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PRESERVICE SCIENCE TEACHERS' COGNITIVE STRUCTURES REGARDING THE CELL AND ITS ORGANELLES

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Abstract: Learning the cell, one of the basic subjects of science education, by preservice teachers in a comprehensive way is important for making sense of its vital activities and teaching the subject in a meaningful way in the future. The study aimed to determine preservice science teachers' cognitive structures related to the cell and its organelles before and after the Biology course. The study group consists of 32 preservice science teachers. The single-group interrupted time series design was adopted in the study. Data were collected through the word association test. As a result of the data analysis, it was determined that some organelles could not be associated with other organelles, there was no knowledge about the peroxisome organelle before the intervention. It was observed that more comprehensive and interrelated cognitive structures were formed after the intervention and the peroxisome organelle was also added to this structure.

Key words: biology, cell, organelle, preservice science teachers, word association test

1. Introduction

Each individual is striving to perceive the universe he/she lives in under the effect of his/her inherent curiosity (Burke, 2018). To understand the structure and functioning of the universe, the individual must first be able to understand himself/herself inductively (Sharot & Sunstein, 2020). It is inevitable for the individual to be able to comprehend the events, structures, and processes that occur in his/her body to be able to get to know himself/herself. The ability of the individual to comprehend the events occurring in his/her body can be provided by the qualified education he/she will receive. Like other living beings, the structure, metabolism, and structural functioning of human beings are addressed within the scope of the biology course (Wibowo & Sadikin, 2019). Therefore, it can be ensured that the individual becomes aware of himself/herself with qualified biology education.

To perceive the universe, it is necessary to understand human beings, which can be regarded as the most basic element, and the cell subject, which forms the basis of biology subjects, must be learned in a meaningful way to understand biology subjects (Alberts et al., 2018). The cell is at the basis of all structures in the human body, the functioning mechanisms of these structures, and metabolic activities (Aversa et al., 2016). Considering that the tissues of cells, the organs of tissues, the systems of organs, and the systems constitute the organism, the basis of the individual's vital activities is based on the cell (Dexheimer & Cochella, 2020). Understanding the cell subject incompletely also plays a preventive role in learning the biology subjects discussed afterward (Duda, 2020; Hayssen, 2020). Just as a construction without a foundation does not have a possibility to keep standing, it will not be possible for biology subjects to be structured in a meaningful way and for the individual to become aware of himself/herself in a cognitive structure in which the cell subject cannot be comprehended.

Updates are experienced in developing and changing world standards with the differentiation of requirements in every field. Updated scientific knowledge, individual differences, and changes in the learning styles of the new generation of individuals have also formed a basis for changes in the education system (Deveci, 2018; Wagbara, 2020). It is emphasized worldwide that different philosophical approaches should be adopted in the education and training process. Updates in scientific information cause differentiation in the content of courses. Although there are cases of adding new subjects, updating some content, removing subjects that have lost their validity and functionality in the content of many courses, it can be said that the basic subjects in these courses

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continue to exist in change (Khaparde, 2020; Sotáková, Ganajová & Babincáková, 2020). The cell subject is also among the fundamental topics of biology (Dexheimer & Cochella, 2020). Since a hierarchical and spiral understanding is adopted in the education and training process nowadays, from simple to complex, from concrete to abstract, from known to unknown (Chang, Lee, & Koay, 2017; Moeller & Frings, 2019), the cell subject continues to be taught in the context of the spirality principle at all levels of the education and training process from the secondary school level (Deveci, 2018; Özcan & Koştur, 2019). Therefore, to create a valid conceptual and cognitive structure in the mind of students about the cell subject, it is important to lay the foundation of this subject at the secondary school level well and to teach this subject correctly.

Considering that teachers tend to teach as they have learned (Ronfeldt, Brockman & Campbell, 2018), it is inevitable that the cognitive structures of teachers who will teach the cell subject regarding the relevant subject should be formed correctly for qualified education. It is obvious that the education received by science teachers who will teach the cell subject during the teacher training process will affect both their cognitive structures and their teaching styles of the subject (Abdi, Malusu & Ogoti, 2020). Considering that the final education that preservice science teachers will receive on the cell subject, which forms the basis of all biology subjects, is within the scope of the biology course (Council of Higher Education, 2018), it is of great importance for preservice teachers to form their cognitive structures correctly, especially in the teaching of the cell subject of the biology course at the undergraduate level. Determining the cognitive structures of preservice teachers regarding the cell subject may play a role in eliminating the misconceptions and incomplete learning that they may create in the teaching process. Many different methods are used in the literature to reveal cognitive structures (Mizin & Petrov, 2017; Yener, 2017; Yener, İnan & Yılmaz, 2023). The Word Association Test (WAT) is one of the most widely used among these methods (Suzuki-Parker & Higginbotham, 2019). The Word Association Test is an effective tool that enables to reveal the cognitive structure of the individual regarding the subject by determining the relationship between the basic concepts of a subject and the sub-concepts with which the basic concepts are associated (Suzuki-Parker & Higginbotham, 2019). Possible misconceptions and incomplete learning can be identified by determining the cognitive structures of preservice science teachers regarding the cell subject through the WAT.

