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Examining the Development Process of Middle School Students' Knowledge Structures for the Concepts of Melting and Dissolution According to Conceptual Change Theories

Ortaokul Öğrencilerinin Erime ve Çözünme Kavramlarına Yönelik Bilgi Yapılarının Gelişim Sürecinin Kavramsal Değişim Teorilerine Göre İncelenmesi

Mehmet Ali KANDEMİR* **Zeki APAYDIN****

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ABSTRACT: The aim of this longitudinal research is to examine the development process of scientific and consistent knowledge structures of first, second, and third-grade students in middle school within the concepts of melting and dissolution according to conceptual change theories at the end of the education and training processes carried out in educational institutions. The research is carried out in a district of a metropolitan city in the Marmara Region with the participation of 43 middle school students. Open-ended questions developed for concepts were used to collect data. Friedman test is used to determine whether there is a difference between students' consistent and scientific knowledge structure scores regarding the concepts of melting and dissolution. As there is a significant difference between the students' consistent and scientific knowledge structure scores regarding the concepts of melting and dissolution, the Wilcoxon Signed Rank Test is used for dual comparisons between student levels. In addition, Spearman's correlation coefficient of rank differences is used to determine if there is a relationship between the class levels of the students and the scores of students' consistent and scientific knowledge structure regarding the concepts of melting and dissolution. As a result of the research, it is determined that the students' consistent and scientific knowledge structure scores regarding the concepts of melting and dissolution differ depending on the students' levels. When all the findings obtained from the research are evaluated together, it can be said that the development process of students' knowledge structures regarding the relevant concepts is more compatible with the knowledge in pieces conceptual change theory. Based on the results of the research, some suggestions were made.

Keywords: Knowledge in pieces structure conceptual change theory, theory-like conceptual change theory, mental model.

ÖZ: Bu boylamsal araştırmanın amacı; eğitim kurumlarında gerçekleştirilen eğitim ve öğretim süreçleri sonunda ortaokul birinci, ikinci ve üçüncü sınıf öğrencilerinin erime ve çözünme kavramlarına yönelik bilimsel ve tutarlı bilgi yapılarının gelişim sürecini kavramsal değişim teorilerine göre incelemektir. Araştırma Marmara Bölgesi'ndeki bir büyükşehrin bir ilçesinde 43 ortaokul öğrencisinin katılımı ile gerçekleştirilmiştir. Araştırmada verilerin elde edilmesinde erime ve çözünme kavramlarına yönelik geliştirilen açık uçlu sorular kullanılmıştır. Araştırma verilerinin analizinde Friedman testi, Wilcoxon İşaretli Sıralar Testi ve Spearman'ın sıra farkları korelasyon katsayısı kullanılmıştır. Araştırma sonucunda, öğrencilerin erime ve çözünme kavramlarına ilişkin tutarlı ve bilimsel bilgi yapısı puanlarında, sınıf düzeyine göre farklılıklar olduğu saptanmıştır. Araştırmadan sağlanan tüm bulgular birlikte değerlendirildiğinde öğrencilerin ilgili kavramlara yönelik bilgi yapılarının gelişim sürecinin, daha çok parça nitelikli kavramsal değişim kuramıyla uyumlu olduğu söylenebilir. Araştırma sonuçlarına dayanarak bazı önerilerde bulunulmuştur.

Anahtar kelimeler: Parça nitelikli kavramsal değişim teorisi, teori benzeri kavramsal değişim teorisi, zihinsel model.

* *Corresponding Author*: Primary School Teacher, Ministry of National Education, Balıkesir, Türkiye, mehmetalikandemir10@gmail.com, https://orcid.org/0000-0001-9340-2559
** Prof. Dr., 19 Mayıs University, Samsun, Türkiye, zapaydin@omu.edu.tr, https://orcid.org/0000-0002-6581-4828

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The teaching process of the concepts of melting and dissolution, which are among the concepts included in the science lesson curriculum, is maintained starting from the fourth grade in primary school to the university level (Kirman-Bilgin et al., 2014). Although the students have gone through a long education and training process for the concepts of melting and dissolution, the knowledge structures of the students about the concepts of melting and dissolution may be in conflict with scientific knowledge. In the literature, some findings are reached related to the existence of knowledge structures that are in contrast with scientific and consistent knowledge about the concepts of melting and dissolution in primary school students (Durmus & Donmez-Usta, 2020; Kandemir & Apaydin, 2022, 2023); in university students (Akgun & Aydın, 2009; Kirman-Bilgin et al., 2014; Sen & Yilmaz, 2012) and in middle and high school students as well (Calık & Ayas, 2005). In addition, studies in the international literature reveal that this situation is not unique to our country (Eilks et al., 2007; Goodwin, 2002; Pinto et al., 2023; Ramesh et al., 2020). The contents of the relevant studies in the literature are given below. In their research, Durmus and Donmez-Usta (2020) asked students to draw drawings regarding the concept of melting. It was determined that the drawings made by third-grade primary school students at the scientific level constituted 39.3% of the group, and the drawings made by fourth-grade students at the scientific level constituted 8.1% of the group. In another study in the literature, Kirman-Bilgin et al. (2014) found that science teacher candidates used alternative concepts such as melting, extinction, disappearing, imprisonment, and neutralization instead of the concept of dissolution. Calık and Ayas (2005) examined the knowledge structures of students studying between the seventh and tenth grades regarding selected solution concepts. As a result of the research, it was concluded that some students' answers were inconsistent and that all those depended on the mixture used. In another study, Pinto et al. (2023) examined the knowledge structures of undergraduate and master's degree students regarding the dissolution of oxygen in water. The research revealed that only 11% of the students had scientific knowledge. In their research conducted in primary school, Kandemir and Apaydın (2023) found that, as a result of the pre-test application, the scientific and consistent response score of the students towards the concepts of melting and dissolution was lower than the non-scientific response score.

