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Research Article

A Different Approach to Preparing Novakian Concept Maps: The Indexing Method*

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Abstract

People who claim that applying Novakian concept maps in Turkish is problematic base their arguments largely upon the structural differences between the English and Turkish languages. This study aims to introduce the indexing method to eliminate problems encountered in Turkish applications of Novakian maps and to share the preliminary results of its application. For this purpose, 20 pre-service chemistry teachers who had mastered the concept-mapping method after seven weeks of intense education were asked to prepare concept maps on the topic of atoms by using both the Novakian and indexing methods. The maps were qualitatively assessed by experts regarding informational content. The participants were asked to state in writing their opinions about the indexing method. The resulting analysis revealed that the participants were able to express the relation between two concepts more realistically when they used the indexing method, and the resulting maps were much richer in informational content. Almost all participants (95%) stated that the new method was more convenient in terms of reflecting the necessary mental information. The results of the study show the indexing method to be a much more convenient and informative way of preparing concept maps for both teachers and students.

Keywords

Concept maps • Concept mapping tasks • Indexing method • Pre-service Chemistry teachers • Opinions of pre-service teachers

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The meaning of a concept depends on how it is understood in relation to other concepts. In other words, in order to understand what a concept means, one must see how it is placed into an informational structure (Taber, 2002, p. 31). Mastering a certain topic means having sound knowledge about the related conceptual structure (Ruiz-Primo, Shavelson, & Schultz, 1997a). Concept maps can enlighten a significant portion of these relations (Ruiz-Primo, Schultz, & Shavelson, 1997b). This is why concept maps are very useful in promoting meaningful learning and determining whether this type of learning has taken place or not. The various uses of concept maps in the learning process are as follows. Concept maps:

- help students understand how a concept is mentally located during the learning process (Novak, 1990).
- provide teachers with the opportunity to organize knowledge in the educational process and offer students the opportunity to find key points and major principles in the teaching material (Novak, 1998, p. 27).
- are very useful for teachers in perceiving students' mental models and in planning lectures in accordance with their needs and interests (Kinchin, Hay, & Adams, 2000).
- indicate inadequacies in students' informational structure (Francisco, Nakhleh, Nurrenbern, & Miller, 2002).
- are unique graphical tools for showing how students should organize, relate, and synthesize knowledge. This is why concept maps are highly useful for both teachers and students (Vanides, Yin, Tomita, & Ruiz-Primo, 2005).
- can be used to determine how students relate concepts, their prior knowledge, and their alternative conceptions (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996).
- are very useful for enlightening students' misconceptions (Taşçı, 2015; Djanettea & Fouadb, 2014; Aykutlu & Şen, 2012; Çıldır & Şen, 2006; Karamustafaoğlu, Ayas, & Coştu, 2002).

Concept mapping is a method developed by Novak in the 1970s based on Ausubel's (1968) meaningful learning theory (Novak & Gowin, 1984; Novak & Musonda, 1991). Concept maps are two-dimensional schemes that enable one to express concepts mentally and relate them pictorially (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; Safayeni, Derbentseva, & Cañas, 2005). Its basic units are concepts and relationships among them. Concepts are connected to each other through relational lines. The relationship (a word or short phrase) is written above these lines (Novak & Cañas, 2008). The resultant phrase expressing the relationship between two concepts is called a *proposition*, the major component of concept maps (Novak & Gowin, 1984; Ruiz-Primo et al., 2001).

Concept maps were first developed by Novak in English. In accordance with the syntax structure of the English language, if one follows the order of the first concept, relational phrase, and second concept, one is provided with a meaningful clause describing the relationship between the concepts. This is because the syntax order of the English language (subject + verb + object) is highly suitable for this type of application. However, in non-Latin, agglutinative languages such as Turkish, Hungarian, Mongolian, Finnish, Slovakian, Korean, or Japanese where the syntax order differs being a non-modal suffix-additive type, the application of this method becomes highly problematic because the sequential reading of 1st concept + verb + 2nd concept do not often provide a meaningful clause. Lee (1999) claimed that the syntax difference in Korean and Japanese makes the preparation of Novakian concept maps highly cumbersome. Park and Kim (2008) stated that there are syntax problems in preparing concept maps in Korean, and they added an adverbial word between the concepts to avoid these types of problems.

The syntax order of the Turkish language (subject + object + verb) causes problems if concept maps are prepared based upon English syntax. If one reads a content map prepared in Turkish in the sequential order of the English language, the resulting clauses are often meaningless or hard to understand. In order to obtain a meaningful clause in Novakian concept maps in Turkish, it must be read in the order of 1st concept + verb + 2nd concept. Sometimes the order of 1st concept + 2nd concept + verb gives almost meaningful phrases. Examining the examples of propositions in Figure 1, if one chooses the first option in the first proposition, a perfectly meaningful clause is obtained, such as "*element atomlardan oluşur*" (Elements are formed from atoms) in total compliance with Turkish syntax. If the second order in the second proposition is chosen, then one ends up with the understandable but somewhat distorted clause "*atomlar kimyasal yollarla birleşerek oluştururlar bileşik"* (Atoms combined through chemical ways form compounds). The change of the reading order according to the language used causes quite a bit of ambivalence when concept maps are used for evaluative purposes (note: If one literally translates from Turkish into English, the clause may make sense in English but may be hardly understandable and distorted according to Turkish syntax. Therefore some sentences will be given in total accordance with the reading order in order to emphasize this point).

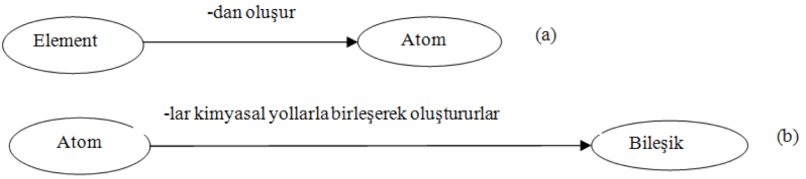


Figure 1. Examples of propositions.

The fact that English is a prefixed language and Turkish is suffixed, along with the difficulty in expressing suffixes in concept maps, causes inevitable shifts in expressions. In Turkish, in order to form an understandable and syntaxially sound clause, one has to add suffixes to the verb (İngeç, 2009). When examining the first proposition in Figure 1, it seems to mean that elements are formed from a single atom due to the difficulty involved in writing the suffixes into the concept maps. If this expression had been written in answer to an open-ended question, it would be regarded as a misconception. Therefore it is highly difficult to determine whether the misconception was intrinsic to the student or the student had written it like that due to the nature of concept maps. The evaluation must be free of these sorts of dilemmas to be reliable and valid.

This immense difference between English and Turkish lingual syntax causes problems in preparing Novakian concept maps in Turkish (Turan & Ekmekci, 2011; İngeç, 2009; Sağlam, 2009; Ünlü, İngeç, & Taşar, 2006; Bağcı Kılıç, 2003). Ünlü et al. (2006) reported in their study that they had had too many problems due to the syntaxial differences between Turkish and English and that the expressions between the concepts describing their relationship were often not compatible with Turkish grammar. They claimed that this syntaxial distortion may well result in misconceptions. Similarly, Sözbilir and Neacşu (2014) stated that the incompatibility of Novakian concepts maps with Turkish had caused problems in describing relationships between concepts. They said that these problems were the greatest disadvantage in using concept maps in Turkish. Didiş, Özcan, and Azar (2014), in their study carried out with physics teachers working in schools where the medium of instruction was in Turkish or English, discovered that participants had too many problems constructing concept maps in Turkish, which was further verified by analyzing the resultant concept maps. İngeç (2009) reported in her study on pre-service physics teachers that the participants' concept map scores were much lower than their scores on multiple-choice questions. The researcher concluded that they knew the concept but could not express them on their maps. This situation was attributed to the syntaxial difference between Turkish and English. Turan and Ekmekci (2011) in their study involving 22 pre-service chemistry teachers regarding concept maps, determined that one of the

problems that had immediately emerged was the syntaxial incompatibility between Turkish and English. Similarly, Ünlü et al. (2006) observed that participants had managed to perfectly relate the concepts with each other, but had failed to write down the relational clauses. The authors explained this situation as being due to the syntaxial difference between Turkish and English, pointing to the poorly constructed clauses that resulted from phrases employed to describe the relationship between two concepts. In the study carried out by Bilici, Doğan, and Avcı (2015) where they investigated the effectiveness of concept maps in Turkish as an education tool most students were found to have a hard time writing relational phrases between concepts. Bağcı Kılıç (2003), in his study carried out upon 134 primary education students, realized that 63.6% of students had difficulty writing relational clauses between concepts and that they had resorted to alternative methods, such as writing a complete sentence above the concepts, writing the relationship in textual form under the map, or trying to make oral explanations. Although all three methods remedied the problems stemming from writing the relationship in a one- or two-word phrase in Turkish, they had certain limitations (Sağlam, 2009). Writing whole sentences complicated the maps and made them extremely difficult to evaluate. The second method did not allow the reviewer to make a relation-based assessment. The third method made the map evaluations take too long.

