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CONTENT ANALYSIS OF STUDIES CONDUCTED BETWEEN 2007-2022 ON MISCONCEPTIONS ABOUT THE HEAT AND TEMPERATURE

Mehmet GÜLER
Science Teacher, Iskenderun General Şükrü Kanadlı Secondary School, Hatay, Turkey, alismguler84@gmail.com
ORCID: 0009-0008-5547-0161

Abdulkadir ÖZKAYA
Assist. Prof. Dr., Hatay Mustafa Kemal University, Hatay, Turkey, kayakadir78@gmail.com
ORCID: 0000-0002-6962-4597

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ABSTRACT

This study aims to provide an overview of scientific articles written in the field of misconceptions about heat and temperature in elementary science education. The study is a document analysis study. The data were analyzed by content analysis method. In this study, "Yöktez", "Google Scholar", "ERIC" and "Ulakbim" databases of national and international articles, theses and congress studies on heat and temperature between 2007 and 2022 were examined. The keywords "heat and temperature", "heat", "temperature", "misconception" and "elimination" were used to access these studies scanned in the databases. This study constitutes a compilation of 21 scientific studies that meet the specified criteria. One hundred and eighty-six misconceptions about heat and temperature were identified in the studies analyzed for the years 2007-2022. Multiple-choice tests have been widely used to identify misconceptions about heat and temperature. Recently, it is seen that open-ended questions or semi-structured interview forms are preferred along with multiple-choice tests to identify misconceptions. In the studies conducted, it was determined that conceptual change texts technique and 5E learning model were widely used in eliminating heat and temperature misconceptions. In line with the findings, it is suggested that starting concept teaching at an early age will have more positive results for the learners. It may be useful to emphasize cross-sectional, longitudinal and sequential studies on concept teaching. Including the methods and techniques used in concept teaching more in subjects with misconceptions such as heat and temperature may contribute to teaching. Similar studies can be included in subjects such as force and motion.

Keywords: Heat, temperature, misconceptions, content analysis.

INTRODUCTION

When students start school, they bring with them many concepts they have acquired from daily life. Many students attribute non-scientific and inconsistent meanings to these concepts. Such scientifically unaccepted ideas that make it difficult to learn scientific knowledge are defined as misconceptions (Clark, 2010; İşcan, 2020). In short, misconceptions are a negative factor that directly affects meaningful learning. Therefore, misconceptions are a problem that needs to be solved for teachers and students (Yavuz & Büyükekşi, 2011; Schnittka & Bell, 2011).

Students' misconceptions make it difficult to carry out science education in accordance with its achievements. Failure to learn the concepts correctly negatively affects the student's ability to establish relationships between subjects. This prevents complete learning (Köksal, 2006). For this reason, in order for the science concepts to be permanent and meaningful, students' misconceptions before the lesson should be known and the lesson should be planned accordingly (Kumlu, 2016; Kocakülah & Turan, 2019).

Yeşiltaş et al. (2017) emphasize the inadequacy of multiple-choice tests in identifying misconceptions in recent studies. It is seen that these tests mostly show students' errors due to lack of knowledge and do not fully detect misconceptions. In this context, it is concluded that not every misconception is an error and not every error is a misconception (Tamkavas et al., 2016). It has been emphasized in the studies that semi-structured interviews (Clark, 2010), three-stage tests (Turgut & Gürbüz, 2011; Yavuz & Büyükekşi, 2011), four-stage tests (Tamkavas et al., 2016) or more than one assessment tool (Aksu, 2019; Sarıkaya, 2019) should be used to determine misconceptions. For this reason, unlike the conceptual misconceptions identified superficially by multiple-choice tests, deeper conceptual misconceptions are desired. Eliminating the misconceptions identified in students is a process that will take a long time (Akgül, 2010; Aksu, 2019). Considering this process, methods in which students construct knowledge should be preferred instead of traditional methods (Damlı, 2011; Schnittka & Bell, 2011). A group of science educators and philosophers of science at Cornell University created the conceptual change model that supports students to achieve conceptual change by constructing concepts (Davis, 2001). According to the conceptual change model, conceptual change can occur when certain conditions are met. These conditions can be listed as follows (Posner et al., 1982);

1. Dissatisfaction: The learner should be dissatisfied with the concept he/she has. The student does not feel the need to change the information that he/she is not unhappy with.

2. Understandability: The concept to be given to the student should be understandable.

3. Logic: The concept should be plausible and logical.

4. Efficiency: The concept should be useful and be able to solve similar problems.

In summary, although the method and technique of identifying students' misconceptions are important, they are not sufficient to ensure concept change (Calik et al., 2008). It would be appropriate to prefer methods and

techniques based on conceptual change. If conceptual change cannot be achieved, students will carry these misconceptions with them throughout their educational life (Schnittka & Bell, 2011).