Not only formal education institutions but also observations of the outside world, communication, and interaction with the social environment are effective in the formation of students' ideas about scientific concepts (Cepni, 2016; Furlough & Gillan, 2018; van Ments & Treur, 2021; Yuzbasıoglu & Kurnaz, 2020). However, the ideas about the concepts obtained in this way are not always correct. Nevertheless, ideas formed as a result of students' misperception of the relevant concept may conflict with scientifically accepted information (Sen & Yilmaz, 2012). Therefore, knowledge structures should be examined in order to know how students construct a concept, to learn their level of knowledge about that concept, and to see whether there are any misconceptions (Kayhan, 2010). The most important reason for analyzing knowledge structures is that knowledge structures are effective in learning new concepts (Ilyas & Saeed, 2018; Sozcu et al., 2016; Vosniadou, 1994). According to the constructivist learning theory, which forms the basis of our science lesson curriculum, meaningful learning occurs by associating the individual's prior knowledge with the new knowledge (Acıkgöz-Ün, 2014; Cepni, 2016). For that reason, it is possible for teachers to know the knowledge structures of the students about the concept to be learned and to prepare the education-teaching processes by taking these knowledge structures into consideration. Thus, meaningful learning and the quality of education and training process will increase (Ilyas & Saeed, 2018; Malatyali & Yilmaz, 2010; Sozcu et al., 2016). Otherwise, incomplete or incorrect information about concepts may prevent students from learning concepts in a meaningful and permanent way (Ecevit & Simsek, 2017). In this context, knowledge structures are crucial in learning concepts in a meaningful way in the teaching process (Ultay et al., 2017).

Research on conceptual change in science is mainly concerned with two questions: (1) What knowledge of the natural world do pupils have before formal education? (2) How does this knowledge change as children develop and scientific expertise is acquired? After more than two decades of research on the topic, there are still deep disagreements about these questions. Most notable in this context is the question of coherence: Some researchers argue that students' common-sense knowledge of the natural world is coherent. Others argue that it is inconsistent (Sherin et al., 2012). There are different theories in the literature examining students' knowledge structures. However, it is possible to say that research in the literature is mostly grouped into two theories. According to the theory-like conceptual change theory, which is the first of the related theories, students form some naive concepts as a result of their daily experiences. These knowledge structures, which are formed by the individual as a result of their daily experiences, show consistency within themselves (Ozdemir, 2007; Vosniadou, 2012, 2019). However, students' knowledge structure does not have scientific consistency like scientists'. The reason is that students cannot hypothesize and test their ideas (Vosniadou, 2003). These constructs are developed unconsciously as a result of daily experiences and have explanatory power to make consistent predictions and explanations in different domains (Parnafes, 2012). According to the theory mentioned above, students' knowledge structures are tightly interconnected and integrated (Hannust & Kikas, 2007). According to the related theory, when individuals are asked similar questions about a concept, the individuals' answers are based on the same knowledge structures (schema, mental model), so it provides consistency in their answers (Ozdemir, 2007). In addition, according to the theory, students' knowledge structures of the related concept follow a process from a non-scientific consistent structure to a scientific and consistent one (Apaydın, 2020; Ioannides & Vosniadou, 2002; Ozdemir, 2007; Vosniadou, 2003, 2012). According to the theory, students can combine the scientific knowledge that they have encountered in formal education institutions with the naive knowledge that they have created as a result of their daily experiences and can create synthetic structures (Vosniadou, 2012). Even though a synthetic concept may be scientifically incorrect, it still allows the student to advance in the process of acquiring knowledge. A synthetic concept must have both internal consistency and explanatory adequacy (Vosniadou & Skopeliti, 2014). For example, a student comes to a formal education institution knowing that sugar melts in water. At school, he encounters scientific knowledge that sugar dissolves in water. This case creates a mental imbalance for the student. The student combines his prior knowledge of the concept with scientific knowledge in order to get rid of the confusion that surrounds him. As a result, when the student is asked how it is named when water and sugar are mixed, he is likely to say, "Sugar dissolves in water, and sugar disappears in water." This response proves the existence of the student's synthetic structures.

Synthetic concepts are dynamic, not fixed. It constantly changes as students' information systems evolve. In other words, when the student encounters new information, the student's knowledge structure is reinterpreted. This process continues until complete conceptual change occurs. According to the relevant theory, conceptual change in individuals occurs slowly and gradually. Additionally, in this process, fragmentation and synthetic concepts may occur in students' knowledge structures. The relevant theory emphasizes that rather than telling students that their ideas are wrong and need to be changed, it would be more productive to design instruction that will help them understand that scientific explanations represent a different perspective with more explanatory power compared to their initial understanding (Vosniadou & Skopeliti, 2014).