The first method designed to obviate the problems involved in Novakian maps in Turkish was Sağlam's (2009) numbering method. According to this method, relational phrases are replaced by numbers, which are explained in complete sentences on a different page due to inadequate space on the concept-map page. The author found that, although this method resulted in uniform concept maps, it was difficult to follow the relationships and explanations on a separate page (Sağlam, 2009). The method was observed to correct the poorly constructed sentences for the propositions, but it demanded more time to write explanations onto a separate page, which made it very cumbersome to follow. It also violated the basic principle of concept maps, which is to have all concepts and relationships seen on the same page.

According to Novak and Gowin (1984), concept maps can be employed as a learning strategy, a tool for planning to teach curriculum, and an evaluation tool. Similarly, Taber (2002) claims that concept maps can be utilized as educational, evaluative, learning, and self–assessment tools. The readability of concept maps becomes much more important when used as an assessment tool for illuminating how students relate concepts to each other (Edmonson, 2000, p 20). Assessors can only measure participants' mental concepts as reflected on paper. Therefore, the reliability and validity of assessments are largely dependent upon the clarity of phrases on the maps. People who claim that preparing Novakian maps in Turkish is

highly problematic point to the problem of reading maps in Turkish as evidence of their claim (Bağcı Kılıç, 2003; Didis et al., 2014; Sağlam, 2009; Turan & Ekmekci, 2011; Ünlü et al., 2006).

The main goal of concept maps, different from mind-maps, is to elucidate concepts and the relations among them to fully illuminate the conceptual structure (Novak & Musonda, 1991). Therefore, writing relationships clearly and understandably is of double importance with regard to elucidating students' conceptual structures through the use of concept maps (Novak & Gowin, 1984). Şahin (2001) found that pre-service teachers used concept maps mostly to see concepts in an organized manner. Similarly, Gündüz (2014) found that teachers resort to concept maps for presenting topics in an integrated, meaningful, and permanent format. If one thinks in this pretext, the problems encountered in preparing concept maps in Turkish are the greatest barrier to using them in line with this purpose. Bağcı Kılıç (2003) claims that it is not possible to write in Turkish the relationships among concepts in concept maps that were originally designed for English due to the syntaxial differences between these two languages. Because of that, the author claims that Novakian concept maps are not suitable for Turkish. However, concept mapping is a very unique method for enlightening conceptual structures in students' minds, and is too valuable to abandon it due to some application problems. At this point, we suggest a new method, the *indexing method*, developed by the authors to increase the readability of concept maps and to provide the opportunity to express concepts more distinctly and clearly. The purpose of this study is to illustrate the efficiency of the indexing method and gather pre-service teachers' opinions about using this method.

Method

Pilot Study

This study is part of the first author's doctoral dissertation, investigating and comparing three types of existing concept maps: Novakian, numbered, and fill-in-the-blank. All three methods were assessed by a group of pre-service chemistry teachers in terms of their advantages and disadvantages. The participants (N = 25) were observed to have difficulties, particularly with finding relations in Novakian concept maps, which are supposed to provide grammatically correct clauses when read sequentially. The participants stated they had failed to write the appropriate phrase even when they knew the relation. This situation was subjected to in-depth analysis to define and find a remedy to these problems. The authors developed an alternative method, the *indexing method*, which could be a solution to all these problems.

Developing the Indexing Method

The indexing method was developed over the subject of covalent bonds with five participants chosen arbitrarily from the entire sample of the pilot study. The participants first prepared Novakian concept maps, which were assessed with regard to the relationships among concepts. The participants were then interviewed by the author and asked to verbally state the relations on their concept maps. The participants had been observed to verbally explain 50% of the relations correctly, but this ratio was not reflected onto their concept maps. They were then asked what should be done to remedy this situation. The relative problem was determined to be certain situations where the relational phrase between two concepts should include a third concept as well. For example the true relationship between atoms and covalent bonds should be "a covalent bond is formed between nonmetallic atoms" (*kovalent bağlar ametal atomları arasında oluşur*). However, almost every participant expressed this as *"the covalent bond is formed between atoms"* (kovalent bağ atomlar arasında oluşur). They realized that something was missing in this picture and immediately stated that "it is not between every atom but between the nonmetallic atoms" during the interview. It was as if the problem could be solved by separating the relational phrase. However, another problem immediately emerged: What should be the order of words when the phrase is read? There author proposed an ingenious way to cope with this problem: The relational phrase is separated into two parts and indexed with a "1" and "2;" these numbers refer to Concept 1 and Concept 2, as numbered arrows also indicate. If the relational phrase indexed like that is read as *Concept 1 + first-indexed proposition* followed by *Concept 2 + second-indexed proposition*, it gives a perfectly meaningful clause in complete compliance with Turkish syntax. The participants were then asked to construct the relation in accordance with the new method. All five participants unanimously agreed that the new method was better than Novakian concept maps for expressing their knowledge. The effectiveness of the indexing method was thoroughly compared with Novakian concept maps in the framework of the main study.

Indexing Method

This method provides a new point of view on Novakian maps and is thought to be able to simplify and increase their usefulness. The basic principle of the new method is to construct meaningful sentences from the relational phrases by using the indexing process. If the indexed proposition formed between two concepts is read in the order of *1st concept + first-indexed relational phrase* then *2nd concept + second-indexed relational phrase*, one ends up with a perfectly sound sentence describing the relationship. For instance, the proposition between the concepts of atom and ion (see Figure 2) when not using the indexing method result in the clause "atom

(atom) electron (electron) kaybederek (by losing) veya (or) kazanarak (by gaining) oluşturur (forms) iyon(ion)," which, though sensible in English, is incompatible with the syntaxial structure of Turkish. On the other hand, when using indexing, this proposition becomes *atomlar elektron kaybederek veya kazanarak iyon oluştururlar*; this literally translates as *atoms electron by losing or by gaining ion form*; this complies perfectly with Turkish grammatical structure. In addition to the suffix added at the end of verb to complete the sentence in Turkish, a (+) can be written in front of the relational phrase to connect the numbered concepts appropriately.

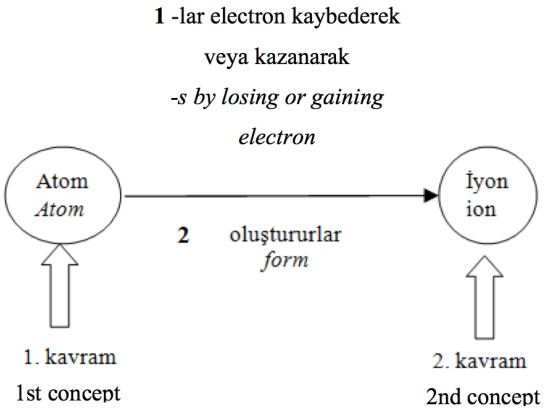


Figure 2. Indexing method.