One of the most researched topics in the studies on misconceptions is "heat and temperature" (Aydın, 2007; Gürbüz, 2008; Clark, 2010; Bayram, 2010; Schnittka & Bell, 2011; Damlı, 2011; Çolak, 2016; Yeşiltaş et al., 2017; Aksu, 2019). This is a subject that students have difficulty with and find it difficult to learn. Students come to school with many ideas about heat and temperature from their daily experiences at an early age. Unfortunately, most of these concepts are wrong. Integrating these ideas with scientific concepts is often difficult for students (Clark, 2010; Schnittka & Bell, 2011).

In this study, it was aimed to reveal the misconceptions about heat and temperature identified in the studies conducted between 2007 and 2022, the methods by which these misconceptions were identified and the methods by which they were tried to be changed.

In this regard, the research questions of the study can be listed as follows:

1- What are the misconceptions about heat and temperature identified in the related studies conducted between 2007 and 2022?
2- What are the methods and techniques used to determine students' misconceptions about heat and temperature in the related studies conducted between 2007 and 2022?
3- What are the methods and techniques used to eliminate students' misconceptions about heat and temperature in the related studies conducted between 2007 and 2022?

METHOD

In general, the document analysis method, which can be used alone in cases where interviews and observations cannot be made, was preferred for the study. Document analysis method is one of the qualitative research methods used to analyze the content of written documents containing information about the topic, events and phenomena under investigation (Yıldırım & Şimşek, 2021). In the content analysis method, similar data are brought together and the relationship between them is tried to be determined.

Data collection

In this study, national and international articles, dissertations and presentations on the subject of "heat and temperature" between 2007 and 2022 in "Yöktez", "Google Scholar", "ERIC" and "Ulakbim" databases were examined. The keywords "heat and temperature", "heat", "temperature", "misconception" and " elimination" were used to access these studies scanned in the databases. In this study, articles and theses in Turkey were selected. The fact that there is enough research on this subject and that learners still have misconceptions about heat and temperature led us to investigate the reasons for this issue. While determining the studies, attention

was paid to determine the misconceptions about "heat and temperature" and to eliminate these misconceptions. In this context, 21 studies on the determination and elimination of misconceptions about "heat and temperature" were reached.

Validity and reliability

In order to ensure the internal validity of the study, a content data analysis table was created and reviewed by an expert in the field. The data analysis table was finalized in line with the feedback received. In order to ensure external validity, detailed explanations about the steps and results of the research were included (Yıldırım & Şimşek, 2021). In order to ensure coder reliability, 5 studies (23.81%) were randomly selected out of 21 studies and coding was performed once again. The consensus between the coders was calculated as 85% using the formula "consensus / (consensus + disagreement) x 100 " suggested by Miles and Huberman (1994).

Table 1 shows that 21 studies were reviewed between 2007 and 2022. Ten of these studies are articles published in academic journals and eleven are theses obtained from the National Thesis Scanning Center (YÖK). One of the studies was at primary school level, fourteen were at secondary school level, and six studies were at higher education level. Table 1 shows the author, publication type, grade level, number of participants and publication date of these studies. While presenting the findings of the research, the study codes S1, S2, S3, ...S21 will be used for the studies analyzed.

Table 1. List of Studies Conducted Between 2007-2022 by Author, Publication Type, Grade Level, Number of Participants, Publication Date and Code

The Authors	Type of publication	Grade level	Sample size	Date of publication	Code of the study
Aydın, Z	Master thesis	Secondary school 7th grade	56	2007	S21
Olgun, Ö.S. Ç	Article	Secondary school 5th grade	75	2008	S14
Gürbüz, F	Master thesis	Secondary school 6th grade	61	2008	S8
Clark, D.B	Article	Secondary school 8th grade	50	2010	S10
Schnittka, C & Bell, R	Article	Secondary school 8th grade	71	2010	S6
Bayram,A	Master thesis	Secondary school 5th grade	64	2010	S3
Akgül, P	Master thesis	Undergraduate science teaching 3rd grade	105	2010	S15
Yavuz, S & Büyükekşi, C	Article	Undergraduate science teaching 1st grade	35	2011	S17
Turgut, Ü & Gürbüz, F	Article	Secondary school 8th grade	37	2011	S7
Damlı, V	Master thesis	Undergraduate physics teaching 1st grade	35	2011	S20
Sarı Ay, Ö	Article	Secondary school 8th grade	40	2015	S13

Akpınar E, & Çite, E.D	Article	Secondary school 6th grade	67	2015	S1
Aydoğan , Ş	Master thesis	Primary school 4th grade	94	2016	S18
Kumlu, G.D.Y	PhD Dissertation	Undergraduate science teaching 3rd grade	29	2016	S4
Solak, E	Master thesis	Secondary school 8th grade	177	2016	S11
Yeşiltaş et. al.	Article	Undergraduate science teaching 1st grade	23	2017	S9
Sarıkaya, S	Master thesis	Secondary school 5th grade	62	2019	S16
Aksu, S	Master thesis	Undergraduate mathematics and science teaching students	57	2019	S5
Kocakülah, A. & Turan, A	Article	Secondary school 5th grade	23	2019	S2
İşcan, Y.V	Master thesis	Secondary school 5th grade	42	2020	S19
Çalgıcı vd.	Article	Secondary school 5th grade	20	2020	S12

FINDINGS

The findings were analyzed under three subheadings. These subheadings are "misconceptions about heat and temperature in students", "methods and techniques used to identify misconceptions about heat and temperature by students" and "methods and techniques used to eliminate misconceptions about heat and temperature".

