulate structure of matter, pure substances, and mixtures both before and after instruction. If educators do not understand what students think and why they think this way, the effect of applied instruction cannot be seen (Osborne & Freyberg, 1985). The study is valuable in alerting researchers to misconceptions revealed in this study and creating a basis for developing effective teaching strategies that future researchers can build upon. As Aguirre and Erickson (1984) noted, informing teachers, researchers, and curriculum developers about misconceptions enables the design of instructional strategies that address these misconceptions and incorporate insights from research findings on how such strategies affect conceptual understanding. As a result of the effect of argumentation instruction on students' conceptual understanding of the particulate structure of matter and dissolution, the rate of students who gave correct answers to the questions in the concept test mainly was between 75% and above and 74-50%. This percentage value indicates that argumentation instruction was effective and adequate for enhancing students' conceptual understanding of the specified topics (Gilbert, 1977). The quantitative results of the study revealed that argumentation instruction was more effective than curriculum-based instruction in developing students' conceptual understanding of the particulate structure of matter and dissolution, with the effect size r=.82. Therefore, to cope with the necessity of thinking between macroscopic and microscopic dimensions in understanding chemistry as well as the perception that understanding chemistry is inherently difficult (Hawkins & Phelps, 2013; Osborne & Freyberg, 1985), argumentation instruction can be preferred to increase students' conceptual understanding (Erduran & Jiménez-Aleixandre, 2012; Jiménez Aleixandre et al., 2000). This method is particularly effective for topics involving the particulate nature of matter, a fundamental concept in chemistry (Preston, 1988). Integrating argumentation in the classroom is valuable, but successful implementation requires teachers to understand how to incorporate argumentation and what steps to follow during the process (Simon et al., 2006). Teachers play a crucial role in this process, as their impact on student learning is significant (Puvirajah, 2007). The activity and lesson plan design used in the present study highlights essential steps for effectively implementing argumentation in the classroom. At this point, some recommendations can be made for teachers; although in-class argumentation activities may appear complex, using well-structured lesson plans can facilitate the process. The present study found that the lesson plans and argumentation activities improved students' conceptual understanding, suggesting that these materials can be effectively applied while teaching the "Nature of Matter" unit. Different argumentation activities can be designed for different topics by following the development steps of these materials, using frameworks recommended by Osborne et al. (2004b). When designing these activities, it is essential to ensure that students engage in individual, in-group, and class discussions. This intensive discussion process allows the students to think continuously. Another key consideration is the use of clear and simple language; ensuring that students fully understand each activity step will help the process run smoothly and effectively.

Moreover, there are some implications regarding the students' argumentation participation processes during the study. Osborne et al. (2004b) used similar question expressions to integrate frameworks that would provide an in-class argumentation environment into the activities, which improved the process of students' argumentation participation. In addition, providing evidence to support the students' arguments in the activities positively affected their argumentation participation (McNeill & Krajcik, 2012). In this context, it is recommended that teachers maintain consistent question patterns and lesson structure in argumentation activities throughout the topic. This consistency can help students adapt to the process more effectively.

Additionally, the science curriculum could include sample lesson plans within each unit, providing practical methods for integrating argumentation into classroom instruction. Research on students' misconceptions has shown that teachers sometimes make ontological category errors during instruction (e.g., using phrases like "heat flows," "heat wants to go," or "sugar dissolves in water”) (Somon, 2000; Lee & Law, 2001; Şen & Yılmaz, 2012). Such language can hinder students' conceptual understanding, so teachers should carefully consider the verbs they use when explaining scientific concepts. Additionally, some recommendations can be made to textbook writers regarding misconceptions. This study observed that students often used science textbooks to provide evidence for their claims during argumentation. Textbooks are one of the primary resources for both teachers and students (Diakidoy et al., 2003); however, they are also known to be a common source of misconceptions (Nahum et al., 2004). Therefore, when designing textbooks, students' misconceptions should be considered, forms and expressions that may cause misconceptions should not be included, and include activities that enhance students’ conceptual understanding.

For researchers, the present study highlights the effectiveness of argumentation instruction in enhancing students' conceptual understanding. The study can be replicated across different science topics and grade levels, allowing for insights into the effect of argumentation instruction across varied contexts. By comparing the findings of studies conducted at different times, detailed implications can be made about how students' prior knowledge and conceptual understanding change over time. Additionally, the study identified particular challenges students face in changing prior knowledge, especially on topics like melting and dissolution. A follow-up study with a larger sample and an expanded set of questions focused on these areas could offer further insights into the reasons behind these persistent misconceptions. The study evaluated quantitative data; however, researchers should consider incorporating qualitative data through interviews with participant groups. This would provide different findings to enrich the literature on the ontological nature of misconceptions. In addition, the study found that argumentation instruction significantly improved conceptual understanding after seven weeks. To assess the long-term effectiveness of this approach, a retention test could be administered after a set period (e.g., three months) to determine if the improvement is sustained.

For curriculum developers, the current study emphasizes the importance of objectives related to animism and macroscopic matter-microscopic particle topics in the science curriculum. The most concrete steps to counter misconceptions are through curriculum arrangement. Therefore, objectives on animism, macroscopic matter, and microscopic particles should be added to the curriculum. As Powell and Anderson (2002, p. 112) state, the curriculum is the tool that embodies the basic steps of reform and plays a crucial role in initiating and sustaining change.

In addition, this study includes some recommendations for the Ministry of National Education. The study determined that the teacher's field knowledge and experience in argumentation teaching played a significant role in integrating argumentation into the classroom. For example, as time progressed in the study, as the teacher's field knowledge and experience in the argumentation process increased, the application of argumentation in the classroom became more accessible, and the teacher gained confidence in argumentation teaching and was motivated to use argumentation teaching in future lessons. Inferring from this, MoNE should organize seminars and practical training that will improve the professional development of teachers in advancing argumentation instruction. The subject content of the seminars should include the importance of presenting evidence in science, the importance and necessity of argumentation in teaching, the introduction of argumentation patterns (such as the Toulmin Argumentation Pattern), the design steps of argumentation activities and plans, the importance of discussing different views in science and finally the role of argumentation in eliminating misconceptions. Simon et al. (2006) found that informative seminars and practices on the specified subject content improved teachers' professional development in argumentation, and this resulted in successful results in teachers effectively integrating argumentation instruction into the classroom.

This study also has some implications regarding determining ontological reasons for students' misconceptions about the particulate structure of matter and dissolution. The study determined that experimental and control group students were more successful in eliminating misconceptions originating from placing in the lateral category than the superordinate category. Although it is emphasized that the reasons for misconceptions are due to assigning in the lateral category based on ontology (Chi, 1997), further research is needed to achieve similar success in addressing misconceptions at the superordinate level. Another finding is that argumentation instruction effectively eliminates misconceptions within ontological categories. Given the limited research analyzing misconceptions through the lens of ontological categories and evaluating the effectiveness of various teaching methods, it is challenging to directly compare the effect of argumentation instruction with other instruction methods. Conducting further studies in this area would, therefore, provide valuable insights.

Moreover, this study observed that the misconceptions detected through PNMCT belong to different branches of the same tree in ontology. This situation limited the conceptual change results presented in the study to a non-radical level. In national and international literature, ontology-based two-tier diagnostic tests are limited to identifying and assessing middle school students' misconceptions about the particulate nature of matter and dissolution. Researchers need to develop ontology-based two-tier diagnostic tests to enrich the literature and, more precisely, diagnose and address these misconceptions.

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APPENDICES

A. MINISTRY OF NATIONAL EDUCATION ETHICAL COMMITTEE APPROVAL

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : E-14588481-605.99-96109102 07.02.2024
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi : a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2020/2 sayılı Genelgesi.
b) 29.01.2024 tarihli ve 557 sayılı yazınız.

Üniversiteniz Matematik ve Fen Bilimleri Eğitimi Anabilim Dalı Yüksek Lisans Programı öğrencisi Hacer MUTLUER'in **"7. Sınıf Öğrencilerinin Maddenin Tanecikli Yapısı ve Çözünme Konularındaki Kavram Yanılgılarının Ontolojik Açıdan Belirlenmesi ve Argümantasyon Destekli Öğretim İle Giderilmesi"** başlıklı çalışması kapsamında Etimesgut ilçemize bağlı ortaokullarda yapılacak uygulama talebi ilgi (a) Genelge çerçevesinde incelenmiştir.

Yapılan inceleme sonucunda, söz konusu araştırmanın Müdürlüğümüzde muhafaza edilen ölçme araçlarının; Türkiye Cumhuriyeti Anayasası, Milli Eğitim Temel Kanunu ile Türk Milli Eğitiminin genel amaçlarına uygun olarak, ilgili yasal düzenlemelerde belirtilen ilke, esas ve amaçlara aykırılık teşkil etmeyecek, eğitim-öğretim faaliyetlerini aksatmayacak şekilde okul ve kurum yöneticilerinin sorumluluğunda, gönüllülük esasına göre uygulanması Müdürlüğümüzce uygun görülmüş olup çalışma tamamlandıktan sonra çalışmanın bir nüshasının **30 iş günü içerisinde arge06_arastirma@meb.gov.tr adresine PDF olarak gönderilmesi** gerekmektedir.

Bilgilerinizi ve gereğini rica ederim.