The other theory that examines students' knowledge structures in the literature is the knowledge in pieces structure conceptual change theory. According to this theory, students have thousands of primitive ideas or understandings that they form as a result of their daily lives, called phenomenological primitives (p-prims). Phenomenological primitives are fragmentary and loosely organized. The fact that students' knowledge structures are fragmented and far from unity may cause them to give inconsistent answers to similar questions about a concept. In addition, according to this theory, students' knowledge structures about a concept follows a process from a fragmented structure to a scientific and consistent structure. The important factor emphasized in this process is the increase in students' knowledge of the relevant concept (Apaydın, 2014, 2020; Clark, 2006; diSessa et al., 2004; Kandemir & Apaydın, 2022; Ozdemir & Clark, 2007; Ozdemir, 2007; Ozdemir, 2018). For example, while a student can state that the salt is dissolved in a salt-water mixture, he can conversely express that sugar melts in a sugar-water mixture. However, dissolution occurs in both mixtures. Phenomenological primitives cannot be removed or destroyed. The loose organization of phenomenological primitives allows a gradual reformation of a student's perception as new information is gathered (Smith et al., 1994). In this theory mentioned before, the student's prior knowledge is valuable because it is emphasized that the advanced knowledge could be reached gradually with the help of rearrangement of the student's prior knowledge. For this reason, they hold the opposite view against the perspective of misconceptions, which is seen as something to be overcome for the development of scientific perception (diSessa, 2014; Smith et al., 1994). According to this theory, conceptual change is a long, gradual, and conceptual process (diSessa, 2014; Furlough & Gillan, 2018; Ozdemir, 2018; Vosniadou, 2019). In the study, the development process of students' scientific and consistent knowledge structures regarding the concepts of melting and dissolution will be discussed within the scope of knowledge in pieces conceptual change theory and theory-like conceptual change theory.

In the literature, there is no longitudinal study that examines the development of scientific and consistent knowledge structures of first, second, and third-grade students in middle school related to the concepts of melting and dissolution. The research is important in terms of filling this gap in the literature and teaching process of the concepts of melting and dissolution. Although there is a long education and training process starting from the 4th grade of primary school and continuing until the university, student knowledge structures regarding the concepts of melting and dissolution may conflict with scientific knowledge (Kandemir & Apaydın, 2020; Ramesh et al., 2020; Sen & Yılmaz, 2012). The middle school level was preferred in the study because it constitutes the basis for the related concepts after the primary school level; the scope of the related concepts expands at this level, and their teaching is carried out in-depth and in detail. It is a known fact that students' knowledge structures about concepts are very important in the realization of meaningful learning (Kandemir & Apaydın, 2022). Knowledge structures inform teachers about how students construct concepts/concepts (Ozgul et al., 2018). In this direction, teachers also organize the education and training process. Research is important in terms of helping teachers organize the education and training process. In addition, it is observed that qualitative research methods are used in the majority of domestic and foreign studies in the literature, and the existing knowledge structures of students around a concept are examined (Akman, 2013; Apaydın, 2020; Clark, 2006; diSessa et al., 2004; Ozdemir, 2018; Turceotte, 2012; Vosniadou & Brewer, 1992). It is noteworthy that quantitative and longitudinal studies are scarce in the literature (Clark, 2006; Øyehaug & Holt, 2013). It is expected to contribute to the literature about this issue as well. The aim of this longitudinal research is to examine the process of development of scientific and consistent knowledge structures about the concepts of melting and dissolution of first, second, and third-grade students in middle school at the end of the education and training processes carried out in educational institutions. Since the studies on the subject in the literature focus on the knowledge in pieces conceptual change theory and the theory-like conceptual change theory, the development of scientific and coherent knowledge structures for the concepts of melting and dissolution has been examined within the scope of two theories. In this context, the following research questions were determined.

1. Is there a significant relationship between the class levels of the students and the scores obtained from the students' consistent and scientific knowledge structures regarding the concepts of melting and dissolution?

2. Is there a significant difference between the scores obtained from the students' consistent and scientific knowledge structures regarding the concepts of melting and dissolution based on their class levels?

Method

Model of the Research

The research is panel research, which is one type of longitudinal survey research model aiming to examine the development of students' knowledge structures for the concept of melting and dissolution at different class levels. In the related research, measurements are conducted for the same individuals each time at different times. The purpose of the measurements conducted in this way is to examine the changes in the variable during a time process (Buyukozturk et al., 2016; Ozmen & Karamustafaoglu, 2019). In survey research, the existing situation is described and defined as the way it exists in its own conditions, without a trial to change the situation (Karasar, 2015).

Ethical Procedures

All procedures in this study were carried out in accordance with the decision of the ethics committee of 19 Mayıs University Social and Human Sciences dated 29.12.2019 and numbered 2019/455.

Participants

The research was conducted starting from the 2019-2020 academic year up to the 2021-2022 academic year in a district of a metropolitan city in the Marmara Region. The research was carried out with the participation of 43 middle school students. The participants were determined by using the convenience sampling method, which is one of the purposive sampling methods. In the convenience sampling sampling method, the researcher chooses a situation that he or she can easily access (Yıldırım & Şimşek, 2018). In other words, the researcher provides data from the participants that he can easily reach. The method in question is very economical in terms of time, money, and labor. It accelerates the research (Buyukozturk et al., 2016). A two-stage sampling method was used to determine the participants of the study. First, a middle school was selected among the 16 middle schools in the district using the lottery method. Then, two classes were selected from the first grades of the selected middle school by lottery method. The sampling method in both stages of the research was cluster sampling.

Data Collection Tools

In the research, open-ended questions about the concepts of melting and dissolution, which were developed by the researchers in accordance with the grade levels, were used (Appendix-1). Open-ended questions evaluate the development of students' knowledge structures within the scope of theory, like conceptual change theory and knowledge in pieces structure conceptual change theory. While the inconsistent answers given by the students to similar questions were evaluated within the scope of the knowledge in pieces structure conceptual change theory, the consistent answers given by the students to similar questions were evaluated within the scope of the theory-like conceptual change theory. In the process of developing open-ended questions, the literature was first reviewed (Apaydın, 2020; diSessa, 2008; Kandemir & Apaydın, 2022; Ozdemir, 2018; Vosniadou & Brewer, 1992). Then, 10 open-ended items suitable for each grade level were written. Then, the opinions of four field experts, one measurement and evaluation expert, and six science teachers were taken to increase content validity and reliability. Necessary corrections were made accordingly. In order to determine whether the questions were understandable by the students, a pre-pilot application was made to 20 students who would not participate in the research. At the end of the application, feedback was received from the students that the test was comprehensible. The open-ended questions prepared after this stage were applied starting in the 2019-2020 academic year and until the 2021-2022 academic year. Data were obtained by applying similar open-ended questions to the same students regarding the concepts of melting and dissolution at all levels from the first grade to the third grade of middle school. As the grade levels of the students changed, the open-ended questions were rearranged according to the grade level. While preparing open-ended questions at all grade levels, the process of developing open-ended questions above was carried out repeatedly (Atılgan, 2009; Özmen & Karamustafaoglu, 2019).