Heat and Temperature Misconceptions

In the studies, 186 different misconceptions were identified. These misconceptions were presented under seven categories: "heat", "temperature", "heat-temperature", "heat exchange-equilibrium temperature", "self-heat-heat capacity", "insulation-conduction" and "expansion-state change". Misconceptions were placed in the relevant category.

Misconceptions about the heat

In this study, 20 misconceptions were identified only about the concept of heat. Table 2 presents the misconceptions identified and the studies in which these misconceptions were identified. The most common misconceptions identified are: "Heat depends on the amount of matter", "the more the amount, the more the heat, the more it vibrates", "heat affects the amount of matter", "when an object receives heat, its mass increases significantly", "heat is stored according to the type of objects" and "heat is a substance".

Table 2. Misconceptions about Heat

Category	Identified misconception	Literature	Frequency
Heat	1. "Heat is a property of a substance"	S4	1
	2. "Heat is the sum of the potential and kinetic energies of an object"	S4	1
	3. "Heat is the average kinetic energy of the particles of an object"	S4-S14-S21	3
	4. "Heat depends on the amount of substance"	S4-S7-S8-S9	4
	5. "Heat is a property that can be stored"	S4	1
	6. "The heated air stays on the ground because it is heavier. Thus the floor heats up. If the heater is located at a medium height in the room, the room heats up more quickly"	S1	1
	7. "Heat cannot be measured"	S16	1
	8. "Heat is a substance"	S3-S14-S15-S16	4
	9. "Heat has mass"	S3-S16	2
	10. "Heat affects the amount of substance"	S3-S7-S16	3
	11. "Heat is always warm or hot"	S6	1
	12. "Heat of melting and heat of freezing are the same concepts"	S7-S8	2
	13. "When an object receives heat, its mass increases significantly"	S7-S8-S13-S18	4
	14. "Heat is stored according to the type of objects"	S7-S8-S9	3
	15. "The greater the quantity, the greater the heat, the more it vibrates"	S11-S15-S19	3
	16. "Heat can flow continuously in all directions"	S13	1
	17. "Heat only moves upwards"	S14	1
	18. "Heat cannot be measured"	S16	1
	19. "There is no relationship between heat and kinetic energy"	S21	1
	20. "If an object has a higher temperature than another object, it always has a higher temperature"	S21	1

Misconceptions about the temperature

In the analyzed studies, 33 misconceptions about the concept of temperature were identified. Table 3 presents the misconceptions identified and the studies in which these misconceptions were identified. The most common misconceptions identified: "Temperature depends on the size of the object (or the amount of matter it contains)", "temperature depends on the type of material the object is made of", "temperature is a type of energy" and "the temperature of the larger volume of two objects made of the same material in the same environment is higher."

Table 3. Misconceptions about Temperature

Category	Identified misconception	Literature	Frequency
	1. "Temperature depends on the type of substance the object is made of"	S4-S7-S8-S9-S13-S15-S17-S18-S20	9
	2. "Temperature depends on the size of the object (or the amount of substance it contains)"	S4-S3-S7-S8-S9-S10-S13-S14-S15-S16-S17-S18-S19-S20	14
	3. "Temperature and coldness are properties of objects"	S4	1
	4. "Hot objects naturally cool; cold objects naturally warm"	S4	1
	5. "Temperature is a storable property"	S4	1
	6. "Temperature and energy are directly proportional"	S4	1
	7. "The temperature of the larger volume of two objects made of the same substance in the same environment is higher"	S1-S8-S13	3
	8. "The fire on the stove gives temperature to the soup"	S2	1
	9. "It gives temperature because it is fire"	S2-S7	2