The conceptual inadequacy in Turkish for the proposition from Figure 1 (*element atomdan oluşur,* or element from atom is formed) is eliminated when it is subjected to indexing method (*elementler aynı tür atomlardan oluşur*, or elements from the same types of atoms are formed). It is clear that the use of indexing results in a much more conceptually sound and meaningful Turkish clause. The fact that suffixes to be used are indicated on the same page as the concepts makes the resulting clause much more meaningful.

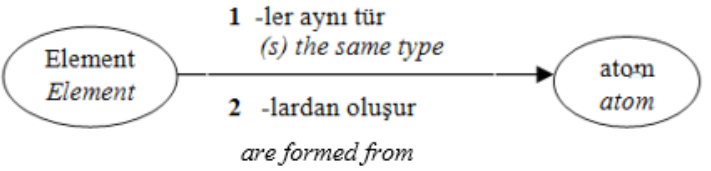


Figure 3. An example of a proposition prepared using the indexing method.

The indexing method developed by the authors is based upon Novak's method. Placing a single word upon the arrow between concepts is enough to indicate the relationship between some concepts. For instance, if one takes the concepts of

elements and *atomic number* and places the word *ordered* above the relational arrow, the final clause would be given as *elements are ordered according to their atomic numbers*. The indexing method is better suited for expressing relations that require more than one word. For one-word simple expressions, the customary Novakian approach fully suffices.

Research Design

The case-study research design was used here in order to make an in-depth analysis of the participants' concept maps, which they had prepared using two different approaches, and to verify the effectiveness of the indexing method. Case-study research models provide in-depth information about a situation by using qualitative and quantitative techniques (Patton, 2002). It is mainly employed to unveil details of a complex situation and collect in-depth information on it (Taber, 2007).

Participants

The study was carried on 20 female and three male pre-service teachers studying in their 4th year at the Chemistry Education Department. However, the male participants were discarded from the study because they had contributed very little to the whole study. Çatalkaya (2005) stated that gender plays no role in the process of making concept maps. Therefore, the fact that the participants were formed only from female students causes no problem. The study was carried out using the purposive sampling method, which is in complete accordance with normal qualitative studies. According to Patton (1987), random sampling allows one to make valid generalizations due to its representational power, while purposive sampling enables one to perform in-depth analyses and draw detailed information about the case (Yıldırım & Şimşek, 2008). The participants had seven weeks of detailed education on constructing and grading concept maps. During this period, the participants prepared concept maps using three different methods (indexing, Novakian, numbering) on different topics in chemistry (matter, periodic table of elements, covalent bonds). Also, their education was directed toward equipping the participants with the capacity to evaluate concept maps. The purpose of this education was to have the pre-service teachers equipped with expert knowledge about preparing and grading different types of concept maps so as to increase the reliability of the study. Srinivasan, McElvany, Shay, Shavelson, and West (2008) stated that mastery increases with constant learning, practice, experience, and feedback. After seven weeks of intense training, the participants were regarded to have become sufficiently acquainted with preparing and assessing concept maps.

Data Collection and Analysis

The effectiveness of the newly developed indexing method was verified in three different ways, as listed below:

1. The content of the propositions obtained through the indexing method were compared with similar propositions on Novakian concept maps.
2. The maps were converted into a textual format by their peers, and these final texts were examined by the author.
3. Content analysis was performed using the pre-service teachers' opinions.

In order to test the effectiveness of the indexing method, the participants were asked to prepare concept maps with 14 concepts about atoms using the Novakian and indexing methods. The purpose of this practice was to define whether there were any differences regarding content as a result of the mapping method, regardless of using the same concepts. The author examined the relationships formed by each participant in both maps one by one using content analysis in terms of the conceptual correctness and syntaxial clarity of the established propositions. There were 570 propositions stored on computer media. The relationships between the same concepts established by each participant in two different maps were compared with regard to clarity and correctness. Phrases that showed differences regarding conceptual content and correctness on the different maps were indicated in different colored boxes. The relationships were classified under five categories: correct phrase, wrong phrase, conceptual error, inappropriate for the scientific model, and phrase with excess information. The analysis table of one participant has been given in Figure 5 as an example. The operational descriptions of the categories are presented in the Appendix. The analysis tables of each participant were checked by an expert in regard to the coding of each phrase. Inappropriately coded relations were re-coded. Reliability between coders was computed using the formula of [agreement / (agreement + disagreement)] x 100, as developed by Miles and Huberman (1994). The reliability coefficient was found to be 95.08 after the expert's examination. There were a total of 570 propositions from both Novakian and indexed concept mappings (285 from each type). There were incompatibilities in 28 of the propositions between coders. These differences were eliminated after nine phrases observed to contain conceptual errors and mislabeled as "correct" were re-coded as "conceptual error," seven phrases coded as "concept error" were re-coded as "incompatible with the scientific model," and 12 phrases coded as "correct" were re-coded as " phrase with excess information."

Explanations	Novakian proposition	Indexing proposition	Explanation
Correct phrase	Elementler "-dan oluşur" atomlar. *(elements "-formed from" atoms)*	Elementler farklı cins atomlardan oluşur. *(element are formed by same types of atoms)*	Phrase with excessive information
Correct phrase	Atomlar "haline dönüşebilir" iyon. *(Atoms "converted" ions)*	Atomlar elektron alış verişi yaparlarsa iyon durumuna geçer. *(Atoms are converted in to ions when they exchange electrons)*	Phrase with excessive information
Incompatible with the scientific model	Yörünge "-da yer alır" atomlar. *(Orbital "–is in" atoms)*	Atomlarda yörünge bulunur. *(orbitals are in atoms)*	Incompatible with the scientific model
Wrong phrase/the arrow is placed in wrong direction	Atom modeli "-ın tarihsel gelişiminde yer alır" atomlar. *(atomic model "are in the historical development of" atoms)*	Atomlar tanımlanırken 4 çeşit atom modelinden yararlanılır. *(There are 4 types of atomic models used in the description of atoms)*	Correct phrase
Correct phrase	Çekirdek "–da yer alır" atomlar. *(Nucleus "–are in" atoms)*	Atomlarda çekirdek bulunur. *(There is a nucleus in an atom)*	Correct phrase
Incompatible with the scientific model	Elektron "-de yer alır" yörünge. *(Electrons "are in" orbital)*	Yörüngede hareket halinde elektronlar bulunur. *(There are moving electrons in orbital)*	Incompatible with the scientific model
Correct phrase	İyonik bileşik "arasında elektron alışverişiyle oluşur" atomlar. *(Ionic compound "are formed by electron exchangebetween" atoms)*	İyonik bileşiklerin formülleri iyon yüklerinin çaprazlanmasıyla oluşturulur. *(Ionic compounds formulas are formed by crossing Ionic charge)*	Phrase with excessive information
Correct phrase	Anyon "çeşididir" iyon. *(Anion "is a type of" ion)*	İyon elektron aldığında anyon oluşur. *(When ion gains electron an anion occurs)*	Concept error
Correct phrase	Katyon "çeşididir" iyon. *(Cation "is a type of" ion)*	İyon elektron verdiğinde katyon oluşur. *(When ion loses electron an cation occurs)*	Concept error
Correct phrase	Nötron "–te yer alır" çekirdek. *(Neutron "are in" nucleus)*	Çekirdekteki yüksüz taneciklere nötron denir. *(The uncharged particles called neutrons in the nucleus)*	Phrase with excessive information
Correct phrase	Proton "–te yer alır" çekirdek *(Proton "are in" nucleus)*	Çekirdekte bulunan + yüklü taneciklere proton denir *(The positive charged particles called protons in the nucleus)*	Phrase with excessive information
Correct phrase	Atom numarası "sayısı olarak da söylenir" proton *(Atomic number "is also called as" number of protons)*	Atom numarasına çekirdek yükü de denir. *(The atomic number is also called as nuclear charge)*	Correct phrase
Correct phrase	Kütle numarası "– na bağlıdır" atom numarası *(mass number "depends on the" atomic number)*	Atom numarası nötron sayısı ile toplanınca kütle numarası elde edilir. (when number of neutron and *atomic number summed up mass number is obtained*)	Phrase with excessive information
Concept error	İzotop atom "farklıdır" atom numarası (*isotope atoms "are different" atomic numbers*)	İzotop atomlarda atom numarası farklıdır. *(The atomic numbers of isotope atoms are different.)*	Concept error

Melek

Figure 4. Content analysis of Novakian and indexed concept maps.