Data Collection and Analysis

In this longitudinal study, the data was gathered by applying the relevant open-ended questions to the same students three times, first in 2019, in 2020, and then in 2021, from the first grade of middle school to the third grade of middle school. If the students' knowledge structures of concepts are developed from a non-scientific consistent structure to a scientifically consistent structure, they are handled according to the theory-like conceptual change theory. If the students' knowledge structures of concepts show a development from a fragmented (inconsistent) structure to a scientifically consistent structure, they are handled according to the knowledge in pieces structure conceptual change theory. Data analysis of the study was started by entitling the student answer sheets. The open-ended question forms were entitled as 1Ö1, 1Ö2, 1Ö3… 1Ö43 for the students going through their education in the first grade of middle school. The open-ended question forms were entitled 2Ö1, 2Ö2, 2Ö3… 2Ö43 for the students attending the second grade of the secondary school. The open-ended question forms were similarly entitled as 3Ö1, 3Ö2, 3Ö3… 3Ö43 for the students attending the third grade of middle school.

Table 1

Rubric for Students' Responses

Point	Criteria
1	Scientifically consistent answers given by students to similar open-ended questions regarding the same concept were given 1 point. Examples of students' responses are given below.
0	Non-scientific consistent and inconsistent answers were given 0 points. Examples of students' responses are given below.

Scientifically consistent answers given by students to different open-ended questions on the same concept were given one point. Non-scientific consistent and inconsistent answers were given zero points (Table 1). In other words, the students were asked different questions about concepts with the same answers. The consistency or inconsistency of the students' answers to these questions was examined and scored accordingly. Students' scientifically correct and consistent answers to the relevant questions (consistency between the answers given to at least two questions) earned points. Other answers did not gain any points.

Examples of students' responses are given below.

Teacher: What happens to the sugar if water and sugar are mixed?

1Ö3: Sugar dissolves in water.

Teacher: What happens to the salt if water and salt are mixed?

1Ö3: Salt dissolves in water and breaks into small pieces.

In the first question, the student was asked what happens to the sugar in the sugar-water mixture. In the second question, the student was asked what happens to the salt in the salt-water mixture. In response to these questions, the student stated the concept of dissolution. Thus, it was determined that the student answers were scientific and there was consistency among their answers. One point was given for a scientifically consistent answer.

Teacher: What happens to the sugar if water and sugar are mixed?

1Ö12: Sugar melts in water.

Teacher: What happens to the salt if water and salt are mixed?

1Ö12: Salt melts in water and disappears.

In the first question, the student was asked what happens to the sugar in the sugar-water mixture. In the second question, the student was asked what happens to the salt in the salt-water mixture. The student gave the concept of melting in response to the questions. Thus, it was determined that the student answers were not scientific, and there was consistency among their answers. A non-scientific consistent answer was given zero points.

Teacher: What happens to the sugar if water and sugar are mixed?

1Ö36: Sugar melts in water and disappears.

Teacher: What happens to the salt if water and salt are mixed?

1Ö36: Salt dissolves in water.

In the first question, the student was asked what happens to the sugar in the sugar-water mixture. In the second question, the student was asked what happens to the salt in the salt-water mixture. The student gave the concept of melting as an answer to the first question and the concept of dissolution as an answer to the second question. Thus, it was determined that there was an inconsistency between the student's answers. An inconsistent response was given 0 points.

Then, the data was put in the SPSS 22 data analysis package program. Then, whether the data had a normal distribution or not was examined. According to the results, it was understood that the data did not match with the normality criterion ($p<.05$). After that, the Friedman test was used to determine whether there was a significant difference between the students' consistent and scientific knowledge structures scores regarding the concepts of melting and dissolution according to their level. As a result of the related test, a significant difference was observed between the scores of the same group. Wilcoxon Signed Ranks Test was used in dual comparisons to determine where the differentiation occurred between the groups. According to the test results obtained, the score ranges used to evaluate the effect of the level variable on the scores are as follows: The effect is low if $0.1<r$; it is moderate if $0.3<r$; and it is found high if $0.5<r$ (Cohen, 2013). Also, Spearman's rank correlation coefficient (r_s) is used to determine whether there is a significant relationship between the class level and students' scores of consistent and scientific knowledge structures regarding the concepts of melting and dissolution. Those reasons are effective in the usage of the related method: The data does not have a normal distribution, and one of the variables is at the level of the ranking scale while the other one is at the level of the equally spaced scale. The correlation coefficient ranges are as follows: high correlation is between 1-0.70; moderate level is between 0.69-0.30; and low level can be attributed as between 0.29-0.00. The determination coefficient is calculated by squaring the correlation coefficient found (R^2). Determination correlation helps to figure out how much a change in one of the variables is explained by the other variable (Kilmen, 2015).

Results

The research findings were examined within the scope of the knowledge in pieces conceptual change theory and theory-like conceptual change in the development of scientific and consistent knowledge structures of students for the concepts of melting and dissolution.

Within the scope of the first research question, the existence or absence of a significant relationship between the student class levels and the scores obtained from the students' consistent and scientific knowledge structures regarding the concepts of melting and dissolution was investigated. Obtained findings are given below.