Yaşar KOÇAK
Vali a.
Milli Eğitim Müdürü

Ek: Uygulama Araçları (7 Sayfa)
Dağıtım:
Gereği:
ODTÜ

Bilgi :
Etimesgut İlçe MEM

Bu belge güvenli elektronik imza ile imzalanmıştır.

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E-Posta: istatistik06@meb.gov.tr
Kep Adresi : meb@hs01.kep.tr

Belge Doğrulama Adresi : https://www.turkiye.gov.tr/meb-ebys
Bilgi için: Aysun AKDEMİR
Unvan : Memur
İnternet Adresi: Faks:

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B. METU ETHICAL COMMITTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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Konu: Değerlendirme Sonucu

29 KASIM 2023

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof. Dr. Jale Çakıroğlu

Danışmanlığını yürüttüğünüz Hacer Mutluer'in ***"7. Sınıf Öğrencilerinin Maddenin Tanecikli Yapısı ve Çözünme Konularındaki Kavram Yanılgılarının Ontolojik Açıdan Belirlenmesi ve Argümantasyon Destekli Öğretim İle Giderilmesi"*** başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek 0489-ODTUİAEK-2023 protokol numarası ile onaylanmıştır.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan

Prof.Dr. İ. Semih AKÇOMAK
Üye

Doç. Dr. Ali Emre Turgut
Üye

Doç. Dr. Şerife SEVİNÇ
Üye

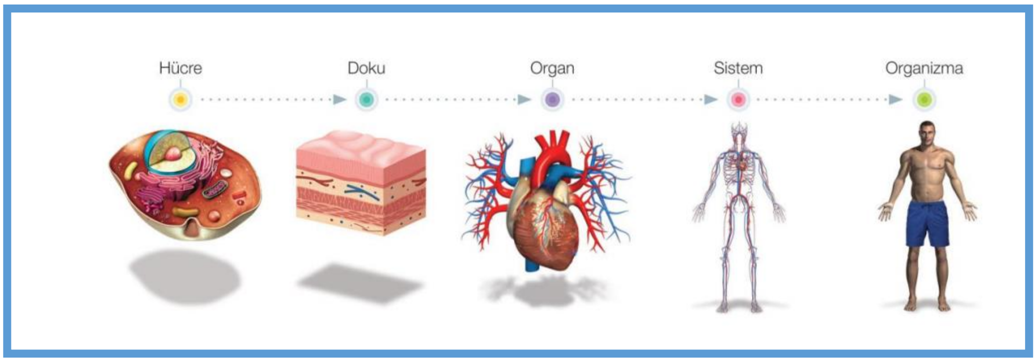
Doç.Dr. Murat Perit ÇAKIR
Üye

Dr. Öğretim Üyesi Süreyya ÖZCAN KARABAKAL
Üye

Dr. Öğretim Üyesi Müge GÜNDÜZ
Üye

C. EXAMPLE of ARGUMENTATION-BASED ACTIVITIES

Etkinlik 2: EN KÜÇÜK BİRİMİ BULUYORUZ!



7. sınıf öğrencisi Sibel **"Hücre ve Bölünmeler"** ünitesinde; canlılarda benzer özelliklere sahip **hücrelerin** görev ve işlevlerini yerine getirebilmek için **dokuları,** dokuların bir araya gelerek **organları**, organların belirli görevlerini yerine getirebilmek için **sistemleri** ve tüm oluşan sistemlerin düzenli bir şekilde çalışabilmek için **organizmayı (canlıyı)** oluşturduklarını öğrenmiştir. Ayrıca, hücrenin canlıları oluşturan ve canlı olabilme özelliğini gösteren en küçük yapı birimi olduğunu öğrenmiştir.

Merhaba, ben Sibel. Hücre konusunda öğrendiklerimden sonra aklıma takılan birkaç soruyu sizlere sormak istiyorum. Bunlar; hücrelerden daha küçük bir birim var mıdır? Cansız maddeleri oluşturan en küçük yapı taşı nedir? Canlıların en küçük yapı taşının canlı olabilme gibi bir özelliği varsa cansız maddeleri oluşturan en küçük yapı taşının da canlı olma gibi bir özelliği var mıdır?

Aklına takılan soruları ilk olarak sınıf arkadaşları Ahmet, Fatma ve Hakan'a soran Sibel, aşağıda yer alan yanıtlarla karşılaşır.

Ahmet:

Canlı ve cansız tüm maddelerin en küçük yapı taşı atomdur. Örneğin, hücrenin, insanın ve defterin temel birimi atomdur. Atom ve hücre aynı kavramlar değildirler ve atomların, hücreler gibi canlı olabilme özelliği yoktur.

Fatma:

Hücre canlı varlıkların en küçük yapı taşı iken; atom cansız maddelerin en küçük yapı taşıdır. Ağaçlar, insanlar hücrelerden oluşurken; kalem, defter, gibi maddeler ise atomlardan oluşur. Atomların hareket halinde olmaları onların canlı olduklarını gösterir.

Hakan:

Atomlar ve hücreler, canlı ve cansız tüm varlıkların en küçük yapı taşlarıdır. Atomlarla hücrelerin boyutu neredeyse aynıdır. Canlılarda bulunan atomlar tıpkı hücreler gibi canlı olabilme özelliğine sahip iken, cansızlarda bulununan atomlar ise cansızdır.

Ahmet, Fatma ve Hakan'ın verdiği yanıtları okudunuz. Verilen yanıtları dikkate alarak aşağıda yer alan soruları lütfen cevaplandırınız.

<u>***Aşağıda yer alan 1., 2. ve 3. numaralı soruları bireysel olarak sizlere belirtilecek olan süre içerisinde yanıtlayınız.**</u>

1. Sibel 'in arkadaşlarından kimin verdiği yanıtın tümüyle doğru olduğunu düşünüyorsunuz? (İddia)

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2. İlk soruya verdiğiniz cevabın doğru olduğunu size düşündüren şey nedir? Yani, hangi verilere dayanarak iddianızı söylüyorsunuz? Lütfen açıklayınız. (Veri)

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3. İddianızı desteklerken yukarıdaki verileri iddianıza dayanak olarak kullanmanızdaki gerekçeleriniz nelerdir? Yani, iddianız ve veriniz arasındaki ilişkiyi, gerekçenizi yazınız. (Gerekçe)

Soruyu yanıtlarken sizlere verilen delil kartlarını gerekçenizi belirlemek amacıyla kullanabilirsiniz. Ayrıca, kendi delil kartlarınızı fen bilimleri ders kitabınızdaki bilgileri ve defterinizde yer alan bilgileri kullanarak oluşturabilirsiniz. Oluşturduğunuz bu delil kartlarını gerekçenizi belirtmek amacıyla kullanılabilirsiniz. Dikkat😊 Tüm delil kartlarını kullanmak zorunda değilsiniz.

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*Şimdi dört kişilik birer grup haline geliniz ve 1.,2. ve 3. soruya verdiğiniz yanıtlar doğrultusunda; **iddianız- veriniz- gerekçenizden oluşan argümanlarınızı** grup arkadaşlarınızla sizlere belirtilecek olan süre içerisinde paylaşarak açıklayınız.

4. Fikirlerinizi grup arkadaşlarınızla paylaştıktan sonra, sizinle aynı düşüncede olmayan kişilerin düşüncelerinin neler olduğunu yazarak açıklayınız.

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*Şimdi fikir birliği sağlayarak ortak bir grup kararı almaya çalışınız ve sizlere verilen “Grup Kararımız” adlı formu, sizlere belirtilecek olan süre içerisinde, grup yazıcısı olarak görevlendirilen kişi tarafından doldurulsun.

** Unutmayınız 😊 Fikir birliği sağlamak zorunda değilsiniz. Fikir birliği olmadığında grubunuzdaki farklı düşüncelerin tamamını **Grup Kararımız** adlı bölüme yazınız.

Grup sözcüsü olan arkadaşınız, grup kararınızı diğer gruplarla paylaşsın. Artık Büyük sınıf tartışması için hazırsınız 😊

5. Fikirlerinizi sınıf arkadaşlarınızla sınıf tartışması sırasında paylaştıktan sonra, fikirlerinizde herhangi bir değişiklik olduysa; değişen fikirlerinizin neler olduğunu açıklayınız. Yani, konu ile ilgili dersin başında var olan düşüncelerin ile dersin sonunda oluşan düşüncelerini karşılaştırarak, gerçekleşen düşünce değişimini yazınız.

Ek olarak, derse başlamadan önce konu ile ilgili neler biliyordun? Dersin sonunda konu ile ilgili neler öğrendin? Lütfen yazınız 😊

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Grup Kararımız

Grup Adı:

Grup Üyeleri:

Bizler, ……………… adlı kişinin verdiği tüm yanıtların doğru olduğunu iddia ediyoruz. Çünkü;

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Diğer gruplar, bizim grubumuzun görüşünden farklı olarak ……………………………………………… adlı kişi veya kişilerin verdiği tüm yanıtların doğru olduğunu iddia edebilir.