The pre-service teachers were then asked to write down their opinions about the two methods, taking into account the maps they had prepared. They carried out this activity within the framework of the questions, "Which method do you think was more successful, why, and what point do you base your conclusion upon?" The opinions of the participants were subjected to a thorough content analysis. The basic process of the content analysis is to gather similar concepts and themes and arrange them in wording that everyone can understand (Yıldırım & Şimşek, 2008). The pre-service teachers' clauses were examined by the primary researcher who had established the codes and raw themes. Forty-two codes and six basic themes were established for the participants' phrases. The raw data was first coded by the main author, then the data was subjected to a thorough review by two experts for the reliability of the research. The first expert was given the raw data (not including the coding carried out by the researcher) and was asked to code from the beginning. For this purpose, both the operational descriptions of the themes were prepared and an expert examination form that included the operational descriptions was formed. The forms were given to an expert with a PhD in a qualified field, and she was asked to carry out the coding again. The coding of the researcher and the expert were compared, and consistency of the coding was determined by labeling each code as "agreed" or "disagreed." The reliability between coders was determined by using the following formula: [agreements / (agreements + disagreements)] x 100, as developed by Miles and Huberman (1994). The fact that the coding process was carried out by an expert

who had started from scratch increased the reliability of the study. The expert was allowed to use new theme names. When the codes and theme names determined by the researcher and the second coder were examined, one disagreement regarding the name of a theme remained between them. The reliability ratio was found to be 80.95 between the two coders. Taking this low value into account, the researcher, together with the first expert who had carried out the coding process, re-examined all the codes and theme names. The resulting codes and theme names were given to a second expert for the final check. In other words, the researcher and the first expert carried out the coding separately, and the second expert checked both of them. The codes and themes, which had taken their final shape, were presented with excerpts taken from the participants' opinions.

The maps that the pre-service teachers prepared using two different methods (Novak and Indexing methods) were photocopied while hiding the names of the participants and arbitrarily distributed to the other participants. The reason for distributing the different types of maps to various peers was to obviate drawing alternative conclusions from the second map in case the first map was not understood. The participant, acting as a peer, was asked to give a number to each relation and write down the relation as she understood it. The purpose of this practice was to determine whether the message of the maps was clear to someone other than the participants and whether the preparation method had caused any difference in terms of meaning when the map was read by a peer. Figure 5 shows an example of the maps' peer review. The maps were then distributed to 40% of the participants, arbitrarily chosen in order to have different maps read by different peers. The goal here was to determine whether two different peers would read the propositions in the Novakian and indexed maps the same way. The maps that the participants had converted into a text format were examined by the researcher last. The practice of having the maps read by another person serves the purpose of understanding how participants formed the relations between two concepts. This concluded our quest to compare Novakian and indexed maps regarding readability. The data were presented together with the participants' propositions.

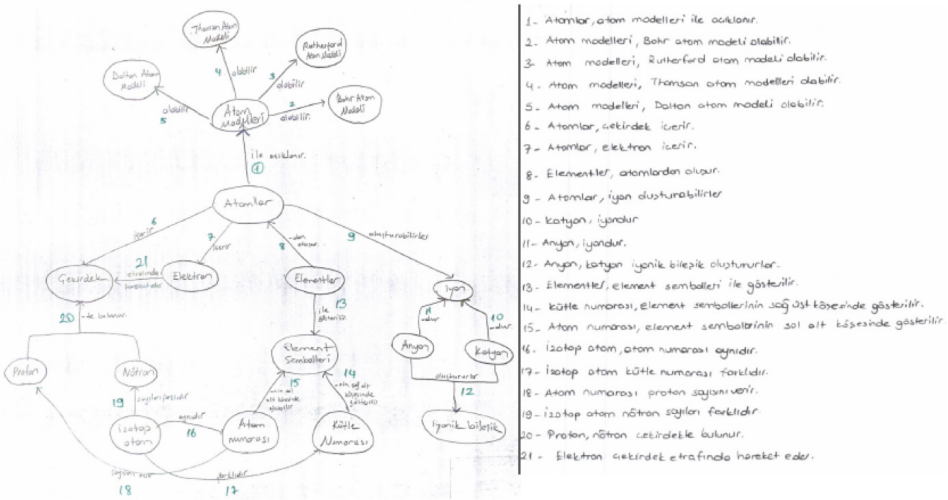


Figure 5. An example of a peer-read concept map prepared in accordance with Novakian concept maps.

Reliability and Validity

The data-triangulation strategy was employed in order to establish the study's validity. Data triangulation is based upon collecting data using different data-collection tools. The consistency of data collected by different tools indicates that validity had been established (Guion, 2002). The effectiveness of the indexing method's development was further verified in three different ways: content analysis of the concept maps, content analysis of the pre-service teachers' opinions about the method, and content analysis of the texts that the peers had converted from the maps. All of these contributed to the validity of the method.

Consistency between coders was established in order to verify validity of the data obtained from the pre-service teachers' opinions about the effectiveness of the method and the data from the content analysis of the concept maps. The consistency of the data obtained from the participants' opinions was found to be 80.95. The corresponding value for data obtained from the concept maps' content analysis was 95.08. The consistency values of the data from the participants' opinions were supported by their statements, and the data obtained from the concept maps' content analysis were supported by the propositions stated in the maps.

Findings

This part is devoted to the content analysis of the participants' Novakian and indexed concept maps and to determine the effectiveness of the indexing method.

Data Obtained from Content Analysis of the Concept Maps and Peer Reading

The data obtained from the maps and peer-read texts regarding the content of the maps support each other and are provided under the same topic.

Investigating the Novakian and indexed maps that the participants had prepared on the same topic in terms of content shows poorly constructed relational clauses to be much more prevalent in Novakian maps due to the unclear order in which propositions are read. The inherent difficulty of including informational content also has a big effect on this problem. Additionally, examining peer-read texts shows the Novakian texts to not be uniform and to have been read differently by different peers. Peers generally read the propositions incorrectly in Novakian mapping.

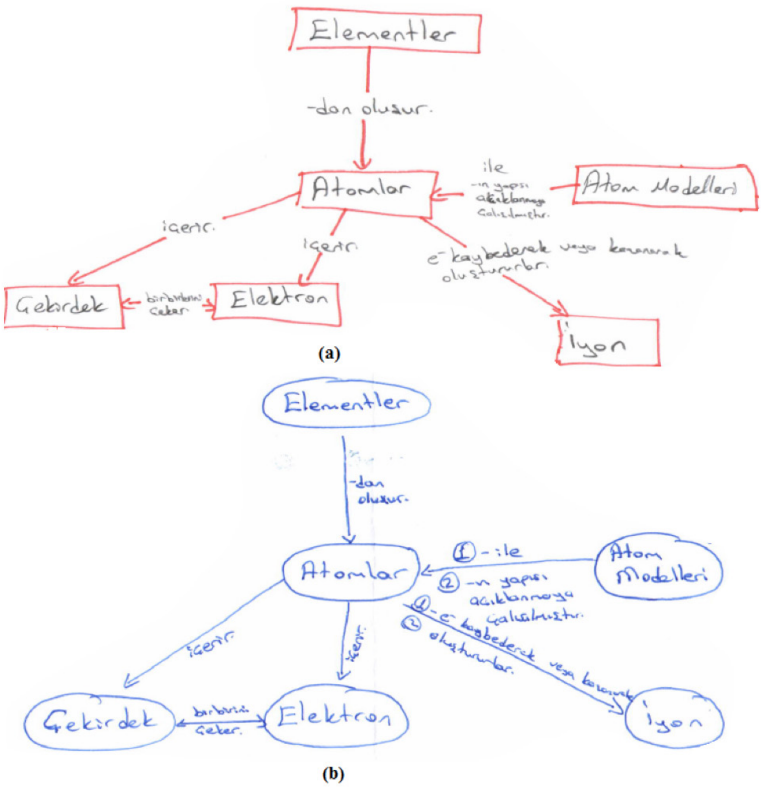


Figure 6. Mehtap's concept maps.