Table 2

Spearman's Rank Differences Correlation Coefficient Test Results

		Points
Class level	Correlation Coefficient	.305
	Sig. (2-tailed)	.000*
	N	129

*p<.05

According to the test result in Table 2, there is a moderate, positive, and significant relationship between the class level of the students and the scores of scientific knowledge structures (r_s=.305, p<.05). According to this result, it can be stated that as the student level increases, the students' consistent and scientific knowledge scores about the concepts of melting and dissolution increase. The determination coefficient is calculated by squaring the correlation coefficient obtained. R^2=.305*.305=.09. Based on this result, it can be stated that approximately 9% of the variability in the consistent and scientific knowledge structure scores can be explained by the student class level variable.

Within the scope of the second research question, the scores obtained from the consistent and scientific knowledge structures by the students related to the concept of melting and dissolution were compared at the first, second, and third class levels of middle school. The findings obtained in this term are given below:

Table 3

Friedman Test (X^2) Results Between Different Class Levels

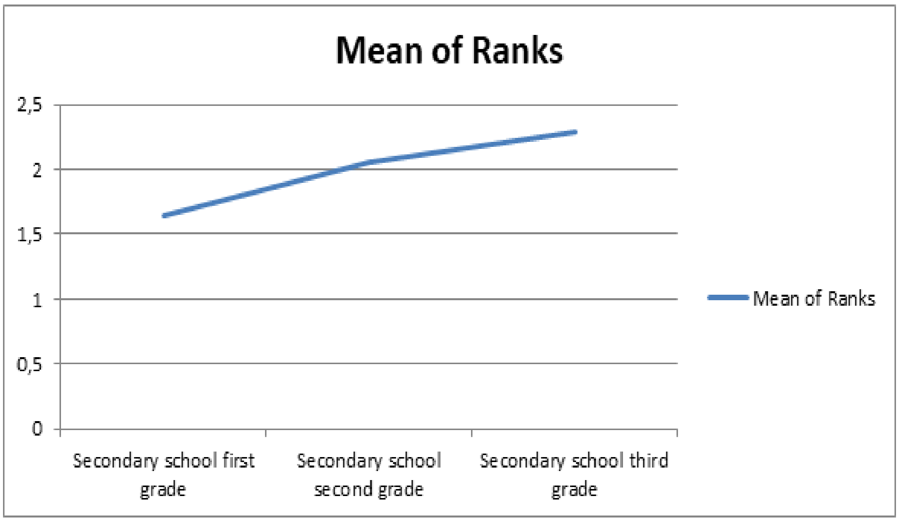
Class levels	N	Mean of Ranks	sd	x^2	p
Middle school first-grade	43	1.65	2	19.872	.000*
Middle school second-grade	43	2.06			
Middle school third-grade	43	2.29			

*p<0.05

According to the results of the analysis in Table 3, a significant difference is found between the scores obtained from the students' scientific and consistent knowledge structures for the concepts of melting and dissolution in the first grade of middle school, second grade of the middle school, and third grade of the middle school (X^2=19.872, p<.05). In order to find out between which grades this difference occurs, dual comparisons are made between middle school first grade-middle, school second grade, middle school first grade-middle school third grade, middle school third grade-middle school second grade. Wilcoxon Signed Rank Test is used for dual comparisons.

Figure 1

Line Graph of the Mean of Ranks for Different Class Levels



In Figure 1, it is observed that the mean rank of the middle school first grade is 1.65, the mean rank of the middle school is 2.06, and the mean rank of the middle school third grade is 2.29. Based on these findings, it can be stated that students' scientific and consistent knowledge structures about the concept of melting and dissolution make progress slowly and gradually. In addition to that, as the class level increases, it is observed that scientific and consistent knowledge structures about the concepts of melting and dissolution increase, too.

Table 4

The Test Result of the Comparison of the Middle School First Class and Second Grade Scores

Class levels		*N*	Mean of Rank	Sum of Ranks	*Z*	*p*	*r*
Middle school first-grade Middle school second-grade	Negative Ranks	1[a]	5.50	5.50	-3.087	.002	.46
	Positive Ranks	13[b]	7.65	99.50			
	Ties	29[c]					
	Total	43					

p<.05

a. Middle school second-grade<Middle school first-grade

b. Middle school second-grade>Middle school first-grade

c. Middle school second-grade=Middle school first-grade

When the test analysis results in Table 4 are examined, it is seen that 13 results are positive, 29 results are equal, and one result is negative if the consistent and scientific knowledge structures scores of the second-grade students in middle school are subtracted from the consistent and scientific knowledge structure scores of the first-grade students in middle school. Based on these findings, it can be stated that the scores of the second-grade (middle school) students' consistent and scientific knowledge structures are higher than the knowledge structure scores of the first-grade students. In addition, according to the Wilcoxon Signed Rank Test result, a significant difference is found in the dual comparison between the consistent and scientific knowledge structure scores of the second-grade students in middle school and the consistent and scientific knowledge structures scores of the first-grade students in middle school (Z=-3.087, p<.05 r=.46). In order to determine which class level is in favor of this difference, the mean values of the rows are checked. A higher mean of ranks means higher scores. While the mean row value for the measurements of the first graders in middle school is = 5.50, the average row value for the measurements of the second graders in middle school is = 7.65. Therefore, this difference is in favor of the consistent and scientific knowledge structure scores of the second-grade students in middle school. In other words, the student class level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is moderate (r=.46).