Nowadays, there is an understanding that an individual can permanently structure in his/her mind by transferring the new knowledge he/she has acquired to his/her daily life and using it as a solution to the problem situations he/she encounters (Xu & Shi, 2018). It can be stated that this understanding is tried to be provided with a life-based approach in today's education process. The life-based approach aims to form a basis for the permanent learning of knowledge by providing experiences to the individual in which he/she can transfer the knowledge acquired to his/her daily life (Cabbar & Şenel, 2020; Kastur & Riyanto, 2020). Furthermore, as emphasized by the constructivist approach philosophy adopted nowadays, knowledge can be learned in a meaningful way in lessons in which the student is active, experiences and assumes responsibility (Fernando & Marikar, 2017). To learn the cell subject in a meaningful way, it is important to create an education-training process in which students are active and a life-based understanding is adopted.

Since the individual's learning of a subject in the past years affects the learning of subjects in the following years and the misconceptions in the past years play a preventive role in learning (Burga, Leblanc & Rezania, 2020), it is important to teach especially basic subjects in a qualified manner. Teachers should have a tendency to teach as they have learned (Ronfeldt, Brockman & Campbell, 2018), and especially the biology course, which is the last course in which science teachers receive training on the cell subject during their undergraduate education, should also be of quality to create a correct cognitive structure (Abdi, Malusu & Ogoti, 2020). This can be achieved by biology education with qualified and enriched content (Gilissen et al., 2019). Therefore, this study's goal is to determine the cognitive structures of preservice science teachers, provided with enriched education such as context-based approach, simulations, laboratory and drama method, regarding the cell and organelles subject of the General Biology course, before, after, and one year after the course.

2. Method

2. 1. Research design

To determine the cognitive structures of preservice science teachers regarding the concept of the cell before and after the General Biology course, the phenomenological approach, one of the qualitative research methods, was preferred (Tekindal & Uğuz Arsu, 2020). For this purpose, a single-group pre-test post-test experimental design was used and one year after the post-test application, the same test (WAT) was re-administered to the same group to check its permanence.

2. 2. Study group

The study group consists of 32 (2 male, 30 female) preservice science teachers studying at the 2nd grade level at the education faculty of a university in the Western Black Sea region in the fall semester of the 2016-2017 academic year. Although the number of preservice teachers who participated in the pre-test before the General Biology course was 35 (5 males, 30 females), in the post-test applied after the General Biology course and the retention test applied one year after the General Biology course, 32 (2 males, 30 females) of the preservice teachers participating in the pre-test were included in the study. The pre-test data of the three preservice teachers not participating in the post-test and retention test were not included in the study.

2. 3. Education process

Within the scope of the General Biology course, preservice teachers received 24 hours of education about the cell and its organelles, including 4 hours of theoretical education and 2 hours of laboratory practice a week for 4 weeks. In the theoretical part of this teaching, subjects related to the cell structure and functioning, such as eukaryotic and prokaryotic cell structure and differences, basic organic and inorganic substances in the cell, the structure of the cell membrane and substance transitions through the membrane, the structures and functions of the organelles in the cell, were taught in interaction with students in the classroom setting on the basis of a context-based approach using discussion, question-answer, brainstorming, drama, analogy, opposing panel, circle discussion, problem-solving, simulation, observation and verbal expression techniques.

During the course, analogies were created with examples from daily life with regard to the cell and its organelles, and different practices were performed to create meaningful learning with the specified techniques regarding the structure and functions of the cell and its organelles. Various activities were carried out to reinforce the subjects with techniques such as circle discussion, opposing panel, and brainstorming. The education and training process was completed by learning the structure and functions of the cell and its organelles, answering possible questions about the relevant subject, and eliminating the misconceptions that occurred. In laboratory practices, the process was carried out by making experiments, observations, and microscopic examinations related to the cell and its organelles. Plant and animal cells were examined under a light microscope in the laboratory environment, and bacteria with prokaryotic cell structure and living beings with eukaryotic cell structure such as paramecium, euglena, and amoeba were observed through cultures prepared with preservice teachers. Moreover, since it is not possible to see each of the organelles under the light microscope, the laboratory of the Department of Biology of the Faculty of Science and Letters was visited during a week's class, and the microscopic images of the cell organelles were examined by means of a transmission electron microscope, and the structure and functions of the organelles were discussed. Additionally, microscope images were reinforced with simulation applications providing a virtual laboratory environment.