Temperature	10. "As the temperature of a substance increases, its mass also increases"	S3-S16	2
	11. "The temperatures of substances in the same environment can vary according to the material, volume and mass of which they are made"	S3-S16	2
	12. "The same substances with different masses have different temperatures"	S3	1
	13. "A small piece of ice is hot, a large piece of ice is cold"	S3	1
	14. "A big piece of ice is hot, a small piece of ice is cold"	S3	1
	15. "Temperature is a form of energy"	S5-S16-S19	3
	16. "Temperature is an energy released due to heat"	S5	1
	17. "Temperature is the average energy of the substance"	S5	1
	18. "Temperature is the kinetic energy of the substance"	S5	1
	19. "Open air pressure does not change with temperature"	S5	1
	20. "If temperature increases, pressure and volume increase"	S5	1
	21. "Liquids are colder than solids in the same environment"	S15	1
	22. "It is a cold substance"	S6	1
	23. "Particles of substance do not vibrate at zero degrees"	S11	1
	24. "If the temperature is the same, the vibrations of all particles are the same"	S11	1
	25. "The more the quantity, the less it vibrates. Less temperature falls on the particle"	S11	1
	26. "Particles of substance do not vibrate at zero degrees"	S11	1
	27. "If the temperature is the same, the vibrations of all particles are the same"	S11	1
	28. "We can measure temperature with our senses"	S11-S13	2
	29. "Temperature is a given and received concept"	S19	1
	30. "Temperature depends on the air inside the substance"	S17	1
	31. "Ice has no temperature"	S14	1
	32. "Temperature is a physical phenomenon"	S17	1
	33. "If the coldness or temperature of an object is not different from the environment, it has no temperature"	S17-S20	2

Misconceptions related to heat-temperature

In the studies analyzed, 19 misconceptions related to the heat-temperature category were identified. Table 4 shows the misconceptions identified and the studies in which these misconceptions were identified. The most common misconceptions identified: "The concepts of heat and temperature are the same", "thermometer measures heat", "calorimeter measures temperature", "units of heat and temperature are the same" and "25°C is the air heat."

Table 4. Misconceptions Related to Heat-Temperature

Category	Identified misconception	Literature	Frequency
	1. "Instruments that measure heat and temperature are the same"	S2-S8-S14	3
	2. "The concepts of heat and temperature are the same"	S1-S3-S4-S5-S6-S7-S8-S13-S14-S15-S16-S17-S18-S19-S21	15
	3. "The soup gets heat from the tube, it becomes hot"	S4	1
	4. "The heat from the soup is transferred to the spoon"	S2	1

Heat-Temperature	5. "Water boils at a certain temperature"	S2	1
	6. "Thermometer heat meter"	S2	1
	7. "25°C is the air heat"	S2-S7-S14- S16	4
	8. "The heat of hot substances is greater than the heat of cold substances"	S4	1
	9. "Heat is not a form of energy, temperature is a form of energy"	S21	1
	10. "Cold substances do not have heat"	S3	1
	11. "Heat is the sum of the kinetic and potential energy of matter"	S3-S16	2
	12. "Heat can be defined as the internal energy of a substance"	S5	1
	13. "Temperature is the total kinetic energy of matter, heat is the average kinetic energy of matter"	S5	1
	14. "Objects around a burning fire are heated by the heat carried by the light emitted by the fire"	S7	1
	15. "Calorimeter measures temperature"	S7-S14-S16	3
	16. "Heat can be distinguished as hot heat and cold heat, cold heat occurs when the temperature is -(minus)"	S11-S17	2
	17. "The units of heat and temperature are the same"	S13-S19-S21	3
	18."'Joule' and 'calorie' are types of temperature units"	S14	1
	19. "Both heat and temperature are measured with a thermometer"	S13-S18	2

Misconceptions about heat exchange-equilibrium temperature

In this study, only 26 misconceptions related to heat exchange-equilibrium temperature were identified. Table 5 shows the misconceptions identified and the studies in which these misconceptions were identified. The most common misconceptions identified: ''Heat or coldness can flow from one substance to another substance'', ''when waters at different temperatures are combined, their temperatures are added to find the final temperature'', ''heat is transferred from a cold object to a hot object'', ''the temperature of two substances kept in the same environment for a long time is not equal.''

Table 5. Misconceptions about Heat Exchange-Equilibrium Temperature

Category	Identified misconception	Literature	Frequency
	1. "Heat or coldness can flow from one substance to another"	S4-S3-S7-S8-S10-S13-S16-S17-S18	9
	2. "The direction of heat exchange depends on the amount of substance"	S4	1
	3. "Heat conduction depends on the type of substance"	S4	1
	4. "When two blocks with different initial temperatures are brought into contact with each other in a contiguous manner, the temperature of the two blocks will be the same"	S4	1
	5. "The direction of heat conduction is from an object with a low temperature to an object with a high temperature. The rate of heat conduction depends on the structure of the substance"	S4	1
	6. "The temperature of a substance that receives heat will definitely change"	S3-S16	2