Bizler görüşümüze karşı olan bu iddialara katılmıyoruz. Bu düşünceye sahip olan kişilerin düşüncelerini çürütmek ve onları ikna edebilmek amacıyla şu gerekçeleri ifade edebiliriz;

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DELİL KARTLARI

Canlı ve cansız tüm maddelerin en küçük yapı taşına atom adı verilir.	Canlı varlıkları cansız varlıklardan ayıran en önemli özellik; canlı varlıkların cansız varlıklardan farklı olarak hücresel bir yapıya sahip olmalarıdır.
Canlıların, canlı olabilme özelliğine sahip en küçük yapı taşı hücredir.	Evrende var olan tüm maddeler atomların bir araya gelmesi sonucu oluşur.
Robert Hooke mikroskop altında hücreyi ilk gözlemleyen bilim insanıdır.	Çok küçük boyutta olan atomlar ışık mikroskobu altında gözlenemezler.
Kendi Delilin:	Atomların bir araya gelerek karmaşık yapılar oluşturması sonucunda hücreler meydana gelir.
Kendi Delilin:	Maddeyi oluşturan atomlar titreşim, öteleme ve dönme hareketi olmak üzere çeşitli hareketler yaparlar.

D. EXAMPLE of LESSON PLAN

ARGÜMANTANSYON ORTAMI SAĞLAYAN STRATEJİLER İLE GELİŞTİRİLMİŞ DERS PLANI -I-

Ders:	Fen Bilimleri
Sınıf Seviyesi:	7. sınıf
Ünite/ Konu:	F.7.4. Saf Madde ve Karışımlar/ F.7.4.1. Maddenin Tanecikli Yapısı
Etkinliğin Adı:	En Küçük Birimi Buluyoruz!
Kullanılan Strateji:	Karikatürlerle Yarışan Teoriler
Tavsiye Edilen Uygulama Süresi:	Bir Ders Saati (40 ')

Kazanımlar;

Dersin sonunda öğrenciler,

1. Atom kavramını açıklar.
2. Atomların canlılık özelliğinin olmadığını belirtir.
3. Atom boyutu ve hücre boyutu arasındaki farkı söyler.
4. Canlı varlıkları, cansız varlıklardan ayıran özelikleri açıklar.

Ön Bilgiler;

- Hücre kavramının tanımını açıklama (F.7.2.1. Hücre)
- Hücre-doku-organ-sistem-organizma ilişkisini açıklama (F.7.2.1. Hücre)

Olası Kavram Yanılgıları;

Taneciklerin canlı olmaları (Animizm) Kavram yanılgıları;

1. Tüm atomlar canlıdır (Griffths ve Preston, 1992; Özalp,2008).
2. Canlılarda var olan atomlar canlı iken (Meşeci ve diğerleri, 2013), cansızlarda var olan atomlar cansızdır (Griffths ve Preston, 1992; Özalp,2008; Sarı, 2014; Akman, 2019).
3. Atomların hareket edebilme özellikleri vardır; bundan dolayı atomlar canlıdır (Griffths ve Preston, 1992; Canpolat ve diğerleri, 2004, s.380).
4. Hücrelerin canlı olması gibi atomlarda canlıdır (Harrison ve Treagust, 1996).
5. Atom cansız maddelerin en küçük yapı birimi, hücre ise canlı varlıkların en küçük yapı birimidir (Pideci, 2002).

Taneciklerin Boyutu ile ilgili Kavram Yanılgıları;

6. Atomlar boyut olarak hücre gibi küçük yapılar kadardır (Lee ve diğerleri, 1993).

Ders Materyalleri;

- *"En Küçük Birimi Buluyoruz!" Etkinlik Kâğıdı:* Her bir öğrenciye dağıtılan etkinlik kağıdının amacı, öğrencilerin sınıf içi argümantasyon sürecini kolay bir şekilde takip edebilmelerini ve iddialarını, verilerini, gerekçelerini, olası karşıt iddiaları ve çürütücülerini genel sınıf tartışması öncesinde yazılı bir şekilde etkinlik kağıdına aktararak sınıf tartışması için ön hazırlıklarını tamamlarını sağlamaktır. Etkinlik kâğıdı içerisinde öğrencilerin yazılı bir şekilde bir argümanı yapılandırmalarına olanak sağlayan sorular yer almaktadır.
- *"Delil Kartları":* Her bir öğrenciye dağıtılan delil kartlarının amacı, öğrencilerin oluşturdukları iddialara temel ve dayanak oluşturmasını sağlamaktır. Delil kartları öğrencilerin iddialarını desteleyerek onların

gerekçelerini tartışma ortamında sunmalarını olanak tanır. Delil kartları içerisinde yer alan ifadeler, "En Küçük Birimi Buluyoruz!" adlı etkinlik kağıdında yer alan üç farklı karikatürün ifadesi şeklinde sunulan teorilerden birini ve her ikisini destekleyen, her üçünü de desteklemeyen yapıdadır.

Teknolojik Materyaller;

- *Akıllı Tahta:* Öğretmenin ders süresi boyunca, *"*En Küçük Birimi Buluyoruz!" adlı etkinlik kağıdını tüm sınıfa yansıtması amacıyla kullanılır. Bu durum tüm öğrencilerin etkinlik kağıdındaki yönergeleri daha kolay bir şekilde takip edebilmelerine olanak sağlar. Ayrıca sürenin ders boyunca kolay bir şekilde yönetilmesi amacıyla kullanılan zamanlayıcının tüm sınıfa gösterilmesi için kullanılır.
- *Zamanlayıcı:* Öğrencilerin argümantasyon sürecinde kendilerinden beklenilen görevleri yerine getirmeleri için onlara tanılan süreyi kolayca kontrol altına alabilmelerini ve öğretmenin zamanı iyi bir şekilde yönetmesini sağlar. (https://tr.piliapp.com/timer/countdown/#pause=1797384,all=00:30:00)

Öğretim Yöntem ve Teknikleri;

- Argümantasyon Destekli Öğretim Yöntemi

ÖĞRETİM SÜRECİ

1. Derse Hazırlık

Öğretmen derse giriş yapmadan önce, öğrencilerin argümantasyon süreci boyunca katılım gösterecekleri grupları belirler. Sınıf mevcudu dikkate alınarak, her biri dörder kişilik dört grup ve bir tane üç kişilik grup kendi içlerinde fen bilimleri dersi akademik başarısına göre heterojen ve diğer gruplarla homojen olacak şekilde oluşturulur, grup numarası ve grup üyeleri şeklinde bir ön liste hazırlanır. Her bir grubun grup sözcüsü ve grup yazıcısı belirlenir. Bu belirlemeler tüm etkinlikler süresince her bir öğrencinin görev alacağı şekilde yeniden oluşturulur. Öğretmen, hazırlanan bu ön liste, öğrencilere dağıtılacak etkinlik kağıtları ile birlikte derse giriş yapar.

2. Giriş

Öğretmen sınıfa giriş yapar ve öğrencilerini selamlar. Ardından, öğrencilerin "hücre" konusunda var olan ön bilgilerini ortaya çıkarmak amacı ile soru-cevap yöntemini kullanarak öğrencilere; *"Hüre nedir?", "Hücreyi nasıl tanımlarsınız?"* ve *"Hücre-doku-organ-sistem-organizma ilişkisini hatırlıyor musunuz?", "Hücrelerden daha küçük şeyler var mıdır?"* şeklinde sorular yöneltir. Ortaya çıkarılması planlanan ön bilgiler *"En Küçük Birimi Buluyoruz!"* etkinliğinin ilk sayfasında yer almaktadır. Öğretmen bu ön bilgiler hakkında öğrencileri güdüledikten sonra, öğrencilere *"Maddenin Tanecikli Yapısı"* konusuna geçiş yapacaklarını söyler. İlk başta hücre ve maddenin tanecikli yapısı arasında ilişki kuramayan öğrencilerin bu aşamada meraklandırılarak, derse motive olmaları hedeflenir.

3. Gelişme;

Öğretmen, öğrencilerine dersi argümantasyon odaklı bir şekilde işleyeceklerini söyler. Öğretmen akıllı tahta yardımı ile etkinlik kağıdını ekrana yansıtır ve her bir öğrenciye etkinlik kâğıdı dağıtılır. Ardından öğrenciler, önceden öğretmen tarafından belirlenen grup düzenine göre argümantasyon süreci boyunca bağlı kalacakları gruplara göre yerleştirilir.

Etkinlik kağıdına başlanılmadan önce öğrencilere argümantasyon süreci boyunca uymaları gereken kurallar hatırlatılır. Bunlar;

- *Kendi grubunuz ile çalışınız.*
- *Bireysel veya grup içi yapılan etkinlik kâğıdı doldurma işlemlerinde sessiz olunuz ve diğer kişilerin dikkatini dağıtacak herhangi bir gürültüden kaçınınız.*
- *Sizlere verilen etkinlik kağıdında yer alan tüm soruları eksiksiz bir şekilde doldurmaya çalışınız.*

- *Etkinlik kağıdını doldururken zorlandığınız yerlerde öğretmenden yardım isteyiniz.*
- *Grup halinde çalışma yaparken, grup içi iletişime tüm grup üyelerini dahil ediniz.*
- *Sınıf tartışması sırasında, grup sözcüleriniz ile birlikte tartışmaya katılım göstermek ve müdahalede bulunmak isterseniz lütfen parmak kaldırınız.*

a. ***Bireysel Çalışma Süreci:***

<u>Bireysel çalışma sürecinde öğrencilere toplam 5'-7' süre tanılır.</u>

Süre, akıllı tahtaya yansıtılan zamanlayıcı ile kontrol edilir.