2. 4. Data collection tools and data collection process

In the study, the cognitive structures of preservice teachers related to the concepts of the cell and its organelles were determined using the Word Association Test (WAT) for the subject "Cell and its organelles." The WAT, which is frequently used in science and social domains, is used to determine the concepts in the cognitive structure of individuals and the connections between these concepts (Hovardas & Korfiatis, 2006). In this study, preservice science teachers were given "cell, nucleus, ribosome, mitochondria, chloroplast, centrosome, lysosome, Golgi, endoplasmic reticulum, and

peroxisome" as stimulus words for the WAT. The WAT developed by the researchers with regard to the cell and its organelles was applied to preservice science teachers before (pre-test), after (post-test) the General Biology course, and one year after the teaching process to determine the permanence of knowledge. To prevent the risk of chaining responses in the implementation of the WAT, the papers (see Figure 1) on which these words were written one after the other were given to preservice teachers, and they were asked to write the first concepts brought to mind by these words within 30 seconds. Forms on which ten words could be written were created for each key concept. Thirty seconds has been determined as the most appropriate time unit in pre-tests conducted in many studies (Austin, 2020; Pranoto & Afrilita, 2019). Necessary information was provided to preservice teachers during the application of the measurement tools. After introducing the WAT through another concept not related to the subject, the data collection process was started.

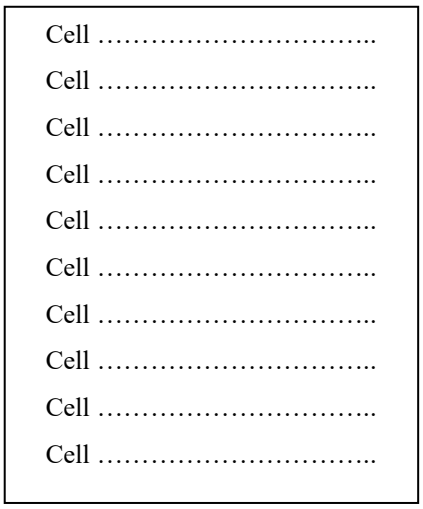

Figure 1. Example of the WAT with regard to the cell

2. 5. Data analysis

The data obtained were analysed by the descriptive analysis method (Chambers, 2018; Sidel, Bleibaum & Tao, 2018). For the results of the WAT applied before the General Biology course, at the end of the course, and one year after the end of the course, a frequency table was created showing how many times all the words suggested for the key concepts given to the participants were repeated, and a concept network clearly revealing the relationships between the words was created. The cut-off point technique developed by Bahar, Johnstone & Sutcliffe (1999) was used while creating the concept network. In this technique, in the frequency table obtained from the WAT, the most given response for any concept is taken as the cut-off point below the specified number of words and is written in the first part of the concept network by determining it as the first limit. Afterward, this limit is pulled down in line with the number range determined at the beginning and is continued until all keywords appear in the concept network. In this study, in line with the frequency values obtained from the pre-test, post-test, and retention test data, the cut-off point interval for each test was selected as 5, and four cut-off points (30-26, 25-21, 20-16, and 15-11) were created. According to the determined cut-off points, the concept networks of preservice teachers regarding the cell and its organelles were created using the "bubbl.us" program, enabling the creation of an online concept network. In the concept networks created, key concepts were indicated in white text on a black background. At the 30-26 cut-off point, the concepts formed in the concept network were indicated in white text on a dark gray background. At the 25-21 cut-off point, the concepts formed in the concept network were indicated in white text on a gray background. At the 20-16 cut-off point, the concepts formed in the concept network were indicated in black text on a light gray background. At the 15-11 cut-off point, the concepts formed in the concept network were indicated in black text on a white background. Even if the concepts produced by the preservice teachers regarding the key concepts were not related to the subject, they

were recorded in the frequency table, and during the analysis process, the researchers did not have any effect on the data such as interpretation or data cleaning.

2. 6. Ethical Consent of the study

This study was approved by the Human Research Ethics Committee in Social Sciences of Bolu Abant İzzet Baysal University (Protocol No: 2017/192).