Figure 6 contains the (a) Novakian and (b) indexed concept maps prepared by the same participant. When examining the Novakian map, it is unclear whether the propositions are to be read in the order of *1st concept + relation + 2nd concept* or *1st concept + 2nd concept + relation*. For instance, when the proposition between the concepts of *elementler* (elements) and *atomlar* (atoms) is read in the *1st concept + 2nd concept + relation* order, a perfectly meaningful clause is formed (*elementler atomlardan oluşur*, or in English, elements are formed from atoms). When the proposition between the concepts of *iyon* (ion) and *atomlar* (atoms) are read in the *1st concept + relation + 2nd concept* order, one obtains the clause *atomlar electron kaybederek veya kazanarak oluştururlar iyon* (atoms by losing or gaining electrons they form ion), which is relatively understandable but grammatically distorted. In the exemplified sample, the propositions in Novakian maps were found to be read differently (with different meanings) by two participants. The first peer read the proposition as "atomlar iyon elektron kaybederek veya kazanarak iyon oluştururlar" (the atoms and ions by losing or gaining electrons form ions) and the second peer read the proposition as "Atomlar elektron kaybederek veya kazanarak oluştururlar iyon" (atoms by losing or gaining electrons form ion). This shows that the order is unclear and that the reader has to take the initiative in establishing a logical clause. This decreases the reliability of the method. On the other hand, the relationship gives a perfectly logical and grammatically correct clause with the indexing method if one obeys the general order of *1st concept + Indexed Phrase 1 + 2nd concept + Indexed Phrase 2*. If one takes the same concepts of *iyon* and *atomlar,* the result is a very suitable clause: "Atomlar electron kaybederek veya kazanarak iyon oluştururlar" (Atoms form ions by losing or gaining electrons). The way to read the final proposition does not depend on the assessor and is immutable.

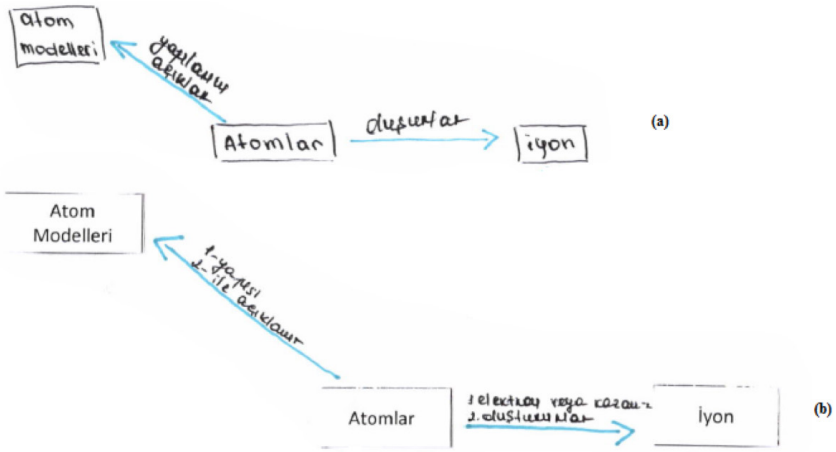
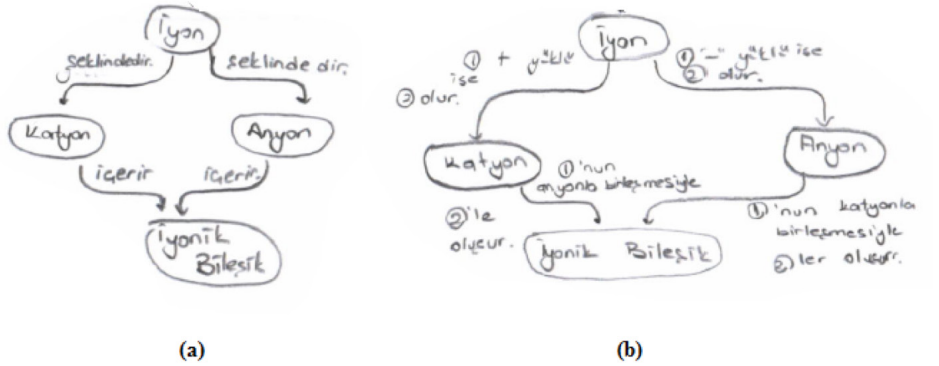


Figure 7. A section of Esma's concept maps.



(a) (b)

Figure 8. Melis's concept maps.

When examining the concept maps in Figures 7 and 8, the content is seen to be much richer and more explanatory in the indexed maps (b) than the Novakian maps (a). For instance, the grammatically incorrect and hardly understandable clause "Atomlar yapılarını açıklar atom modelleri" (It explains the structures of atoms the atomic models) between the concepts of *atoms* and *atomic models* in Novakian maps becomes perfectly syntaxial and understandable in the indexed method: "Atomların yapısı atom modelleri ile açıklanır" (The structure of atoms is explained by atomic models). Because the reading order is obscure in Novakian maps, the proposition was read as "Atomlar atom modelleri yapılarını açıklar" (Atoms explain the structure of atomic models), which was regarded as an incorrect relationship and graded as zero by a peer. However, the fact that the same peer read the same proposition correctly in the indexed map indicates that the ambivalence directly stems from the difference in how the two mapping methods are used. Also, the participants could only write short explanatory phrases such as *şeklindedir* (shaped), *içerir* (contains) and *oluşturur* (forms) when using Novakian maps. However, when they used the indexing method, they could write a detailed phrase explaining the correct relationship between concepts.

Investigating the Novakian and indexed concept maps revealed that the relationships established between some concepts showed marked differences. The explanatory clauses formed using these two methods were observed to be much more meaningful and syntaxially correct with the indexing method. The participants' relational phrases between the concepts of *atom* and *ion* with the Novakian and indexing method are presented in Table 1.

Table 1
Examples of Propositions Established by Participants Using the Novakian and Indexing Methods

Participant	Proposition in Novakian concept maps	Proposition in indexed concept maps
Melek	Atomlar "haline dönüşebilir" iyon. *(Atoms "can turn into" ions)*	Atomlar elektron alış verişi yaparlarsa iyon durumuna geçer *(If atoms transfer an electron, they become an ion)*
Sinem	Elementler "–lardan oluşur" atomlar *(Elements "occur from" atoms)*	Elementler aynı cins atomlardan oluşur. *(Elements consist of the same atoms)*
Beyhan	Atomlar "oluşturabilirler" iyon. *(Atoms "can form" ion)*	Atomlar elektron kaybederek veya kazanarak iyon oluştururlar. *(Atoms, by losing or gaining electrons, form ions)*
Fatma	Atomlar "oluşturabilirler" iyon *(Atoms "can form" ion)*	Atomlar elektron alıp vererek iyon oluştururlar *(Atoms form ions by taking or giving electrons)*
Zeynep	Atom "haline geçerken electron verir ya da alır" iyon *(atom "takes or gives an electron while becoming" ion)*	Atomlar electron vererek ya da alarak iyon haline geçebilir *(atoms may become ions by taking or giving electrons)*

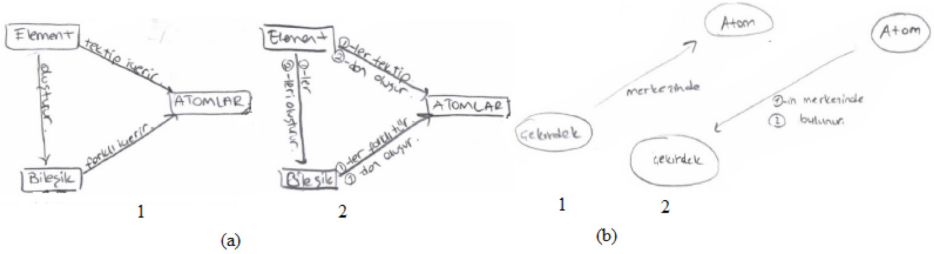


Figure 9. Sections from participants Defne's (a) and İpek's (b) concept maps.