Table 5

The Test Result of the Comparison of Middle School Third Class-Middle School First Grade Scores

Class levels		N	Mean of Rank	Sum of Ranks	Z	p	r
Middle school first-grade Middle school third-grade	Negative Ranks	2[d]	7.50	15.00	-3.740	.000	.56
	Positive Ranks	20[e]	11.90	238.00			
	Ties	21[f]					
	Total	43					

p<.05

d. Middle school third-grade<Middle school first-grade

e. Middle school third-grade>Middle school first-grade

f. Middle school third-grade=Middle school first-grade

When the test analysis result in Table 5 is examined, it is seen that 20 results are positive, 21 results are equal, and two results are negative as long as the consistent and scientific knowledge structures scores of the first-grade students in middle school are subtracted from the coherent and scientific knowledge structures scores of the third-grade students in middle school. Based on this result, it can be stated that the consistent and scientific knowledge structures scores of the third-grade students in middle school are higher than the consistent and scientific knowledge structures scores of the first graders in the middle. Furthermore, according to the Wilcoxon Signed Rank Test result, a significant difference is found between the consistent and scientific knowledge structures scores of the third-grade students in middle school and the consistent and scientific knowledge structures scores of the first graders in middle school (Z=-3.740, p<.05, r=.56). In order to specify which class level is in favor of this difference, the mean values of the rows are checked. A higher mean of ranks means higher scores. When the mean of ranks for the measurements of the first graders in middle school is = 7.50, the mean of ranks for the third graders in middle school is = 11.90. Thus, this difference is in favor of coherent and scientific knowledge structure scores of the third-grade students in middle school. That is to say, the student-level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is high (r=.56).

Table 6

The Test Result of the Comparison of Middle School Third Class and Second Grade Scores

Class levels		N	Mean of Rank	Sum of Ranks	Z	p	r
Middle school second-grade	Negative Ranks	5[g]	6.50	32.50	-2.173	.030	.32
Middle school third-grade	Positive Ranks	12[h]	10.04	120.50			
	Ties	26[i]					
	Total	43					

p<.05

g. Middle school third-grade <Middle school second-grade

h. Middle school third-grade>Middle school second-grade

i. Middle school third-grade=Middle school second-grade

When the test analysis result in the table is examined, it is seen that 12 results are positive, 26 results are equal, and five results are negative if the consistent and scientific knowledge structure scores of the second-grade students in middle school are subtracted from the coherent and scientific knowledge structures scores of the third-grade students in middle school. Based on this result, it is clear that the consistent and scientific knowledge structure scores of the third graders in middle school are higher than those of the second graders in middle school. In addition, according to the Wilcoxon Signed Rank Test result, a significant difference is observed between the consistent and scientific knowledge structure scores of the third-grade students in middle school and the consistent and scientific knowledge structure scores of the second-grade students in middle school (Z=-2.173, p<.05, r=.32). In order to determine which class level is in favor of this difference, the mean values of the rows are checked. A higher mean of ranks means higher scores. When the mean of ranks for the measurements of the second graders in middle school is = 6.50, the mean of ranks for the measurements of the third graders in middle school is = 10.04. Therefore, this difference is in favor of coherent and scientific knowledge structure scores of the third-grade students in middle school. In other words, the student-level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is moderate (*r*=.32).

Table 7

The Number of Students Giving Consistent and Inconsistent Answers According to Grade Level Regarding the Related Concepts

	Middle school first-grade	Middle school second-grade	Middle school third-grade
Number of students who responded scientifically consistent	5	18	30
Number of students with non-scientific consistent response	13	10	9
Number of students with inconsistent response	25	15	4

When Table 7 is analysed, it is observed that in the first grade of middle school, the number of students giving scientifically consistent answers was five, the number of students giving non-scientifically consistent answers was 13, and the number of students giving inconsistent answers was 25. In the second grade of middle school, the number of students giving scientifically consistent answers was 18, the number of students giving non-scientifically consistent answers was 10, and the number of students giving inconsistent answers was 15. In the third grade of middle school, the number of students giving scientifically consistent answers was 30, the number of students giving non-scientifically consistent answers was nine, and the number of students giving inconsistent answers was four.

Discussion and Conclusion

In this part of the study, the findings obtained from the research questions are compared with a few research findings in the literature. In the research, the findings related to the scientific and consistent knowledge structure and the process of development of the students regarding the related concepts were discussed within the scope of the knowledge in pieces conceptual change theory and the theory-like conceptual change theory.

Within the scope of the first research question, whether there is a significant relationship between the students' class levels and the scientific and consistent knowledge structure scores related to the concept of melting and dissolution is investigated. According to the findings in Table 2, there is a moderate, positive, and significant relationship between student level and consistent and scientific knowledge structure scores (r_s=.305, p<.05). According to this result, it can be said that as the students' level increases, the scores of consistent and scientific knowledge structures related to the concepts of melting and dissolution increase (Kilmen, 2015). In addition, Table 7 shows that the number of students giving scientific and coherent answers increased as the grade level increased, which supports this finding. This research finding indicates an increase in students' scientific knowledge of the related concept, which is one of the important factors in the formation of scientific and consistent knowledge structures about a concept, and also stated in the related conceptual change theories. Therefore, these findings are consistent with conceptual change theories (diSessa, 2014; Vosniadou, 2012).

The scores obtained in the first, second, and third grades of middle school regarding the scientific and consistent knowledge structures of the students are compared within the scope of the second research question. According to the analysis result in Table 3, a significant difference is found between the scores obtained from the students' consistent and scientific knowledge structures related to the concepts of dissolution and melting in the first, second, and third grades of middle school (X^2=19.872, p<.05). Wilcoxon Signed Rank Test was used for dual comparisons between the first and the second grade of middle school, the first and third grade of middle school, the first and third grades of middle school, and the third and second grades of the middle school in order to find out between which grades this difference is.