Öğretmen, öğrencilerin etkinlik kağıdının 1. ve 2. sayfasını okumalarını söyler. Ardından, öğretmen etkinlik sayfasında yer alan 1.,2. ve 3. soruları öğrencilerden bireysel olarak cevaplandırmalarını ister. Bu aşamada her bir öğrenciye delil kartları dağıtılır. Öğretmen, öğrencilerin iddia- veri- gerekçe ögelerini içeren bireysel argümanlarını oluşturmaya çalıştığı sırada, gruplar arası gözlem yapar ve süreç içerisinde zorlanan öğrencileri cesaretlendirmek ve yardım edebilmek adına, gerekli rehberliği yerine getirir. Örneğin, gerekçesini yazmada zorlanan bir öğrenciye "Argümantasyon Nedir? Öğreniyorum" adlı etkinlikte öğrencinin daha önce görmüş olduğu bir argümantasyon örneğindeki gerekçeyi söyleyerek, bir gerekçenin nasıl oluşturulması gerektiği hakkında öğrenciye örnek bir model sunabilir. Ayrıca, öğretmen, öğrencilere delil kartlarında yer alan ifadelerin hepsinin kullanılma zorunluluğunun olmadığını ve ihtiyaç duymaları halinde Fen Bilimleri ders kitabını kendi delillerini, gerekçelerini oluşturmaları için kullanabileceklerini ifade eder.

**Bireysel çalışma süreci sonunda oluşabilecek örnek öğrenci argümanı; Canlı ve cansız tüm maddelerin en küçük yapı taşı atomdur. Hücrenin, insanın ve defterin en temel birimi atomdur. Atom ve hücre aynı kavramlar değildirler ve atomların, hücreler gibi canlı olabilme özelliği yoktur (Veri). Bu yüzden, Ahmet'in verdiği yanıtın tümüyle doğru olduğunu düşünüyorum (İddia). Çünkü; evrende var olan tüm maddeler atomların bir araya gelmesi sonucu oluşur, Canlı varlıkları cansız varlıklardan ayıran en önemli özellik; hücresel bir yapıya sahip olmasıdır ve canlıların, canlı olabilme özelliğine* *sahip en küçük yapı taşı hücre iken atom tüm maddelerin en küçük yapı taşıdır (Gerekçe).*

b. *Grup Kararının Alınma Süreci:*

Grup kararının alınma süreci için öğrencilere toplam 7'-10' süre tanılır.

Süre, akıllı tahtaya yansıtılan zamanlayıcı ile kontrol edilir.

Öğretmen, soruların bireysel olarak yanıtlanmasından sonra öğrencilerin oluşturdukları argümanları grup arkadaşlarıyla paylaşmalarını söyler. Bu aşamada, öğrencilerden kendilerinden farklı olan düşünceleri etkinlik kağıdına yer alan 4. soruya aktarmaları istenilir.

Ardından her bir gruba "Grup Kararımız" adlı form dağıtılır. Öğrencilerden, grup içi farklı düşünceleri tartışarak, tüm grubu temsil eden bir argüman oluşturmaları istenilir. Böylece öğrencilerin tartışmada fikir birliği sağlanarak anlaşmaya varılabileceğinin farkına varmaları sağlanır. Formun grup sözcüsü tarafından doldurulması gerekliliği ifade edilir. Grup sözcüsünün kim olduğu her bir grup için öğretmen tarafından söylenir. Ayrıca, öğrencilere her bir çalışmada bu rolün değişime uğrayacağı açıklanır. Bu aşamada, öğretmen grupları gözlemleyerek, grup içi tartışmanın gerçekleşemediği veya duraksadığı gruplara gider ve herhangi bir yönlendirmeden bulunmaksızın sadece öğrencileri tartışmanın içerisine dahil etmek amacıyla her bir öğrenciye;

- *Neden bu şekilde düşünüyorsun?*
- *İddianı destelemek için hangi delil kartlarından faydalandın? Neden?*
- *Not ettiğin farklı görüşlere karşı, kendi fikrini savunabilmek için neler söyleyebilirsin?*
- *Not ettiğin farklı görüşlerin geçerli olmadığı durumlar var mıdır? Onları ne söyleyerek çürütebilirsin?* gibi çeşitli sorular yöneltir.

c. *Grup Kararlarının Açıklanması ve Sınıf Tartışmasının Başlama Süreci:*

Grup Kararlarının Açıklanması ve Sınıf Tartışmasının Başlama Süreci için öğrencilere toplam 10'-15' süre tanılır.

Süre, akıllı tahtaya yansıtılan zamanlayıcı ile kontrol edilir.

Grup kararımız adlı formlar her bir grubun yazıcısı tarafından doldurulduktan sonra, grup sözcüsü olarak görevlendirilen her öğrenci sırası ile kendi gruplarının kararlarında yer alan iddia ve gerekçelerini diğer gruplar ile paylaşır.

Grup tartışmasının başlaması ile birlikte öğretmen, grup sözcülerinden kendi grup argümanlarını desteklemek ve olası karşı argümanları çürütmek amacıyla Grup Kararımız adlı formda yazdıkları ifadeleri kullanabileceklerini söyler. Bu süreçte grup sözcüsüne destek vermek isteyen diğer grup üyelerine söz hakkı tanınır. Eğer grupların nedenleri/gerekçeleri arasında ciddi oranda bir farklılık varsa, öğretmen gruplar arası bu farklılığın öğrenciler tarafından fark edilmesini sağlamak için "*Bu grubun görüşleri diğer grubun görüşlerinden nasıl farklıdır?* veya *"Bu grubun gerekçesi diğer grubun gerekçesinden nasıl farklıdır?"* şeklinde tüm sınıfa sorular yöneltir.

4. Sonuç

Dersin sonuç kısmının tamamlanması için tavsiye edilen süre 5 ' dır.

Sınıf tartışması sonlandırıldıktan sonra öğretmen öğrencilerde var olabilecek kavram yanılgılarını da dikkate alarak tüm konuyu toparlar. Öğretmenin amacı olası tüm kavram yanılgılarını çürütecek bir ders bitimi sağlamaktır. Bu aşamada öğretmenin örnek konuşma metni;

Evet sevgili çocuklar, tartışma sonucundan da anlayabileceğiniz üzere Ahmet'in Sibel'e verdiği yanıt bilimsel açıdan doğru kabul edebileceğimiz yanıttır. Çünkü, canlı ve cansız tüm varlıkların en temel birimi/yapı taşı atomdur ***(kazanım-1)****. Evrende var olan tüm varlıklar, hücre dahil, atomların bir araya gelmesi sonucu oluşur* ***(kavram yanılgısı-5)****.*

Yani, hücrelerin oluşumunda bile atomların bir araya gelerek farklı yapılar oluşturması söz konudur. Hücre; bir canlının canlılık özelliği gösteren yani canlı olan en küçük yapı birimi olarak tanımlandırılır. Atom ise; tüm varlıkların/ tüm maddelerin en temel birimidir ***(kavram yanılgısı-5)****. Ayrıca, bir hücrenin boyutu bir atomun boyutuna oranla milyonlarca kat daha büyüktür. Atomlar o kadar küçüktür ki mikroskoplarla dahi gözlenemezler* ***(kazanım-3; kavram yanılgısı-6)****. Bir varlığı canlı olarak tanılandırabilmemiz için o varlığın hücresel bir yapıya sahip olması*

gereklidir ***(kazanım-4)****. Hareket halinde olması bir varlığın canlı olarak nitelendirilmesi için yeterli bir dayanak değildir. Bu sebeple, atomların hareket edebilmelerine karşın canlı olarak nitelendirilemezler* ***(kavram yanılgısı-1; kavram yanılgısı- 3; kazanım-2).*** *Atomların ait oldukları varlıkların canlı veya cansız olması bu durumu değiştirmez* ***(kavram yanılgısı-2)****. Çünkü, hiçbir varlığın canlılık özelliği ait olduğu canlıya göre değil, kendi barındırdıkları özelliklere göre belirlenir.*
Bu bağlamda hücreler zaten hücresel bir yapı olduklarından canlılık özelliğini gösterirler, ancak hücreleri oluşturan atomlar cansızdırlar ***(kavram yanılgısı-4)****.*

**Öğretmenin süreç sonunda yukarıda yer alan her bir ifadesinin hangi kavram yanılgısı üzerinden gerçekleştiğini gösterebilmek adına (kavram yanılgı- numara) şeklinde belirteçler kullanılmıştır. Sınıf tartışması sürecinde öğrencilerin oluşturdukları gerekçe ve dayanaklar, dersin kazanımlarına yönelik bir eğilim gösterecektir. Aynı zamanda öğretmen dersi toparlarken kullanacağı metinde öğrencilerin kazanımları yeniden duymasına olanak sağlar. Kazanım – numara şeklinde yer alan belirteçler, ait olduğu cümlenin hangi kazanıma yönelik olduğunu belirtmek için kullanılmıştır.*

Ardından öğrencilerin, argümantasyon süreci içerisinde öğrendikleri bilgileri kayıt altına alarak farkına varmalarını sağlamak amacıyla, etkinlik kağıdında yer alan 5. sorunun evde doldurularak En Küçük Birimi Buluyoruz! Etkinlik kâğıdı ve Grup Kararımız adlı dokümanların öğretmene bir sonraki derste teslim edilmesi istenir.