When the concept maps (Figure 9) prepared by participant "Defne" is examined, the Novakian maps result in some poorly worded and grammatically incorrect relational clauses because of the limitation on suffixes. When using the concepts of *elements* and *atoms*, the proposition obtained by the use of Novakian mapping was "element tek tip içerir atomlar (element single-type includes atoms). The participant wants to express the relation "elementler tek tür atomlardan oluşur" (elements are formed from one kind of atom), but she couldn't due to Novakian concept map restrictions. The clause was read as "elements atoms single" in the peer reading process, which was syntaxially incorrect and did not convey correct information to the reader. On the other hand, indexed mapping solved this problem, and the information was conveyed in both a syntaxially compatible and scientifically correct manner as "elementler tek tip atomlardan oluşur" (elements are formed from single types of atoms). This relation was read correctly in the peer reading. Similarly, the relational clauses obtained by participant "İpek," which investigated the relationship between *atoms* and *nucleus* using Novakian and indexing methods, were "çekirdek merkezinde atom" (atom in

the center of the nucleus) and "atomun merkezinde çekirdek bulunur" (nucleus is found in the atom's center). The absence of suffixes and the incompatible order of the clause elements resulted in virtually meaningless clauses in Novakian maps. The indexing approach seems to be a perfect remedy for all these problems.

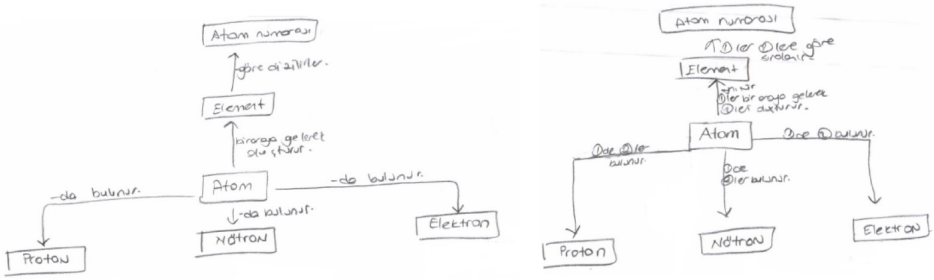


Figure 10. A section of the (a) Novakian and (b) indexed concept maps from pre-service teacher "Kevser."

The final proposition of Novakian maps in Figure 10 is highly distorted, grammatically incorrect, and confusing because the suffixes that should be added at the end of the verb are not allowed on the maps. The indexing approach is a solution to these types of problems and gives more grammatically and conceptually correct clauses. The relation between *atoms* and *elements* is "atomlar bir araya gelerek oluşturur element" (atoms together by combining forms element), obtained using Novakian concept maps. This relation reads much more clearly and grammatically correct as "aynı tür atomlar bir araya gelerek elementleri oluşturur" (the same type of atoms come together to form elements) in the indexed approach. Not only did the peer correct the grammatical format, she also added a new informational phrase. When all these facts are taken into account, one can easily conclude that the grammatical and conceptual flaws in the final proposition were not due to a lack of knowledge but to the intrinsic nature of the mapping system.

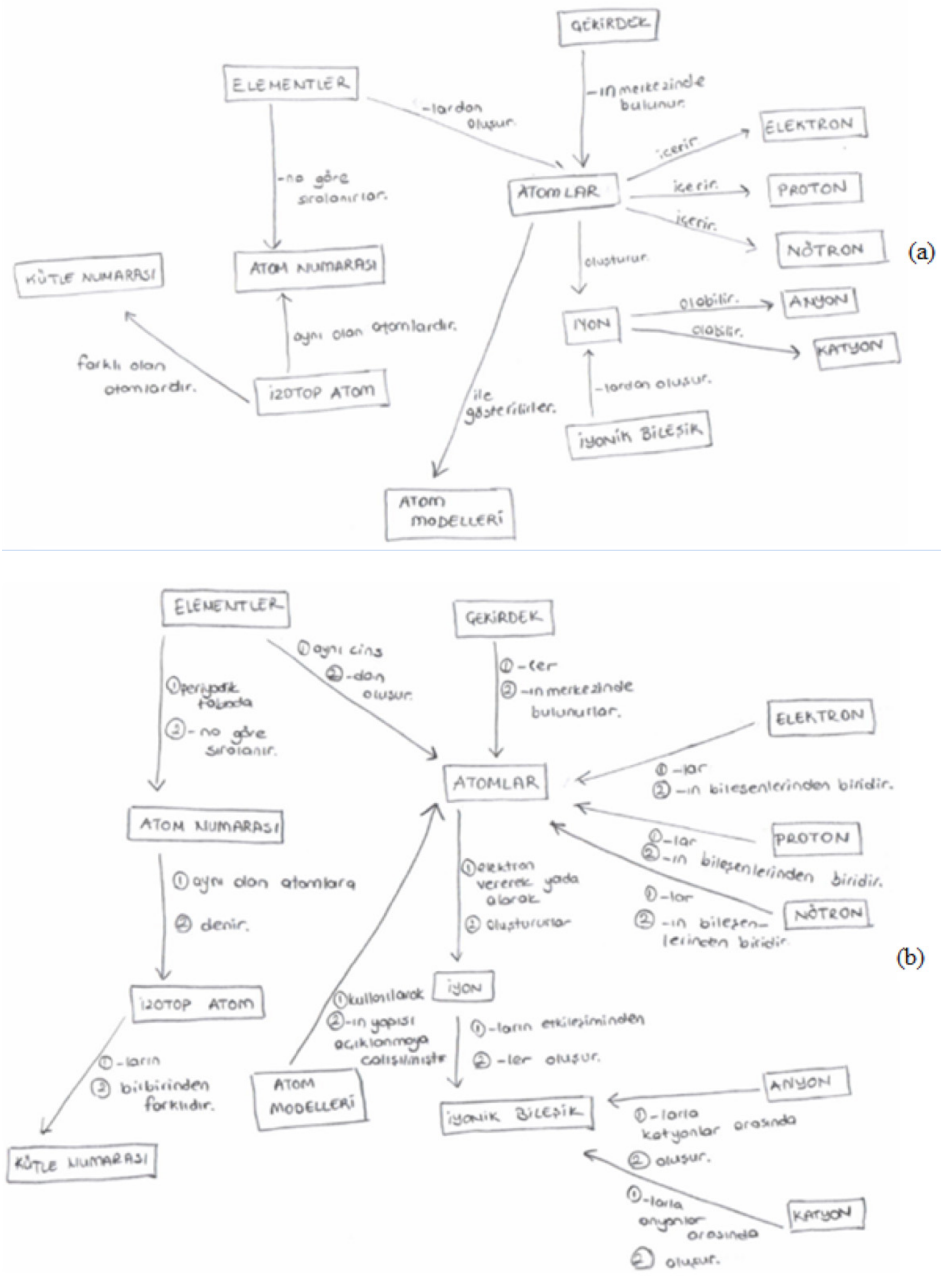


Figure 11. The Novakian and indexed concept maps drawn by participant "Sinem."