According to the first comparison results (Table 4), a significant difference is found between the consistent and scientific knowledge structure scores of the second graders of the middle school and the consistent and scientific knowledge structure scores of the first-grade students of the middle school (Z=-3.087, p<.05, r=.46). This difference is in favor of the consistent and scientific knowledge structure scores of the second-grade students of the middle school with a high mean of ranks (Table 3). The student-level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is moderate (r=.46).

For the second comparison (Table 5), a significant difference is found between the consistent and scientific knowledge structure scores of the third grade of the middle school and the consistent and scientific knowledge structures scores of the first grade of the middle school according to the test results (Z=-3.740, p<.05, r=.56). This difference is in favor of the consistent and scientific knowledge structures scores of the third-grade students of the middle school with a high mean of ranks (Table 4). The student class level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is high (r=.56).

In the third comparison (Table 6), based on the test results, a significant difference is found between the consistent and scientific knowledge structure scores of the third-grade students of the middle school and the consistent and scientific knowledge structures scores of the second-grade students of the middle school (Z=-2.173, p<.05, r=.32). This difference is in favor of the consistent and scientific knowledge structure scores of the third-grade students of the middle school with a high mean of ranks (Table 6). The student class level variable has a significant effect on students' consistent and scientific knowledge structures. This effect is moderate (r=.32).

When the findings obtained in the research and the graph in Figure 1 are evaluated together, it can be stated that the students' consistent and scientific knowledge structures regarding the concept of melting and dissolution become more scientific and consistent as the students' class level increases. The findings of the research are in harmony with the statement, "Students' knowledge structures about a concept become scientific and consistent as their knowledge about that concept increases," which is emphasized in the knowledge in pieces conceptual change theory and the theory-like conceptual change theory (diSessa, 2014; Vosniadou, 2012).

Moreover, when Table 4, Table 5, and Table 6 are examined, the closeness of the mean of ranks indicates that the scientific and consistent process of students' knowledge of the concepts of melting and dissolution takes place slowly and gradually. This research finding is in harmony with the related conceptual change theories. Also in the literature, Clark (2006), diSessa et al. (2004), Ozdemir (2007), Ozdemir (2018), diSessa (2014), Smith et al. (1994), and Vosniadou (2012, 2019) state in their research that scientific and consistent knowledge structures in students are formed as a result of a slow, long and gradual process. These statements support the research findings. However, when Sagdıc and Sahin's (2023) research on the phases of the moon is compared to our study, it is observed that students make conceptual changes in a shorter time. This contradiction can be attributed to the fact that many factors are effective in conceptual change.

When Table 7 is analysed, it is seen that the number of students giving inconsistent answers has the highest frequency among the first-grade middle school students. It is also noteworthy that the number of students giving inconsistent answers decreases as the grade level increases. In the related table, it is seen that the number of students giving scientific and consistent answers increased, while the number of students giving non-scientific and consistent answers did not change much. These findings show that students' knowledge structures about the related concepts transformed from a fragmented structure to a coherent scientific structure. When all the findings of the study are evaluated together, it can be said that the development process of students' knowledge structures for the related concepts is more compatible with the knowledge process in the theory of the knowledge in pieces conceptual change theory.

In the longitudinal studies on the subject in the literature, Øyehaug and Holt (2013) conducted two years of longitudinal research and found that students' knowledge structures regarding the concepts of the substance and chemical reaction are fragmented and inconsistent; it gradually develops towards an integrated and coherent structure. Another research in the literature is Clark's (2006) longitudinal study on students' knowledge structures on the subject of thermodynamics. It shows that students' knowledge structures about thermal equilibrium evolve from an inconsistent structure to an integrated and consistent structure. The common finding of the studies given above in the literature is that students' knowledge structures become more scientific and consistent over time. With the related finding, it can be stated that the mean ranks of the students' scientific and coherent knowledge structure scores in the related table (Table 2) obtained from the research show parallelism to the finding obtained from the first grade of the middle school to the third grade of it.

Although there are few longitudinal studies within the scope of this subject in the literature, there are some studies whose findings are compatible with our research at different class levels. In the literature, Ozturk and Doganay (2013), in their research, examined the students' knowledge structures about the Earth's shape and gravity from the first grade to the fourth grade of the middle school. As a result of the research, they came up with the result that there is an increase in the scientific and consistent knowledge structures of the students from the first grade to the fourth grade of the middle school. Bilir and Karacam (2021), who examined the knowledge structures of pre-service science teachers regarding the concept of chemical reaction, revealed that the knowledge structures of the students become more scientific and consistent as the education level increases. Durmus and Donmez-Usta's (2020) research makes it clear that the knowledge structures of the concept of melting are more scientific for fourth-grade students compared to third-grade students. The study by Atasoy et al. (2020), which includes all levels of primary school consisting of one hundred students for each grade, demonstrates that their students' knowledge of marine environments is parallel to their education level. The common result of the studies above in the literature supports the finding of this research: "As the education level of the students increases, the knowledge structures of the students become more scientific and consistent." The relevant finding coincides with the characteristics of the scientific and consistent knowledge development process of students stated by the relevant conceptual change theories. Another study in the literature by Ulu and Ocak (2018) determined that the knowledge structures of the fourth grade of primary school and the first grade of middle school science lessons did not differ. This finding contradicts the research finding. This contradiction can be attributed to the slow and gradual realization of the knowledge structure development process when the mean ranks of the students are examined, as found in our research findings (Table 3).

As the student class level increases, many factors can be effective in increasing the scientific and consistent knowledge structures of the students. Relevant factors can be expressed as follows: The field and pedagogical competence of the teacher who guides the education and training process (Fulmer, 2013), the models, methods, and techniques used in the education and training process (Sozcu & Aydinozu, 2018; Turk at al., 2016), developing students' theoretical reasoning skills as students' cognitive development shifts from concrete operations to abstract operations (Cepni, 2016; Lawson, 1995), the increase in students' knowledge about the concept and their accessibility to scientific knowledge more (diSessa, 2014; Ozdemir, 2007; Ozdemir, 2018) and students' reaching to sufficient or insufficient number of examples regarding the concept (Saygili, 2015; Tas & Karatas, 2012).