5. Değerlendirme

Öğrencilerin argümantasyon süresince oluşturdukları tüm argümanlar, öğrencilerin ders süresince konu ile ilgili düşüncelerinin neler olduğu hakkında öğretmene bilgi verir. Öğrencilere ev ödevi formatında verilen etkinlik kağıdının 5. Sorusunun cevaplanması ile birlikte öğrencilerin dersin başlangıcında ve ders sonunda oluşan bilgi değişiminin incelenmesi, öğretmenin öğrencilerdeki olası kavramsal değişimi hızlı bir şekilde değerlendirmesini sağlar. Ayrıca, öğrencilerden geri alınan etkinlik kağıtlarına ve grup kararımız dokümanlarına verilen tüm cevaplar, süreç boyunca öğrencilerde gerçekleşen kavramsal değişim hakkında öğretmenin detaylı bir değerlendirme yapmasına olanak tanır.

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E. TEACHER INFORMATION FORM

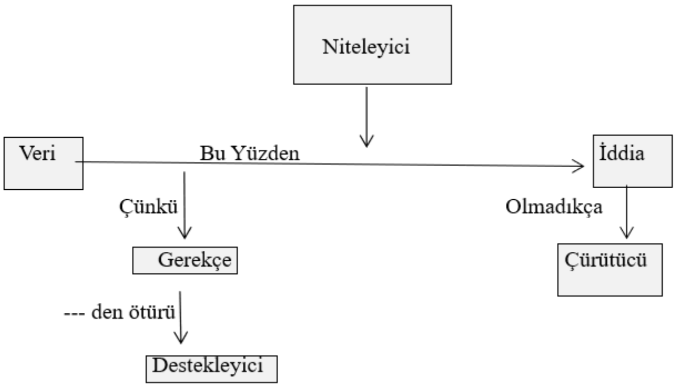
Argümantasyon ve Argümantasyon Ortamı Sağlayan Stratejiler Üzerine Uygulayıcı Öğretmen Bilgilendirme Materyali

Argümantasyon, aynı veya farklı düşünce yapılarına sahip kişilerin, bir araya gelerek, bir problemin çözümü, bir olgunun anlamlandırılması, bir konunun karara bağlanması veya bilimsel konular üzerine gerçekleştirilen düşüncelerin değerlendirilmesi, eleştirilmesi ve desteklenmesi amacıyla ifade edilen farklı bakış açılarının değerlendirilme süreci olarak tanımlandırılır (Kuhn,1991). Bir başka ifade ile, argümantasyon, bireylerin bir durum, konu veya problemin çözümü hakkında fikirler yürüterek iddia öne sürmeleri, öne sürdükleri iddiaları destekleyecek nedenler kullanarak, fikirlerinin doğru olduğunu diğer kişilere ispat etme sürecidir (Jime´nez Aleixandre ve Erduran, 2007).

Argümantasyon bir önermeyi doğrulayan ya da çürüten önermeler kümesi ve bir bakış açısının kabul edilmesi ile sonlanan sözlü, yazılı ve rasyonel etkinliktir (van Eemeren ve Grootendorst ,2004). Argüman ise, bir fenomenin ya da konunun güçlü kısımlarını vurgulayarak açığa çıkarmak ve diğer bireyleri buna ikna etmek amacı ile ileri sürülen tüm ifadelerdir (Erduran vd.,2009).

Toulmin (2003) ‘e göre bir argümanın yapısında yer alan ögeler; iddia, veri, gerekçe, destekleyici, çürütücü ve niteleyicidir. İddia, veri, gerekçe, destekleyiciye katkı sunan ifadeler argüman, tüm bu ögelerin bir araya toplanılma süreci ise argümantasyondur (Simon, Osborne ve Erduran, 2003).

Toulmin argüman modelinde yer alan ögeler ve aralarındaki ilişki;



Toulmin Argüman Modeli (2003, s. 97)

İddia: Bir konu, fikir ya da düşünce hakkında öne sürülen fikirdir.

Örneğin; Harry İngiliz vatandaşıdır

Veri: İddiayı desteklemek için kullanılan gerçeklerdir.

Örneğin: Harry Bermuda' da doğmuştur.

Gerekçe: Veri ile iddia arasındaki ilişkiyi açıklayan ifadelerdir. Verinin öne sürülen iddiayı hangi şekilde desteklediğini açıklar.

Örneğin: Bermuda'da doğan bir adam genellikle Britanya vatandaşı olacaktır.

Destekleyici: Gerekçenin yetersiz kaldığı durumlarda, veriyi desteklemek amacıyla kullanılan ifadelerdir.

Örneğin: İngiltere'nin en az göç alan yeri Bermudadır.

Çürütücü: İddianın geçerli olmadığı durumları açıklamak için kullanılan görüştür.

Örneğin: Harry'nin ailesi yabancı veya sonradan İngiliz vatandaşı olmuş olabilirler.

Niteleyici: İddianın doğruluğunun derecelendirilmesidir. *İmkânsız, büyük olasılıkla* gibi ifadeler örnek verilebilir (Toulmin, 2003, s. 97; Simon vd., 2006)

Bir argümanın temel bileşenleri; iddia, veri ve gerekçe ögeleridir. Daha kompleks argümanlar ise tüm bileşenleri içerir (Osborne, Erduran ve Simon, 2004).

Argümantasyonun sınıf içerisinde sağlanabilmesi için bazı stratejiler bulunmaktadır. Gerçekleştirilecek olan bu çalışmada kullanılacak olan argümantasyon ortamı sağlayan stratejiler ve tanımlamaları şu şekildedir;

İfadeler Tablosu: Belirlenen fen konusu ile ilgili öğrencilere bazı ifadeler tablo şeklinde sunularak, öğrencilerin her bir ifadeye katılıp katılmadığı üzerine tartışma gerçekleştirilir

Karikatürlerle Yarışan Teoriler: Öğrencilere iki ya da daha fazla zıt teorileriler, karikatür diyalogları şeklinde sunulur. Hangi karikatür karakterinin teorisini doğru buldukları ve neden bu şeklide düşündükleri tartışma ortamında açığa çıkarılır.

Fikirler ve Kanıtlarla Yarışan Teoriler: Öğrencilere iki ya da daha fazla teori verilir. Bu teorilere ek olarak, teorilerden birini, ikisini ya da hiçbirini destekleyen veya desteklemeyen kanıtlar verilir. Öğrencilerden her bir kanıtın önemini tartışarak, teori içerisindeki rolünün tartışılması istenir (Osborne, Erduran ve Simon, 2004).

Tahmin Et – Açıkla- Gözle- Açıkla: Öğrencilere bir olayı göstermeden önce, olay başlamadan önce neler olacağına dair tahminlerde bulunulması istenir. Ardından, öğretmen olay öğrencilerle paylaşılır ve öğrencilerden olay öncesi tahminleri ile olayı gördükten sonraki gözlemleri arasındaki tutarlılığın ifade edilmesi istenir (White ve Gunstone ,1992)

Bir Argümanı Yapılandırma: Öğrencilere "Dünyanın kendi ekseni etrafında dönmesi sonucu gece ve günüz ortaya çıkar" şeklinde bir olayın açıklaması ve olay ile ilgili bazı veriler sunulur. Öğrencilerden, en iyi verinin seçilerek, neden bu şekilde seçim yaptıklarına dair düşüncelerini tartışma ortamında sunmaları istenir (Osborne, Erduran ve Simon, 2004).

Modellerle Tartışma: Öğrencilerin bir kavram üzerine çizdikleri modellerin, neye göre tasarlandığına dair düşüncelerini tartışma ortamında sunulması istenir (Osborne, Erduran ve Simon, 2004).

Delil Kartları: Öğrencilere bir konu hakkında iki veya daha fazla iddia verilir. Öğrencilerin, verilen iddiaları kanıtları için bazı delil kartları hazırlanır. Öğrenciler, seçtikleri delil kartlarının iddiayı nasıl doğruladığına yönelik düşüncelerini ifade ederler. Kanıtlar ve iddialar arasında gerekçelendirmeler ifade edilir (Osborne, Erduran ve Simon, 2004).

Yukarıda belirtilen argümantasyon ortamı sağlayan stratejilerin, detaylı bir şekilde uygulayıcı öğretmen tarafından sınıf içerisine nasıl entegre dileceği, ders planlarında araştırmacı tarafından ayrıntılı bir şekilde açıklanmıştır.