Heat Exchange-Equilibrium Temperature	7. "When equal heat is given, the temperature of the substance with more quantity increases more"	S3-S16	2
	8. "When given equal heat, substances reach equal temperatures regardless of their amounts"	S3	1
	9. "When heat exchange between substances stops, the temperature of both substances is not equal"	S3-S14-S16	3
	10. "When waters of different temperatures are combined, their temperatures are summed to find the final temperature"	S3-S7-S8-S11-S13-S15-S19	7
	11. "In the same environment, metal objects are cold and non-metal objects are hot"	S1-S10-S15	3
	12. "A material medium is always needed for heat transfer"	S16	1
	13. "Cold moves from cold places to warmer places"	S6-S10	2
	14. "The final temperatures of objects kept in the same environment for a long time vary according to the type of objects"	S7	1
	15. "The amount of heat given to objects has no effect on the increase in their temperature"	S8	1
	16. "When two substances of the same mass and temperature are kept in the same hot environment for a long time, the smaller one becomes hotter"	S8	1
	17. "The temperature of two substances kept in the same environment for a long time is not equal"	S8-S10-S11-S18	4
	18. "Heat is transferred from a cold object to a hot object"	S8	4
	19. "Heat transfer is faster from a substance with less quantity"	S8	1
	20. "If objects with the same temperature have different masses, heat is exchanged between them"	S11	1
	21. "Since there is no temperature (or heat) at 0 °C, there is no heat exchange with a colder object"	S11	1
	22. "Of two substances in contact, the one with more mass is hotter"	S11	1
	23. "Of two substances in contact, the one with less mass is hotter"	S11	1
	25. "When heat exchange is completed, both the temperatures of the substances are equalized and their heats are equalized"	S15	1
	26. "The heat received between heated substances depends on the size of the substance"	S17	1

Misconceptions related to self-heat and heat capacity

In this study, only 12 misconceptions related to self-heat and heat capacity were identified. Table 6 shows the misconceptions identified and the studies in which these misconceptions were identified. "Self-heat and temperature are directly proportional" and "objects with larger self-heat conduct heat more" can be given as examples of the misconceptions identified.

Table 6. Misconceptions Related to Self-Heat and Heat Capacity

Category	Identified misconception	Literature	Frequency
	1. Self-heat and temperature are directly proportional.	S4	1
	2. Objects with higher specific heat conduct heat more.	S4	1
	3. Heat capacity and self-heat are two concepts that are often confused with each other.	S5	1
	4. Self-heat varies depending on the amount of substance.	S5	1
	5. Self-heat is the amount of heat that must be given to increase the temperature of m grams of matter by one degree.	S5	1

Self-Heat and Heat Capacity	6. Heat capacity does not depend on the amount of matter.	S5	1
	7. Heat capacity is the amount of heat that must be given to increase the temperature of one gram of substance by one degree.	S5	1
	8. Conductors cool slowly/slowly heat up.	S10	1
	9. Insulators heat up/ cool down fast.	S10	1
	10. The type of substance does not affect heat exchange.	S11	1
	11. If substances are different in heat exchange, it can be concluded by looking at the density.	S11	1
	12. Substances have the capacity to retain heat.	S15	1

Misconceptions about insulation-conduction

In the analyzed studies, 47 misconceptions about insulation-transmission were identified. Table 7 shows the misconceptions identified and the studies in which these misconceptions were identified. The most common misconceptions identified: "Woolen objects are better suited for keeping objects warm than for keeping objects cold", "aluminum foil does not transmit heat, it is the best method for keeping objects cold", "insulators keep the cold out and/or generate heat", "metals are naturally colder than non-metals", "wool and woolen materials are always warmer and therefore wool and woolen materials always keep us warm" and "metals absorb heat".

Table 7. Misconceptions about Insulation-Conduction

Category	Identified misconception	Literature	Frequency
Insulation-Conduction	1. "Woolen objects are more suitable for keeping things warm than for keeping things cold"	S4-S3-S10-S15-S16-S20	6
	2. "Aluminum foil provides more thermal insulation than wool"	S1	1
	3. "All solids conduct heat in the same way"	S1	1
	4. "Aluminum foil is heat-proof, the best method to keep objects cold"	S3-S6-S10-S15-S16	5
	5. "Glass is heat-proof, the best way to keep objects cold"	S3	1
	6. "Plastic does not transmit heat, it is a good way to keep objects cold"	S3	1
	7. "Wool and materials made of wool are always warmer and therefore wool and materials made of wool always keep us warm"	S3-S10	2
	8. "Aluminum is always colder because it is metal"	S3	1
	9. "Wood is colder because it does not pass heat and cold"	S3	1
	10. "A wool sweater in winter increases your body temperature"	S3-S16	2
	11. "The temperature of a metal spoon is higher because it is metal"	S3	1
	12. "A wooden spoon is warmer. A metal spoon is colder because metals are cold."	S3-S21	2
	13. "Insulators keep the cold out and/or generate heat"	S6-S10	2
	14. "Lighter colored clothes keep you cooler because they let in more air"	S6	1
	15. "Metals absorb heat"	S6-S10	2
	16. "Metals are naturally colder than non-metals"	S6-S10	2
	17. "Heat moves because it accumulates in one place that cannot hold it"	S6	1
	18. "Light colored and shiny objects absorb radiation"	S6	1
	19. "Objects slightly exceed the equilibrium temperature as they cool/heat in the room"	S6	1
	20. "Something heats up unless it is actively keeping an object cold"	S10	1
	21. "Air circulating through an object moves heat through the medium"	S10	1
	22. "Objects keep heat differently inside and on the surface"	S10	1