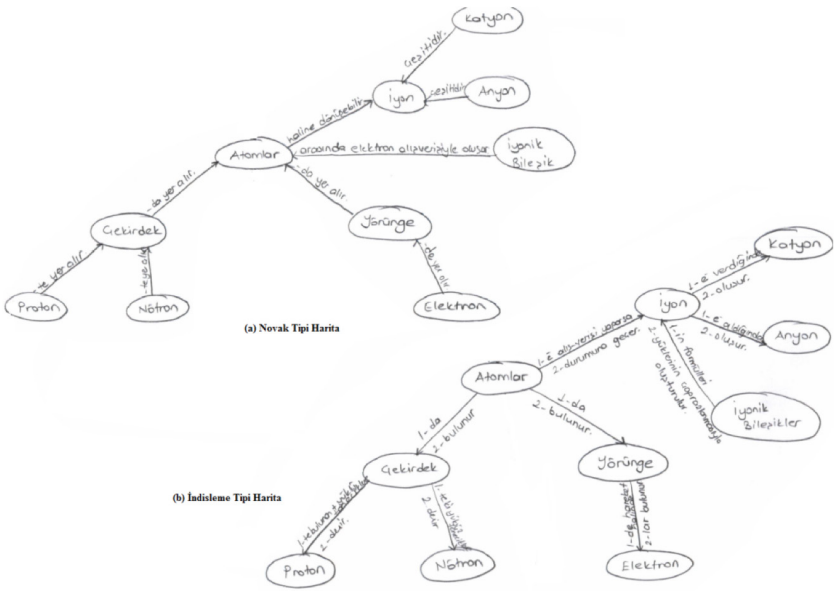


Figure 12. The Novakian and indexed concept maps drawn by participant "Melek."

Figure 11 shows the concept maps using the Novakian and indexing methods prepared by the same participant, "Sinem." The indexing method seems to be much richer in terms of conceptual content. When examining the relationship between the isotope atom and mass number, the Novakian method ended up with the proposition "izotop atom kütle numarası farklı olan atomlardır*"* (isotope atomic mass number are atoms that are different) while the proposition for the indexing method was "izotop atomların kütle numarası birbirinden farklıdır" (Isotopes have a different mass number than the atom's mass number). The first proposition may result in the misconception that every atom with a different mass number is an isotope of one another. The second proposition poses no risk of that misconception. The indexing method clearly provides a much wider possibility of explaining complicated systems. This situation is also apparent in the relation between cations and ions. The Novakian approach uses small one- or two-word phrases, whereas the indexing system uses more explanatory phrases and suffixes as are used in Turkish (see Table 2).

Table 2
Propositions Obtained from the Novakian and Indexing Methods

Participants	The propositions in Novakian maps	The propositions in the indexed maps
Beyhan	Katyon "– dur" iyon / Anyon "– dur" iyon *(Cation "is an" ion / Anion "is an" ion)*	Katyon pozitif yüklü iyondur / Anyon negatif yüklü iyondur *(Cation is a positively charged ion / Anion is a negatively charged ion)*
Deniz	Katyon "– dur" iyon / Anyon "– dur" iyon *(Cation "is an" ion / Anion "is an" ion)*	Katyon artı yüklü iyondur. / anyon eksi yüklü iyondur. *(Cation is a positively charged ion / Anion is a negatively charged ion)*
Fatma	Katyon "– dur" iyon / Anyon "– dur" iyon. *(Cation "is an" ion / Anion "is an" ion)*	Katyon pozitif yüklü iyondur / Anyon negatif yüklü iyondur *(Cation is a positively charged ion / Anion is a negatively charged ion)*
Nehir	İyon "olabilir" katyon / İyon "olabilir" anyon *(Ion can be a cation / Ion can be an anion)*	Katyon artı yüklü iyondur. / Anyon eksi yüklü iyondur *(Cation is a positively charged ion / Anion is a negatively charged ion)*

Data related to Pre-Service Teachers' Opinions

Forty-two codes were determined as a result of the opinion content analysis, and they were gathered under 6 themes: clarity, understandability, assessment tool usage, forming relations, usability, and compatibility with Turkish. The operational descriptions of the themes are tabulated in Table 3, and the number of participants who stated opinions is listed in Table 4.

Table 3
Operational Description of the Themes

Themes	Number of codes in the theme	Operational description of the themes
Clarity	10	Includes phrases related to clarity of relations.
Understandability	15	Includes phrases related to relational and/or others' understandability.
Assessment tool usage	2	Includes phrases about when maps are used as an assessment tool
Forming relations	7	Includes phrases used in forming relations
Usability	4	Includes phrases related to the usability of the system
Compatibility with Turkish	4	Includes phrases related to Turkish syntax structure

Table 4
Number of Participants who Stated Opinions

Themes	Number of Codes in the Theme	Number of participants who stated opinions in the theme	Percentage
Clarity	10	9	45%
Understandability	15	14	70%
Assessment tool usage	2	2	10%
Forming relations	7	5	25%
Usability	4	4	20%
Compatibility with Turkish	4	2	10%

When examining the opinions listed under *clarity,* 45% of participants were seen to state the relations on the maps to be much more explanatory and grammatically compatible when using the indexing method. Participants were observed to fail at phrasing the relationship when they used the classical Novakian approach. Some of the opinions given below show the differences between the Novakian and indexing systems in terms of clarity:

> [Indexing method] makes establishing the relation much easier and clearer. (Esma)
>
> The phrases [in the Novakian maps] remained in its simplest form as *plays*, *does*, etc. We are not allowed to use suffixes. That's why it was difficult to fully phrase the relation. (Deniz)
>
> [Indexing method] is much more useful as it provides more meaningful relational clauses. (Pelin)
>
> I think phrases [in the Novakian method] are much more limited. (Melek)

Sixty–five percent of participants who stated opinions under the theme of *understandability* of the resultant relational clauses agreed that the clauses established through the indexing method were much more superior in terms of syntax order and informational content. According to the participants, the indexing method promotes the readability of relational clauses. Some of the pre-service teachers' opinions about this topic clarify this point:

> Indexing is important because when we write phrases directly it becomes hard to read. Therefore, it makes reading and understanding much easier. (Mine)
>
> I think that using indexing obviates confusion. (Esma)
>
> I think that indexing is very important because without it, the resulting clause becomes very complicated. (Fatma)
>
> It is very easy to establish meaningful clauses with the indexing method. Clauses become much more meaningful and clear. (Zeynep)

Only one pre-service teacher stated that the numbers used in the indexing method made it complicated.

> Concept maps may be more informative with the indexing method, *but they are also more complicated*. (Beyhan)

This was the only negative opinion about the indexing method's understandability.

Participants' statement about the effect of using different concept mapping methods in preparing concept maps as an assessment tool are placed under the theme of *assessment tool usage*. There are two opinions expressed under this heading: One stated that the difference was minimal, but the second emphasized that the indexing method was much more effective. The opinions of the pre-service teachers about the use of concept maps as an assessment tool are as follows:

> I don't think there's any difference between the two systems. The indexing system is more convenient due to ease of phrasing. (Beyhan)

> The indexing model is much more convenient as an assessment tool due to its phrasal diversity. (Deniz)

Pre-service teachers' opinions about *forming relations* are generally positive, stating that clauses resulting from the indexing method are much more informative and grammatically correct. They also stated that when using the indexing method, expressing and writing phrases about what they were trying to explain was much easier. Here are some of the participants' opinions about this topic:

> I felt a lot more comfortable when I was preparing the maps according to the indexing technique because it was much easier to express what I wanted to explain. I think the indexing method is more practical regarding ease of expression. (Sinem)

> It was very difficult to write phrases in the Novakian system. It took a very long time to form a relation. (Zeynep)

> I think Novakian phrases are too limited. It's much easier to define phrases in the indexing system. (Melek)

> The indexed approach is much easier for establishing appropriate clauses. It's quite difficult to do the same using the Novakian method. (Nehir)

The opinions of the pre-service teachers about the Novakian and indexing methods' *usability* were completely in favor of the latter. Here are some opinions about the usability of the systems:

> Indexed concept maps are more useful because they are easier to understand. (Melek)

> I could easily establish phrases using the index method. I think the indexing system is much more useful. (Sinem)

> Indexed maps are a lot more useful because they provide much more meaningful clauses. (Pelin)

> It is more practical to use the indexing method. Indexing relation as 1 and 2 eliminates the possibility of reading incorrectly. (İpek)