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F. LESSON OBSERVATION FORM

Argümantasyona Yönelik Ders Gözlem Formu

No	Argümantasyona Yönelik Ders Gözlem Formu Maddeleri	HİZ	N	BB	SS	HZ
1.	Öğretmen, dersin başlangıcında yaptığı konuşmalarla öğrencilerde konu ile ilgili merak uyandırmaktadır.					
2.	Öğretmen yönelttiği sorularla sınıfta tartışma yapılmasına olanak sağlamaktadır.					
3.	Öğretmen, öğrencilere meraklarını, araştırma için yönetilebilir sorulara odaklayabilecekleri gösterimler sağlayabilmektedir.					
4.	Öğretmen dersin başlangıcında öğrencilerin konuyla ilgili bir iddia oluşturmaları için gerekli süreyi tanımaktadır.					
5.	Öğretmen öğrencilerin yönelttiği tüm iddialara hoşgörü ve sabırla yaklaşmaktadır.					
6.	Öğretmen, tartışma sürecinde karşıt iddiaların oluşması için öğrencileri yönlendirmektedir.					
7.	Öğretmen öğrencilerin iddialarını veri ve akıl yürütmelere dayandırmalarını istemektedir.					
8.	Öğrenciler oluşturdukları akıl yürütmelerde kaynak göstererek bilimsel bir dil kullanmışlardır.					
9.	Öğretmen, öğrencilerin sorularını cevaplamak için gerekli uygun veriyi toplamaları için teşvik etmektedir					
10.	Öğretmen öğrencilerin iddialarını destekleyecek ya da çürütecek materyalleri sınıf ortamında kullanmakta, öğrencilerin de kullanımını sağlamaktadır					
11.	Öğretmen, öğrencilerin analiz süreci boyunca kullanmaları ve bir veri seti oluşturmaları için bir eğitim aracı olarak çalışma yapraklarından ve/veya ders planlarından yararlanmaktadır.					
12.	Öğretmen, öğrencilerin kanıt elde edebilmelerini sağlayıcı gözlem ve ölçümler yapmalarına yardımcı olmaktadır.					
13.	Öğretmen öğrencilerin iddialarını destekleyecek veri elde etmelerinde öğrencilere yardımcı olmaktadır					
14.	Öğretmen tartışma ortamlarında öğrencilere rehberlik etmektedir.					
15.	Öğretmen tartışma ortamlarında farklı düşüncelere karşı tarafsız davranmaktadır.					
16.	Öğretmen tartışma gruplarına tüm öğrencilerin katılımını sağlamaktadır.					
17.	Bir öğrenci düşüncelerini ifade ederken diğer öğrenciler de onu dikkatle dinlemektedir					
18.	Öğretmen geçerliği kabul edilmeyen iddiaların kabul edilmeme gerekçelerini öğrencilere açıklar					
19.	Öğrencilerin düşünceleriyle ilgili öğretmenin yaptığı açıklamalar üzerine öğrenciler düşüncesini savunmaya devam etmektedir.					
20.	. İddiası çürütülen öğrenci karşı iddiaya katıldığına yönelik ifadelerde bulunmaktadır.					
21.	Öğretmen, öğrencilerden bilimsel olarak kabul edilmiş fikirler hakkında ön bilgilerini kullanarak kendi kendilerine açıklamalar yapmalarını beklemektedir					
22.	Öğretmenin rehberlik ettiği tartışma süreci sonucunda, kuram ve hipotezlere öğrenciler kendi kendilerine ulaşmaktadır.					
23.	Öğretmen, öğrencilerin yeni kazandığı bilgiyi küçük ve/veya geniş grup tartışmalarında savunmalarını beklemektedir.					
24.	Öğretmen, öğrencilerden araştırmalarını daha fazla geliştirmek için internet tabanlı kaynakları ve diğer materyalleri kullanmaları gerektiğini belirtmektedir.					

B: Bazen, SS: Sık sık, HZ: her zaman, N: nadiren, HİZ: hiçbir zaman

G. PARENT PERMISSON FORM

Veli Onay Formu

Sevgili Veli,

Bu çalışma Orta Doğu Teknik Üniversitesi Fen Bilimleri Eğitimi Bölümü Tezli Yüksek Lisans öğrencisi Hacer Mutluer tarafından yürütülmektedir.

Bu çalışmanın amacı nedir? Çalışmanın amacı, 7. Sınıf öğrencilerinin "Maddenin Tanecikli Yapısı ve Çözünme" konusundaki kavram yanılgılarını tespit ederek, bunları ontoloji temelinde kategorileştirmek ve ardından Argümantasyon Stratejileri ile geliştirilen sınıfsal etkinlikler ile gidermeye çalışmaktır.

Çocuğunuzun katılımcı olarak ne yapmasını istiyoruz? Bu amaç doğrultusunda, çocuğunuzdan Fen Bilimleri Öğretmenleri tarafından dağıtılan ve içeriğinde molekül, iyon, bileşik, atom ve çözünme kavramlarını içeren "Maddenin Tanecikli Yapısı Kavram Testi" içerisinde yer alan çoktan seçmeli soruları araştırmanın ilk haftası ve son haftası yazılı olarak cevaplandırmalarını isteyeceğiz ve cevaplarını yazılı biçiminde toplayacağız. Sizden çocuğunuzun katılımcı olmasıyla ilgili izin istediğimiz gibi, çalışmaya başlamadan çocuğunuzdan da sözlü olarak katılımıyla ilgili rızası mutlaka alınacak.

Çocuğunuzdan alınan bilgiler ne amaçla ve nasıl kullanılacak? Çocuğunuzdan alacağımız cevaplar tamamen gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Elde edilecek bilgiler sadece bilimsel amaçla (yayın, konferans sunumu, vb.) kullanılacak, çocuğunuzun ya da sizin ismi ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır.

Çocuğunuz ya da siz çalışmayı yarıda kesmek isterseniz ne yapmalısınız? Katılım sırasında sorulan sorulardan ya da herhangi bir uygulama ile ilgili başka bir nedenden ötürü çocuğunuz kendisini rahatsız hissettiğini belirtirse, ya da kendi belirtmese de araştırmacı çocuğun rahatsız olduğunu öngörürse, çalışmaya sorular tamamlanmadan ve derhal son verilecektir.

Bu çalışmayla ilgili daha fazla bilgi almak isterseniz: Çalışmaya katılımınızın sonrasında, bu çalışmayla ilgili sorularınız yazılı biçimde cevaplandırılacaktır. Çalışma hakkında daha fazla bilgi almak için Fen Bilimleri Eğitimi Yüksek Lisans Öğrencisi Hacer Mutluer ile iletişim kurabilirsiniz. Bu çalışmaya katılımınız için şimdiden teşekkür ederiz.

Yukarıdaki bilgileri okudum ve çocuğumun bu çalışmada yer almasını onaylıyorum (Lütfen alttaki iki seçenekten birini işaretleyiniz.

***Evet onaylıyorum*___**   ***Hayır, onaylamıyorum*___**

Annenin adı-soyadı: ______________   Bugünün Tarihi:________________

Çocuğun adı soyadı ve doğum tarihi:________________

(Formu doldurup imzaladıktan sonra araştırmacıya ulaştırınız).

H. CURRICULUM BASED LESSON PLAN

KONU: Saf Maddeler.

KAVRAMLAR: Element, elementlerin sembolleri, bileşik, bileşik formülleri

KAZANIMLAR:

F.7.4.2.1. Saf maddeleri, element ve bileşik olarak sınıflandırarak örnekler verir.

F.7.4.2.2. Periyodik sistemdeki ilk 18 elementin ve yaygın elementlerin (altın, gümüş, bakır, çinko, kurşun, cıva, platin, demir ve iyot) isimlerini, sembollerini ve bazı kullanım alanlarını ifade eder.

F.7.4.2.3. Yaygın bileşiklerin formüllerini, isimlerini ve bazı kullanım alanlarını ifade eder

DERS İŞLENİŞİ

Öğretmenin konuyu ve kavramları tanıtması

Ders kitabından gerekli bölümlerin okutulması ve deftere notlar alınması

Konu ile ilgili ders kitabında eğer varsa etkinliklerin gerçekleştirilmesi

Soru -cevap yöntemine dayalı sorular sorularak değerlendirilme yapılması

EBA üzerinden ders materyallerinin izlenilmesi ile dersin sonlandı

KONU: Karışımlar

KAVRAMLAR: Homojen karışım, çözelti (çözünen, çözücü), heterojen karışım, çözünme

KAZANIMLAR:

F.7.4.3.1. Karışımları, homojen ve heterojen olarak sınıflandırarak örnekler verir.

- Homojen karışımların çözelti olarak da ifade edilebileceği vurgulanır.

DERS İŞLENİŞİ

Öğretmenin konuyu ve kavramları tanıtması

Ders kitabından gerekli bölümlerin okutulması ve deftere notlar alınması

Konu ile ilgili ders kitabında eğer varsa etkinliklerin gerçekleştirilmesi

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EBA üzerinden ders materyallerinin izlenilmesi ile dersin sonlandırılması

**Yukarıda belirtilen şablon uygulayıcı öğretmen ile birlikte tasarlanmıştır. Şablonda yer alan konu, kavramlar ve kazanımlar 2018- FEN BİLİMLERİ DERSİ ÖĞRETİM PROGRAMI (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar) den alınmıştır.*

İ. PARTICULATE NATURE OF MATTER CONCEPT TES

Sevgili Öğrenciler;

Bu "Kavram Testi", Orta Doğu Teknik Üniversitesi Fen Bilimleri Eğitimi Yüksek Lisans Öğrencisi Hacer Mutluer' in tezinde kullanılmak üzere tasarlanmıştır. Uygulamanın amacı ortaöğretim 7. Sınıf öğrencilerinin "Maddenin Tanecikli Yapısı ve Çözünme" konularıyla ilgili düşüncelerini ortaya çıkarabilmektir. Burada belirteceğiniz yanıtlar yalnızca bilimsel araştırma için kullanılacak ve başka kişilerce paylaşılmayacaktır. Sonuçların güvenilir olması için her bir soruyu dikkatli bir şekilde okuyarak, cevaplandırmanızı rica ederiz. Hiçbir soruyu boş bırakmadan ve her bir soruya yalnızca bir cevap vermeniz oldukça önemlidir. Teste Göstermiş olduğunuz ilgi ve katkıdan dolayı teşekkür ederim.