	23. "Cold objects emit only a little heat energy"	S5	1
	24. "It gets hot or cold according to conductivity"	S10	1
	25. "Wooden object/(other insulator) will be hotter than metal"	S10	1
	26. "Wood/Wool rises above equilibrium temperature in the extreme direction, while metals do not"	S10	1
	27. "Materials that keep cold things cold don't keep warm things warm (or the reverse)"	S5	1
	28. "Weak conductors do not take much heat energy"	S10	1
	29. "Cold energy flows out"	S10	1
	30. "Hot things can give off heat energy without cooling"	S10	1
	31. "Mix 'melting/combustion' with temperature change"	S10	1
	32. "Objects heat up after the equilibrium temperature during their stay in a hot environment"	S10	1
	33. "Metal objects will be above the ambient temperature"	S10	1
	34. "Conductors absorb heat"	S10	1
	35. "Heat (cold) does not pass through metal"	S10	1
	36. "Porous materials allow heat/cold to pass through"	S10	1
	37. "Good conductors/insulators keep heat on the surface, while insulators/insulators/conductors keep it inside"	S10	1
	38. "Only the thickness of the material determines its insulating/conductive properties"	S10	1
	39. "Air conducts heat and cold"	S10	1
	40. "Metals insulate because they reflect heat"	S10	
	41. "Metals keep objects cold because they feel cold"	S10	1
	42. "Styrofoam is not good at keeping cold objects cold"	S10	1
	43. "Only cold things can be cold, warm things keep warm"	S10	1
	44. "Conductors lose heat energy"	S10	1
	45. "Wood/wool/foam only takes a little heat"	S10	1
	46. "Materials that keep cold things cold don't keep warm things warm"	S10	1
	47. "Some substances heat up more than other substances"	S17-S20	2

Misconceptions about expansion and change of state

In this study, 16 misconceptions about expansion and state change were identified. Table 8 presents the misconceptions identified and the studies in which these misconceptions were identified. The most common misconception identified was: "Evaporation occurs only at boiling temperature and higher temperatures". Other examples of misconceptions are "the volume of a substance that receives heat does not change or decreases", "ice freezes when it receives heat", "the volume of a gas does not change when it is heated".

Table 8. Misconceptions Related to Expansion-State Change

Category	Identified misconception	Literature	Frequency
	1. "Gases do not have the property of expansion. Only solids and liquids expand or contract"	S5	1
	2. "The volume of a gas does not change when it is heated"	S5	1
	3. "Using expressions such as 'dissolves, disappears, evaporates, evaporates, boils, condenses' etc. even though they know that snowball or ice turns into water"	S12	1
	4. "Although he knows that the water in wet laundry turns into water vapor, he explains this with alternative concepts (for example, smoke) instead of evaporation"	S12	1

Expansion-State change	5. "Knowing that water vapor hitting the lid of a teapot turns into water, but explaining this with alternative concepts to the concept of 'condensation'"	S12	1
	6. "Although he knows that the water in the freezer turns into ice, he states this event other than 'freezing'"	S12	1
	7. "The volume of a substance that receives heat does not change or decrease"	S8	1
	8. "All liquids boil at 1000°C and freeze at 0°C "	S14	1
	9. "The boiling point is the maximum temperature a substance can reach"	S14	1
	10. "Evaporation only occurs at boiling temperature and higher"	S7-S8-S21	3
	11. "A substance that evaporates in the sun takes heat from the air and loses its temperature"	S21	1
	12. "The heats of melting, freezing, boiling and condensation are distinctive properties of all substances"	S21	1
	13. "Ice freezes when it receives heat"	S2	1
	14. "If vaporization starts from the lower layers of the liquid, it is boiling"	S21	1
	15. "Melting and freezing heat and boiling and condensation heat mean the same thing"	S21	1
	16. "Ice freezes when it receives heat"	S2	1

Methods of Identifying Misconceptions about Heat and Temperature

The second sub-problem of this study is the methods of determining misconceptions in the studies on heat and temperature conducted between 2007 and 2022. We will address this problem in this direction.

The methods of detecting misconceptions and the percentages and frequencies of these methods were examined. It was determined that "multiple-choice test", " three-tiered heat and temperature concept achievement test", "semi-structured interviews", "open-ended questions", "two-tiered heat and temperature concept achievement test" and "semantic features analyses" methods were used in the studies. These data are given in Table 9 and Table 10.