It should be noted that the findings from the research are valid for the concepts of melting dissolution and the participants taking part in the study. In another study, different findings may be concluded about the melting dissolution or other concepts in the science curriculum. As stated above, many factors are effective in increasing the scientific and consistent knowledge structures of students about a concept. As mentioned above, although this research is a longitudinal study, it does not show that students' conceptual change process for all concepts will be realized in this way. However, all research on students' knowledge structures contributes to a better understanding of students' knowledge structures, and teachers, who are the guides of the teaching process, can design the teaching process in accordance with this process (Sherin et al., 2012). As a natural consequence of this situation, it becomes easier for students to learn concepts in a meaningful way and to acquire scientific and coherent knowledge structures.

In summary, the findings of the research are found parallel to the statement, "Students' knowledge structures about a concept gradually and slowly become scientific and consistent as their knowledge about that concept increases," which is emphasized in the knowledge in pieces conceptual change theory and the theory-like conceptual change theory. When all the research findings are evaluated together, it can be said that the development process of the students' knowledge structures for the related concepts is more in line with the knowledge in pieces conceptual change theory.

Suggestions

Based on the results obtained, conceptual change theories can be taught to prospective teachers in education faculties as a course at the undergraduate level. By signing a protocol between the Ministry of National Education and the Higher Education Board, in-service training on the theories of conceptual change can be given to teachers. Science curricula and textbooks can be arranged according to conceptual change theories. Similar longitudinal studies could be carried out by increasing the number of participants and length of the research period for other concepts in the science curriculum.

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Statement of Responsibility

Mehmet Ali Kandemir: Literature review, data collection tool development, data collection and analysis, expert opinion, writing the text, visualization, conclusion and discussion.

Zeki Apaydın: Literature review, text review and editing, data collection tool development, data collection and analysis, expert opinion, conclusion and discussion.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author Bios:

The corresponding author, Mehmet Ali Kandemir, is a primary school teacher doctoral student. He works as a classroom teacher in the Ministry of National Education. He has 18 articles on argumentation, conceptual change theories, active learning, inclusive education.

Second author Prof. Dr. Zeki Apaydın is a lecturer at Ondokuz Mayis University, Faculty of Education, Department of Basic Education. He has more than 30 articles on argumentation, modelling, conceptual change theories, active learning, inclusive education.

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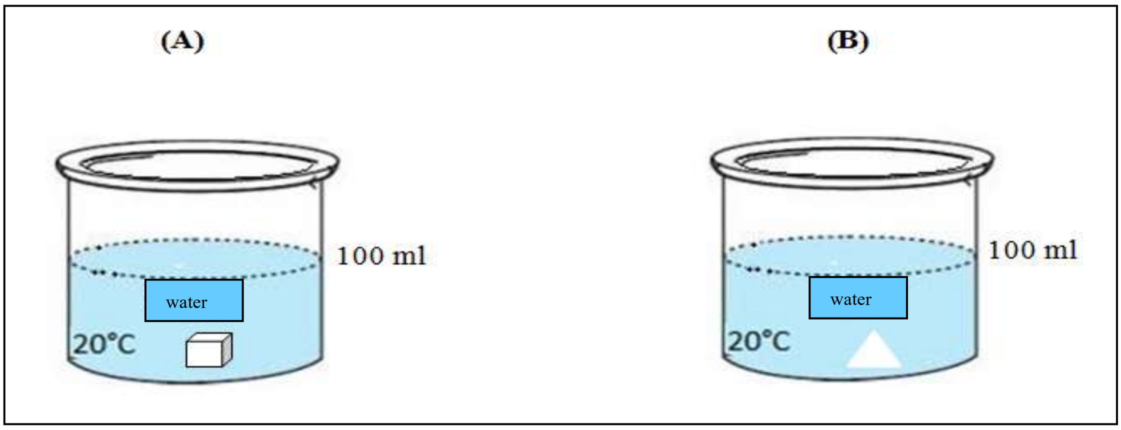
Appendix-1

Open-Ended Questionnaire for the Concepts of Melting and Dissolution (Question Examples)



Note: Conditions are equal.

1. (A) What happens to the sugar if we put a sugar cube in the graduated cylinder and mix it?

………………………………………………………………………………………………

………………………………………………………………………………………………

2. (B) What happens to the salt if we put salt in the graduated cylinder and mix it?

………………………………………………………………………………………………

………………………………………………………………………………………………

3. (A) Where do you think the sugar mixed in the graduated cylinder is? How do you prove the presence or absence of sugar?

………………………………………………………………………………………………

………………………………………………………………………………………………

4. (A) Did the sugar maintain its solid condition? Why?

……………………………………………………………………………………………

5. (B) Where do you think the salt mixed in the graduated cylinder is? How do you prove the presence or absence of salt?

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6. (B) Did the salt retain its solid state? Why?

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7. What can be said about the mass of the sugar if we put a sugar cube into a graduated cylinder with water and mix it?

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8. What we put a sugar cube into a graduated cylinder with water in it and mix it, what can be said about the volume of the sugar?

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9. There are two differently graduated cylinders with the same amount of water and the same temperature. First, the same amount of sugar cubes were placed into these graduated cylinders. Then, some water with the same temperature was added into one of the graduated cylinders. Accordingly, in which graduated cylinder does the sugar dissolve faster?

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10. If we put the same amounts of rock salt and powdered salt into two different graduated cylinders containing the same amount of water at the same temperature, in which graduated cylinder will the salt dissolve faster?

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