Yönerge: Belirtilen **Maddenin Tanecikli Yapısı Kavram Testi** 17 sorudan oluşmaktadır. Her bir soru maddesi iki bölüm içermektedir. İlk bölümde, soruyu dikkatli bir şekilde okuyarak sizlere doğru gelen şıkkı cevaplanmanız gerekmektedir. İkinci bölüm olan "***Nedeni:"*** kısmında ise verdiğiniz yanıta en uygun ***nedeni*** cevap seçeneklerinden seçmelisiniz. Seçenekler içeresinde size uygun bir neden bulamadığınız durumlarda "***Hiçbiri. Bana göre sebep:"*** kısmına soruya verdiğiniz yanıtın nedenini yazmalısınız.

MADDENİN TANECİKLİ YAPISI KAVRAM TESTİ

1) Yeşil yapraklar (kopartılmamış olanlar) canlı hücrelerden oluşmakta, bu hücreler de atomlar içermektedir. Demir elementi de demir atomlarından oluşur. Buna göre;

(A) Yapraktaki atomlar canlıdır.

(B) Demirdeki atomlar canlıdır.

(C) Yapraktaki ve demirdeki atomlar cansızdır.

(D) Yapraktaki ve demirdeki atomlar canlıdır.

(E) Yaprak atomları canlı; demir atomları cansızdır

Nedeni:

1. Demirdeki atomlar hareketli oldukları için canlıdır.

2. Atomlar canlılık özelliğine sahip değildir.

3. Yaprak canlı olduğu için atomları da canlıdır.

4. Hangi tür atom olursa olsun bütün atomlar canlıdır.

5. Yaprak canlı olduğu için atomları canlı, demir cansız olduğu için atomları cansızdır.

6. Hiçbiri. Bana göre sebep:

2) Altın atomlarının özellikleriyle ilgili aşağıdaki ifadelerden hangileri doğrudur?

I. Altın atomları parlak ve serttir.

II. Altın ısıtılırsa atomları da ısınır.

III. Altına şekil verildiğinde atomları da aynı şekli alır.

IV. Altın atomlarının hacimlerinin büyük kısmı boşluktur

A) Yalnız I B) Yalnız II C) Yalnız III

D) Yalnız IV E) I, II ve III

Nedeni:

1. Altına dışarıdan yapılan her değişiklik atomlarını da aynı şekilde etkiler.

2. Atomun hacmi ile çekirdeğinin hacmi düşünüldüğünde çekirdeğin hacmi atomun hacmine göre çok küçüktür. Bu nedenle atomun geri kalan kısmı boşluktur (Atomun hacmi futbol sahası kadar düşünülürse çekirdeğin hacmi bu sahadaki top kadardır).

3. Altına ait her özellik atomlarında da bulunur.

4. Hiçbiri. Bana göre sebep:

3) Bir çay kaşığı şeker oda sıcaklığındaki bir su bardağı suya atılınca şeker suyla kimyasal bir tepkimeye girer.

(A) Doğru (B) Yanlış

Nedeni:

1. Şeker suda çözününce yeni bir bileşik oluşur
2. Şeker suda erir.
3. Şeker suda çözününce suya dönüşür.
4. Şeker suda çözününce şeker taneciklerinin etrafını su molekülleri sarar.
5. Hiçbiri. Bana göre sebep:

4) Su moleküllerile ilgili aşağıdakilerden hangisi doğrudur?

(A) Su katı haldeyken moleküllerin boyutu en büyük, sıvı haldeyken en küçüktür.

(B) Su katı haldeyken moleküllerinin boyutu en küçük, gaz haldeyken en büyüktür.

(C) Su molekülleri üç halde de aynı boyuttadır.

(D) Su sıvı haldeyken moleküllerinin boyutu en büyük, katı halde en küçüktür.

Nedeni:

1. Katıdan sıvıya, sıvıdan gaza doğru molekül hacmi artar.
2. Katıdan sıvıya, sıvıdan gaza doğru molekül hacmi hacim azalır.
3. Hal değişimiyle molekül hacmi değişmez.
4. Hiçbiri. Bana göre sebep:

5) Demir katı haldeyken atomları hareket etmez.

(A) Doğru (B) Yanlış

Nedeni:

1. Katı halde atomlar hareket etmez çünkü atomların aralarında boşluk yoktur.
2. Katı hal maddenin en düzenli olduğu hali olduğu için atomlar hareket etmez
3. Katı halde atomlar titreşim hareketi yapar.
4. Hiçbiri. Bana göre sebep:

6) Sıvılar bulundukları kabın şeklini alırlar. Bu bilgiye göre:

Su moleküllerinin şekli bulunduğu kaba göre değişir.

(A) Doğru (B) Yanlış

Nedeni:

1. Su molekülleri katı olduğu için şekli değişmez.
2. Su molekülleri esnektir.
3. Kabın şekli ne olursa olsun moleküllerin şekli değişmez.
4. Su molekülleri su damlaları şeklindedir.
5. Hiçbiri. Bana göre sebep:

7) Buz ve su molekülleri için düşünülürse aşağıdaki ifadelerden hangisi doğru olur?

(A) Buz molekülleri katı, su molekülleri sıvıdır.

(B) Hem buz hem su molekülleri katıdır.

(C) Hem buz hem su molekülleri sıvıdır.

(D) Moleküller sıvı ya da katı halde bulunmazlar.

Nedeni:

1. Maddenin katı ya da sıvı olması, molekülleri arasındaki etkileşimlerle ilgilidir.
2. Moleküller her zaman sıvı halde bulunur.
3. Buz katı olduğu için molekülleri katı, su sıvı olduğu için moleküller sıvıdır.
4. Moleküller her zaman katı halde bulunur.
5. Hiçbiri. Bana göre sebep:

8) Alkolü oluşturan en küçük tanecik alkol damlası, toz şekeri oluşturan en küçük tanecik ise şeker kristalidir.

(A) Doğru (B) Yanlış

Nedeni:

1. Şeker ve alkolün tanecikleri birbirlerinin aynısıdır.
2. Alkol, alkol moleküllerinden; şeker ise şeker moleküllerinden oluşur.
3. Şeker ve alkolün en küçük tanecikleri onların gözle görülebilen en küçük parçalarıdır.
4. Hiçbiri. Bana göre sebep:

9) Bir miktar su buzdolabında bir süre bekletildiğinde donar ve buza dönüşür. Bu olay sırasında su molekülleri.........................

I. Soğur II. Donar III. Küçülür

IV. Büyür V. Değişmez

(A) Yalnız IV (B) Yalnız V

(C) I ve II (D) I, II ve III

(E) I, II ve IV

Nedeni:

1) Donma sırasında sıcaklık azaldığı için moleküllerin de sıcaklığı azalır böylece moleküller donar.

2) Donma sırasında sıcaklık azaldığı için moleküllerin de sıcaklığı azalır böylece moleküller donar ve hacimleri azalır.

3) Donma olayı moleküllerin büyüklüğünde bir değişikliğe neden olmaz.

4) Donma sırasında sıcaklık azaldığı için moleküllerin de sıcaklığı azalır böylece moleküller soğur, donar ve hacimleri artar.

5) Su donarken hacmi artan bir madde olduğu için moleküller büyür.

6) Hiçbiri. Bana göre sebep:

10) Bir demir parçası ısı verilerek eritildiğinde demir atomları...............

I. Isınır II. Erir III. Büyür IV. Değişmez V. Küçülür

(A) Yalnız IV (B) Yalnız V (C) I ve II

(D) II ve III (E) I, II ve III

Nedeni:

1. Erime sırasında hacim azaldığı için demir atomları küçülür.

2. Erime sırasında demir ısı aldığı için atomları da ısınır böylece atomlar erir ve hacimleri artar.

3. Erime atomlarda bir değişikliğe neden olmaz.

4. Erime sırasında atomların sıcaklığı değişmez ama atomlar erir ve böylece atomların hacmi artar.

5. Erime sırasında sıcaklık arttığı için atomlar ısınır ve erir. Başka değişiklik olmaz.

6. Hiçbiri. Bana göre sebep:

11) İçinde su bulunan bir behere (ısıya dayanıklı cam kap) birkaç küp şeker konuluyor (I. durum). Şekilde gösterildiği gibi, oda sıcaklığında karışım yeteri kadar uzun bir zaman bekletilirse şeker küpleri görünmez hale gelir ve suyun şekerli bir tadı olur (II. durum).

Bu cümle doğru mudur yanlış mıdır?

(A) Doğru (B) Yanlış

Nedeni:

1. Şeker molekülleri çevreden ısı alarak erir ve bir sıvı oluşturur. Bu sıvı, su ile karışır.

2. Şeker, su içindeki hava boşluklarına dolar ve bu nedenle 'kaybolur'.

3. Su molekülleri şeker moleküllerini küplerin yüzeylerinden çevreler ve onları birbirinden uzaklaştırır.

4. Şeker küpleri sadece karıştırıldığı zaman suda çözünür. Karıştırmak, şeker küplerinin daha küçük parçalara ayrılmasına ve böylece su içinde yayılarak görülmeyecek hale gelmesine sebep olur.