Table 9. Methods and Frequency of Identification of Misconceptions about Heat and Temperature

Methods Used for the Identification of Misconceptions	Frequency (f)	Percentage
Multiple choice test	8	29,6
Three-tiered concept achievement test	7	25,9
Semi-structured interviews	5	18,5
Open-ended question	3	11,1
Two-tiered concept achievement test	3	11,1
Semantic features analyses	1	3,7

When Table 8 is examined, it is seen that the most frequently used method to identify misconceptions is multiple-choice test with 29.6%. Three-tiered achievement tests with 25.9%, semi-structured interviews with 18.5%, open-ended questions with 11.1%, two-tiered concept achievement tests with 11.1%, and semantic analysis table with 3.7%.

Table 10. Methods of Identifying Misconceptions about Heat and Temperature

The Authors	Publication	Misconception identification method
Aydın,Z	2007	Open-ended question
Olgun,Ö.S.Ç	2008	Multiple choice test
Gürbüz,F	2008	Three-tiered Heat and Temperature Concept Achievement Test
Clark, D.B	2010	Semi-structured interview
Schnittka,C & Bell,R	2010	Multiple choice test - Semi structured interview
Bayram,A	2010	Three-tiered Heat and Temperature Concept Achievement Test
Akgül,P	2010	Multiple choice test-Semi-structured interview
Yavuz ,S & Büyükekşi,C	2011	Multiple choice test
Turgut,Ü & Gürbüz,F	2011	Three-tiered Heat and Temperature Concept Achievement Test
Damlı ,V	2011	Three-tiered Heat and Temperature Concept Achievement Test
Sarı Ay,Ö	2015	Three-tiered Heat and Temperature Concept Achievement Test
Akpınar E, & Erol Çite,D	2015	Multiple choice test - Open ended questions
Aydoğan ,Ş	2016	Two-tiered Heat and Temperature Concept Achievement Test
Kumlu ,G.D.Y	2016	Multiple choice test - Semi structured interview
Çolak,E	2016	Two-tiered semi-structured - Temperature Conceptual Understanding Questionnaire
Yeşiltaş,H.M., Taş, E. & Özyürek ,C	2017	Three-tiered Heat and Temperature Concept Achievement Test
Sarıkaya,S	2019	Multiple choice test - Semi structured open ended questions - Semantic features analyses
Aksu,S	2019	Multiple choice test - Semi structured interview form
Kocakülah ,A . & Turan , A	2019	Two-tiered conceptual understanding test
İşcan,Y.V	2020	Three-tiered Heat and Temperature Concept Achievement Test
Çalgıcı,G.,Yıldırım,M. & Duru,K	2020	Open-ended question

When Table 10 is reviewed, it is seen that multiple-choice test, three-tiered heat and temperature concept achievement test, open-ended questions, semi-structured interview, two-tiered conceptual understanding test and semantic analysis table were used as methods to identify misconceptions in the studies on misconceptions in heat and temperature concepts. When the table is analyzed, it is seen that two methods were used in some studies and three methods were used together in some studies. After 2011, it is seen that the multiple-choice test was not used alone as a method of identifying misconceptions, and after 2010, the semi-structured method was used.

Methods and Techniques for Elimination of Misconceptions about Heat and Temperature

The methods and techniques of eliminating misconceptions in the studies on heat and temperature conducted between 2007 and 2022 constitute the third sub-problem of this study. We will address this problem in this direction.

In the application studies conducted for the elimination of misconceptions, it is seen that there are techniques commonly used for concept teaching, and the most commonly used technique among these techniques is conceptual change texts. In the studies examined, it is seen that the 5E learning model, which is a learning cycle, is also widely used in eliminating misconceptions. In addition, it is seen that different methods such as problem-

based learning method, education information network (EBA) supported teaching, open-ended experiment technique, creative drama supported teaching were applied in the studies.

Table 11. Methods and Frequency of Elimination of Misconceptions about Heat and Temperature

Elimination methods	Related studies	Frequency (f)	Percentage
Open-ended Experiment Technique	Akpınar & Çite (2015)	1	4,7
5 E Learning Model	Kocakülah & Turan (2019), Sarıkaya (2019), Turgut & Gürbüz (2011), İşcan (2020)	4	19,4
Teaching with Problem-Based Learning Approach	Bayram (2010)	1	4,7
Direct and Peer Reading Strategies Instruction	Yurttaş Kumlu(2016)	1	4,7
Drama and Argumentation Method	Aksu (2019), Solak (2016)	2	9,5
Conceptual Change Text Method	Akgül (2010), Ay & Aydoğdu (2015), Gürbüz (2008)	3	14,2
Creative Drama Supported Science Teaching	Yeşiltaş vd. (2017)	1	4,7
Gamification Method	Çalgıcı vd. (2020)	1	4,7
Concept Maps Method	Aydın (2007), Çakır Olgun (2008)	2	9.5
Concept Cartoons	Yavuz & Büyükekşi (2011)	1	4,7
Eba Supported Teaching	Aydoğan (2016)	1	4,7
Web-based interaction teaching	Damlı (2011)	1	4,7
Engineering Design Events	Schnittka ve Bell (2011)	1	4,7
Computer Curriculum	Clark (2006)	1	4,7

When Table 11 is examined, it is seen that the most frequently used method in eliminating misconceptions about heat and temperature is "5E learning model" with 19.4%. It is followed by "conceptual change texts" with 14.2%. Thirdly, "drama and argumentation" and "concept maps" methods follow with 9.5%. All other methods covered in the study were used once (4.7%).