According to the participants, the Novakian method is not compatible with Turkish because it is not possible to include suffixes, the most important feature of Turkish. The resultant clauses are generally meaningless and grammatically distorted. However, there is no limitation in terms of suffixes with the indexing method, which results in meaningful clauses in line with the grammatical structure of Turkish. Here are the opinions of some pre-service teachers:

> The indexed format allows for clauses that are compatible with the Turkish language. (Mehtap)
>
> It was highly difficult to write phrases without suffixes. (Canan)

Discussion

Most of the literature related to the problems emerging while preparing concept maps in Turkish focus upon the problems associated with writing phrases (Didiş et al., 2014; İngeç, 2009; Lee, 1999; Park & Kim, 2008; Sağlam, 2009; Sözbilir & Neacşu, 2014; Turan & Ekmekci, 2011; Ünlü et al., 2006). The structural differences between Turkish and English cause distortions in the resultant clauses and make it difficult to write propositions. This causes Novakian concept maps to deviate from their primary use of elucidating relations between concepts, and the conceptual structure about a certain topic resurfaces. This study is related to the development of an entirely new method, the indexing method, to remedy all problems involved in preparing Novakian maps in Turkish. Indexed concept maps were found to be richer in informational content. The Novakian system is prepared by using one- or two-word phrases in their simplest form. However, the indexing approach paves the way for including suffixes. Because the order of words in reading is not clear with the classical Novakian method, the difference sometimes contains gross errors or misconceptions. The indexing method is found to remedy most of the problems by improving readability and informational content. When dwelling upon the participants' statements regarding the indexing system's effect on understandability of Novakian maps, they are seen to completely agree that the indexing system greatly increased the final statement's understandability. The peer readings show that Novakian relations are incorrectly read most of the time, and using the indexing method obviates most of these problems. The problems observed in Novakian maps were in accordance with those reported by Bağcı Kılıç (2003) and Ünlü et al. (2006). Bağcı Kılıç (2003) reported the structural difference between Turkish and English to be mainly responsible for the problems of concept maps in Turkish. In our study, the participants stated having serious problems preparing concept maps in Turkish and claimed the indexing method to be much better suited for this purpose. Bağcı Kılıç (2003) stated the failure of adding suffixes at the end of the verb to inevitably cause problems in relational clauses and propositions in

Novakian maps would be meaningless due to the two languages' difference in syntax structure. Ünlü et al. (2006) reported in their study that they had so many problems due to the syntaxial differences between Turkish and English; they stated that the expressions between concepts describing their relationship were often incompatible with Turkish grammatical structure. They claimed that this syntaxial distortion could well result in misconceptions. Participants' written opinions revealed that they had difficulties establishing clauses and were forced to establish relations using short phrases with little expressive power. Investigations of the participants' concept maps clearly showed this (see Figure 11 and Table 2). Additionally, data collected from the opinions listed under *clarity* and *forming relations* support this situation. The participants were reported to have had great difficulty establishing relational clauses between two concepts using a few simple words in the Novakian tables because of the restrictions imposed by Novak's method, even if they understood the relation. The numbering method developed by Sağlam (2009), where phrases are replaced with straight clauses, eliminated the poor grammatical structure inherent in the Novakian method. However, because the maps and relationships are on different pages, following the whole process becomes a huge problem (Sağlam, 2009). This situation also clearly violates the basic feature of concept maps: "concept maps show students' informational structure in an integrated fashion" (Novak & Musonda, 1991). In this context, the indexing system appears to be superior. The fact that the phrases are written on the relationship line is the biggest advantage of the indexing approach. This system is thought to enable students to establish concept maps much more easily, as well as provide teachers with the opportunity to more realistically assess the relations that students establish. The problem of complicating maps by writing whole clauses on the relational lines, as stated by Sağlam (2009) in his numbering system, exists in the indexing system as well. However, writing clauses on the relational lines are very important if one is to take the main target of concept mapping into account: visualizing students' concepts.

When looking at the pre-service teachers' opinions, almost all of them stated positive opinions about the indexing method. Participants (65%) stated that the indexing method was much more compatible and understandable with Turkish compared to the Novakian method. Only one participant expressed concern that the indexing system would complicate things. However, the rest of the participants agreed that phrasing maps and establishing relations is much easier using the indexing method. They thought the resulting relations were much more understandable compared to the classical Novakian method. This data complies with that from the study of Didiş et al. (2014), which investigated students' opinions about concept maps. As a result of this study, concept maps should be clearly understandable, appealing, and rich in

informational content. In summary, concept maps prepared in accordance with the indexing method are much more clear and understandable.

When the Novakian and indexing methods are evaluated using the Novakian scoring method (Novak & Gowin, 1984), both mapping systems score the same points because every proposition is given 1 point regardless of its quality. However, if one considers that the primary purpose of concept maps is to illuminate students' conceptual structures, indexed concept maps are a better alternative. Take the concept maps prepared by pre-service teacher "Melek" as an example: "A neutron is located in the nucleus" is a correct proposition and is graded with one point. However, the proposition "Neutral particles in the nucleus are called neutrons" is also graded with one point. A vast difference is reflected in regard to informational content in these two propositions. Lopez et al. (2011) proposed a four-tier grading system: 0 = wrong or scientifically inappropriate, 1 = partly wrong, 2 = correct but cognitively weak, and 3 = scientifically correct and fully clear. The correct but cognitively weak category fits well the small phrases used in Novakian-type maps. On the other hand, the much clearer expressions that are used with the indexing approach fall into the final category. Therefore, most small phrases in Novakian maps score two points. Although Novakian grading does not differentiate between the Novakian and indexed approaches, detailed grading clearly indicates the superiority of the indexing system as an assessment tool over the traditional Novakian approach when the application language is Turkish. Although concept maps are graded qualitatively, they are used as a quantitative tool in assessment for enlightening students' misconceptions and conceptual structures (Koca & Şen, 2004). In this type of application, participants' relational phrases are of great importance. That is why the indexing approach is much more superior for elucidating students' conceptual structures. Two participants compared the Novakian approach and the indexing method in terms of being an assessment tool. One of them stated the difference to be minimal, and the second claimed the indexing method to be much more superior.

Concept maps are two-dimensional schemes for determining how students relate concepts and define their prior knowledge and alternative concepts (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996). This study showed that some of the relational phrases in Novakian maps that could be regarded as misconceptions give perfectly sound and conceptually correct relational clauses in the indexing system, which indicates that the incorrect phrasing did not result from a misconception. Concept maps are tools that can be employed to elucidate misconceptions (Aykutlu & Şen, 2012; Çıldır & Şen, 2006; Djanettea & Fouadb, 2014; Karamustafaoğlu et al., 2002; Taşçı, 2015). That is why it is recommended to employ the indexing method when concept maps are used as a tool for defining misconceptions in Turkish due to its greater power of expression.

Limitations and Proposals

All data collection tools being in written format and the lack of individual participant interviews are the biggest limitations of the study. Also, the study being limited to only 20 participants is another important limitation that decreases the external validity of the study. The decreased quota for chemistry teachers made finding an adequate number of samples quite difficult. Future studies are recommended to be performed with larger sampling groups, including participants from other disciplines if necessary. Additionally, study topics are recommended to be enumerated, and both written and oral data collection methods should be employed. The indexing method should be introduced to teachers prior to the application. Teachers who use Novakian concept maps as an assessment tool in Turkish in their classes should be urged to use the new indexing system. The need to write relational phrases may complicate the process but is absolutely necessary for integrating the process. In order to obviate this problem, maps could be drawn on larger-sized paper and the number of concepts could be restricted by dividing the topic.

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Appendix

Operational Description of the Themes Used in Analyzing Participants' Novakian and Indexed Concept Maps

Category Name	Operational Description
Correct phrase	Proper and compatible with the scientific model's proposition written between two concepts.
Wrong phrase	Wrong or misconceived proposition written between two concepts.
Concept error	Incorrect proposition because it connects to the wrong concept.
Incompatible with the scientific model	The proposition is not suitable to the current scientific model but is appropriate to an out-of-date model.
Phrase with excessive information	The propositions between the same two concepts in different mapping types contain an excess of information.