5.Hiçbiri. Bana göre sebep:

12) <u>Bilgi</u>: Kükürt, sembolü S, atom numarası 16 olan ve periyodik tablonun VI A grubunda bulunan bir elementtir. Oda sıcaklığında limon sarısında bir katı olarak bulunur.

Katı haldeki bir kükürt örneği aşağıdaki özelliklere sahiptir

(I) Kırılgan, (II) Erime noktası 113°C.

Varsa, yukarıdaki özelliklerden hangisi veya hangileri örnekten alınan bir tek <u>kükürt atomu</u> için aynıdır?

(A) I ve II (B) Yalnız I (C) Yalnız II (D) Hiçbiri

Nedeni:

1. Kükürt ametaldir bu nedenle kükürt atomu nispeten daha düşük bir sıcaklıkta erir.

2. Bir elementin özellikleri bu elementin tanecikleri arasındaki etkileşimin bir sonucudur.

3. Atom, bir elementin bütün özelliklerini taşıyan en küçük taneciğidir.

4. Bir kükürt atomu, düz bir yüzeye ve keskin kenarlara sahiptir bu nedenle kükürt atomuna bir kuvvet uygulandığında kolayca kırılır.

5.Hiçbiri. Bana göre sebep:

13) Ayşe bir bardak suya iki tane küp şeker atar ve karıştırır. Elde ettiği maddenin saf bir madde olduğunu söyler. Ayşe'nin ifadesine katılıyor musun?

(A) Evet (B) Hayır

Nedeni:

1. Şeker suda çözününce yeni bir madde oluşmuştur.

2. Şekerli suyun içinde, şeker ve su özelliklerini kaybetmiştir.

3. Şeker, suda erir.

4. Şekerli suyun içinde birbirinden farklı tanecikler vardır.

5. Hiçbiri. Bana göre sebep:

14) Bir katı ısıtıldığı zaman tanecikleri büyür.

(A) Doğru (B) Yanlış

Nedeni:

1. Isınan maddenin tanecikleri de ısınır.

2. Isı, maddenin taneciklerinin genleşmesine sebep olur.

3. Isı, tanecikler arası mesafeyi etkiler, taneciklerin yapısını etkilemez.

4. Hiçbiri. Bana göre sebep:

15) Sofra tuzunu (NaCl) oluşturan en küçük tanecik, toz halindeki en küçük tuz parçasıdır.

(A) Doğru (B) Yanlış

Nedeni:

1. Tuzun en küçük taneciği onun gözle görülen en küçük parçasıdır.

2. Tuz, moleküler yapılı bir bileşik olduğundan en küçük taneciği, tuz molekülüdür.

3. Tuz, bir element olduğundan en küçük taneciği, tuz atomudur.

4. Tuz, iyonik yapılı bir bileşik olduğundan en küçük taneciği ne atom ne de moleküldür.

5. Hiçbiri. Bana göre sebep:

16) Termometrelerde kullanılan civanın en küçük taneciği bir cıva damlasıdır.

(A) Doğru (B) Yanlış

Nedeni:

1. Cıvanın en küçük taneciği, onun gözle görebildiğimiz en küçük damlasıdır.

2. Cıva bir bileşiktir, bu yüzden en küçük taneciği moleküldür.

3. Cıva, bir elementtir, bu yüzden en küçük taneciği moleküldür.

4. Civanın en küçük taneciği, cıva atomudur.

5. Hiçbiri. Bana göre sebep:

17) Sodyum klorür (NaCl) oda sıcaklığında molekül olarak bulunur.

(A) Doğru (B) Yanlış

Nedeni:

1. Sodyum atomu, klor atomuyla bir elektronunu ortaklaşa kullanarak molekül oluşturur.

2. Sodyum atomu, son katmanındaki bir elektronu klor atomuna vermek istediği için klor atomuyla bir molekül oluşturur.

3. Sodyum klorür, sodyum ve klor iyonlarından oluşan bir iyon yığını şeklinde bulunur.

4. Sodyum ve klor atomları arasındaki çengel/yay/ip benzeri fiziksel bir yapı onları bir arada tutar.

5.Hiçbiri. Bana göre sebep:

J. ETHICAL PERMISSIONS

For Lesson Observation Form

Re: TEZ ETİK İZİN

HiLAL AKTAMiS göndericisinden 2024-01-04 09:15 tarihinde

Ayrıntılar Düz Metin

Sayın Hacer Mutluer,
Tez çalışmanız kapsamında, "Argümantasyona Yönelik Ders Gözlem Formunu" kaynak göstererek kullanabilirsiniz.

İyi çalışmalar dilerim.

Hacer Mutluer < >, 3 Oca 2024 Çar, 23:25 tarihinde şunu yazdı:

> Sayın Hocam Merhaba,
> Ben Hacer Mutluer, Orta Doğu Teknik Üniversitesi Matematik ve Fen bilimleri Eğitimi Bölümü/ Fen Bilimleri Eğitimi programı yüksek lisans öğrencisiyim. Prof. Dr. Jale Çakıroğlu danışmanlığında " 7. Sınıf Öğrencilerinin Maddenin Tanecikli Yapısı ve Çözünme Konularındaki Kavram Yanılgılarının Ontolojik Açıdan Belirlenmesi ve Argümantasyon Destekli Öğretim İle Giderilmesi" üzerine tez çalışması yürütmekteyim. " Fen Bilimleri Derslerinde Kullanılan Argümantasyon Düzeyinin Belirlenmesi" adlı araştırma makalenizde yer alan "Argümantasyona Yönelik Ders Gözlem Formunu" , etik kurallar çerçevesinde kullanabilmek için sizlerden izin istemekteyim. Bu konuda yardımcı olursanız çok sevinirim. Şimdiden geri dönütünüz için çok teşekkür ederim.
>
> Saygılarımla

For the Particulate Nature of Matter Concept Test

Ynt: TEZ ETİK İZİN

Dilek ÖZALP göndericisinden 2023-10-22 12:18 tarihinde

Ayrıntılar Düz Metin

Merhaba Hacer,

Testi kullanabilirsin. Çalışmanda kolaylıklar dilerim.

Başarılar.

Dr. Ögretim Üyesi Dilek ÖZALP

Gönderen: Hacer Mutluer
Gönderildi: 20 Ekim 2023 Cuma 17:09:47
Kime: Dilek ÖZALP
Konu: TEZ ETİK İZİN

Sayın Hocam merhaba,
Ben Hacer Mutluer, Orta Doğu Teknik Üniversitesi Matematik ve Fen bilimleri Eğitimi Bölümü/ Fen Bilimleri Eğitimi programı yüksek lisans öğrencisiyim. Prof. Dr. Jale Çakıroğlu danışmanlığında " 7. Sınıf Öğrencilerinin Saf Madde ve Karışımlar Konusundaki Kavram Yanılgılarının Ontolojik Temelde İncelenerek , Argümantasyon Tabanlı Uygulamar ile Giderilmesi" üzerine tez çalışması yürütmekteyim. " İLKÖĞRETİM VE ORTAÖĞRETİM ÖĞRENCİLERİNİN MADDENİN TANECİKLİ YAPISI KONUSUNDAKİ KAVRAM YANILGILARININ ONTOLOJİ TEMELİNDE BELİRLENMESİ" adlı çalışmanızda yer alan "MADDENİN TANECİKLİ YAPISI TESTİ" adlı ölçeği, etik kurallar çerçevesinde kullanabilmek için sizlerden izin istemekteyim. Bu konuda yardımcı olursanız çok sevinirim. Şimdiden geri dönütünüz için çok teşekkür ederim.

Re: TEZ ETİK İZİN

Dr. Aylin Sarı göndericisinden 2023-10-15 14:20 tarihinde
Ayrıntılar

Merhaba Hacer Hanım,
Bahsettiğiniz testi kullanmanızı onaylıyorum.
İyi çalışmalar, sevgiler
Dr. Aylin Sarı

> Hacer Mutluer < > şunları yazdı (8 Eki 2023 21:44):
>
> Sayın Hocam merhaba,
> Ben Hacer Mutluer, Orta Doğu Teknik Üniversitesi Matematik ve Fen bilimleri Eğitimi Bölümü/ Fen Bilimleri Eğitimi programı yüksek lisans öğrencisiyim. Prof. Dr. Jale Çakıroğlu danışmanlığında " 7. Sınıf Öğrencilerinin Saf Madde ve Karışımlar Konusundaki Kavram Yanılgılarının Ontolojik Temelde İncelenerek , Argümantasyon Tabanlı Uygulamar ile Giderilmesi" üzerine tez çalışması yürütmekteyim. " Kavram Haritası ve Bilgisayar Destekli Öğretimin 7. Sınıf Öğrencilerinin Madde Konusundaki Kavram Yanılgılarına Etkisinin Ontolojik Açıdan İncelenmesi" adlı çalışmanızda yer alan "Maddenin Yapısı ve Özellikleri Kavram Testi" adlı ölçeği, etik kurallar çerçevesinde kullanabilmek için sizlerden izin istemekteyim. Bu konuda yardımcı olursanız çok sevinirim. Şimdiden geri dönütünüz için çok teşekkür ederim.