In the literature, 4 studies on 5E learning model, 3 studies on conceptual change text, 2 studies on concept maps, 2 studies on drama and argumentation method and one study on other methods were found.

CONCLUSION and DISCUSSION

The first research question of this study aims to identify students' misconceptions about heat and temperature in the studies conducted between 2007 and 2022. In this direction, it has been determined that there are many misconceptions about heat and temperature in the studies conducted on the identification and elimination of misconceptions about heat and temperature. It can be said that the misconceptions are generally based on using the concepts of heat and temperature interchangeably or considering the two concepts as the same. The fact that "heat and temperature are the same concepts" was found in 15 of the 21 studies and that "heat is measured

with a thermometer", "temperature is measured with a calorimeter", "temperature depends on the amount of matter" misconceptions are very common supports this idea. Our results show similar results with Tamkavas et al. (2016).

The misconceptions identified in the studies were analyzed under seven categories: "heat", "temperature", "heat-temperature", "heat exchange-equilibrium temperature", "self-heat-heat capacity", "insulation-conduction" and "expansion-state change". When the studies in the literature are examined, it is seen that "heat", "temperature", "heat-temperature", "heat exchange-equilibrium temperature" and "insulation-distribution" are emphasized. When the six studies conducted with the fifth grade are examined, it is seen that there are a limited number of misconceptions about the subject of "expansion and state change" in the fifth grade curriculum. Similarly, it is noteworthy that misconceptions related to the subject of "self-heat" in the eighth grade curriculum were not found in five studies conducted with eighth graders.

In addition, in studies on misconceptions about heat and temperature starting from the fourth grade and extending to university students, it was determined that the same misconceptions were observed among students regardless of grade level. These results show that misconceptions in students are not completely eliminated despite long-term formal education (Akgül, 2010; Aksu, 2019; İşcan, 2020; Kocakülah & Turan, 2019).

The second research question of this study aims to determine the methods and techniques used to identify students' misconceptions about heat and temperature in the studies conducted between 2007 and 2022. In this direction, when misconception detection methods are examined, it is seen that the commonly used method is multiple-choice test. However, in recent studies, it is seen that multiple-choice tests are not used alone to determine misconceptions, they are preferred together with open-ended questions or semi-structured interview forms, and in some studies, three-tiered concept tests or open-ended questions are used alone. The reason for this is the idea that multiple-choice tests cannot fully detect students' misconceptions.

When the studies conducted in this direction are examined, Clark's (2010) study is noteworthy. In his study, Clark (2010) used semi-structured interview method to determine students' misconceptions at certain intervals throughout a semester. Thus, he restructured the education process by seeing the change and development of the misconceptions he identified in the students during the process.

The third research question in the study aims to determine the methods and techniques used to eliminate misconceptions about heat and temperature in students in studies conducted between 2007 and 2022. When the methods and techniques used to eliminate misconceptions are examined, we see that the educational process is mostly constructed by confronting students' misconceptions with scientific truths and creating cognitive conflict in students. In some studies, 5E learning model (Bayram, 2010; Gürbüz, 2011; İşcan, 2020; Sarıkaya, 2019), conceptual change texts technique (Akgül, 2010; Gürbüz, 2008; Kocakülah & Turan, 2019) and

concept cartoons technique (Aydın, 2007; Olgun, 2008) are common. In some studies (Akpınar & Çite, 2015; Çalgıcı et al., 2020), it is seen that teaching plans for concept change are not clearly presented.

Conceptual change requires a long process (İşcan, 2020; Gürbüz, 2008). In this context, Clark (2010) and Schnittka and Bell (2011) focused on the fact that conceptual change can occur in a long process by working with students for a semester. Kocakülah and Turan (2019) tried to realize concept change in students with plans and applications prepared according to the 5E learning model in four lesson hours. This study contradicts the principle that conceptual change requires a long process.

SUGGESTIONS

In line with the results of the study, the following suggestions can be made to researchers and teachers; Misconceptions are learnings that are acquired more in early childhood. Once misconceptions are formed, they are very difficult experiences to change. Therefore, more time can be spent on teaching topics such as heat and temperature in the early grades. For this purpose, studies can be conducted on misconceptions in the change of state of matter and expansion subjects in the fifth grade unit of change of matter in our country. Techniques such as word association test, diagnostic branched tree, fishbone etc. related to concept teaching should be tried.

ETHICAL TEXT

This study does not require an ethics committee. In this article, journal writing rules, publication principles, research and publication ethics rules, journal ethics rules have been followed. The responsibility for any violations that may arise regarding the article belongs to the authors.

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