3. Findings

The WAT regarding the cell and its organelles was applied to preservice science teachers before the General Biology course, and the concept networks created in line with the frequency table obtained from the data analysis are shown in Figures 2-5, respectively.

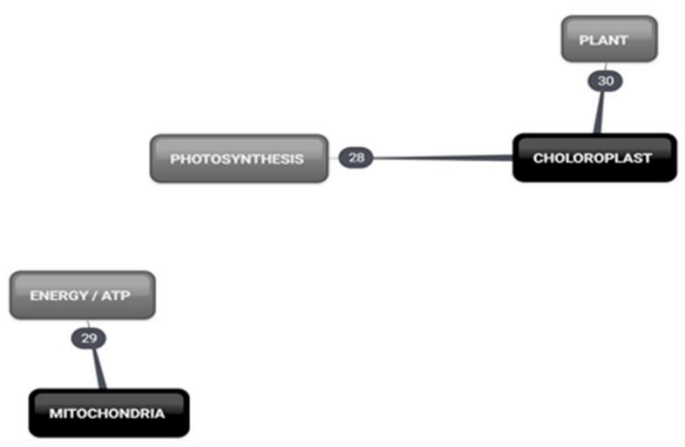

Figure 2. Pre-Test Concept Network (Cut-off Point: 30-26)

When the concept network in Figure 2 was examined, it was observed that only the chloroplast and mitochondria key concepts emerged at the cut-off point determined at a rather high frequency compared to other key concepts. It is observed that the chloroplast key concept, among these key concepts, is associated with photosynthesis and the plant, while the mitochondria key concept is associated only with energy/ATP. The concept network for the next 25-21 cut-off point is presented in Figure 3.

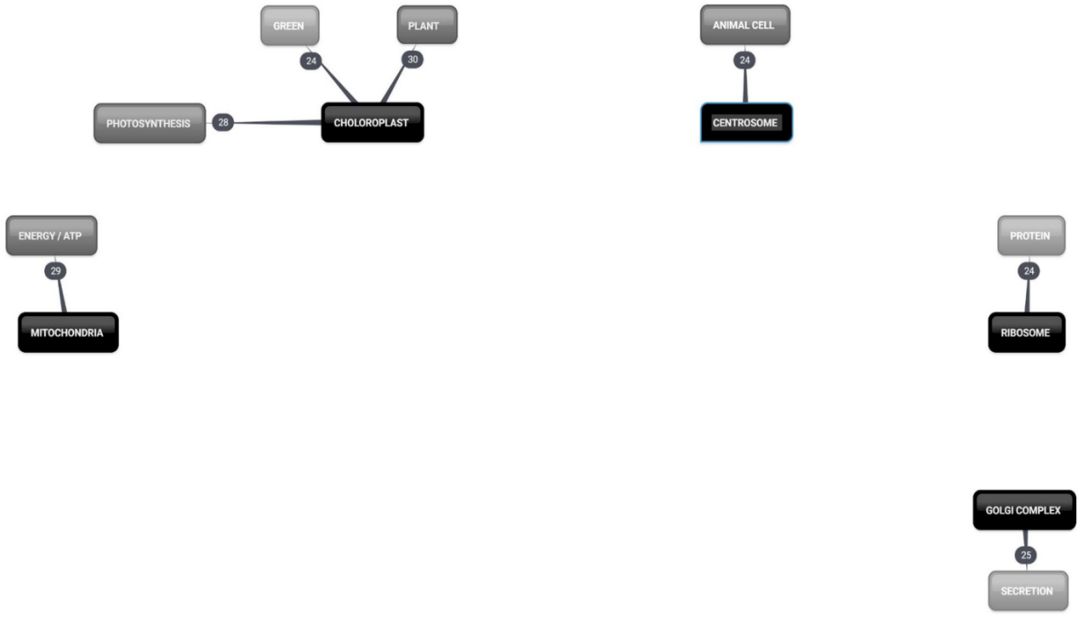

Figure 3. Pre-Test Concept Network (Cut-off Point: 25-21)

When the concept network in Figure 3 is examined, it is observed that the ribosome, centrosome, and Golgi are included in the concept network at the specified cut-off point. At the 25-21 cut-off point, the preservice teachers have a cognitive structure in which the chloroplast key concept is associated with green, the centrosome key concept is associated with the animal cell, the ribosome key concept is associated with the protein, and the Golgi key concept is associated with secretion. The concept network for the 20-16 cut-off point is presented in Figure 4.

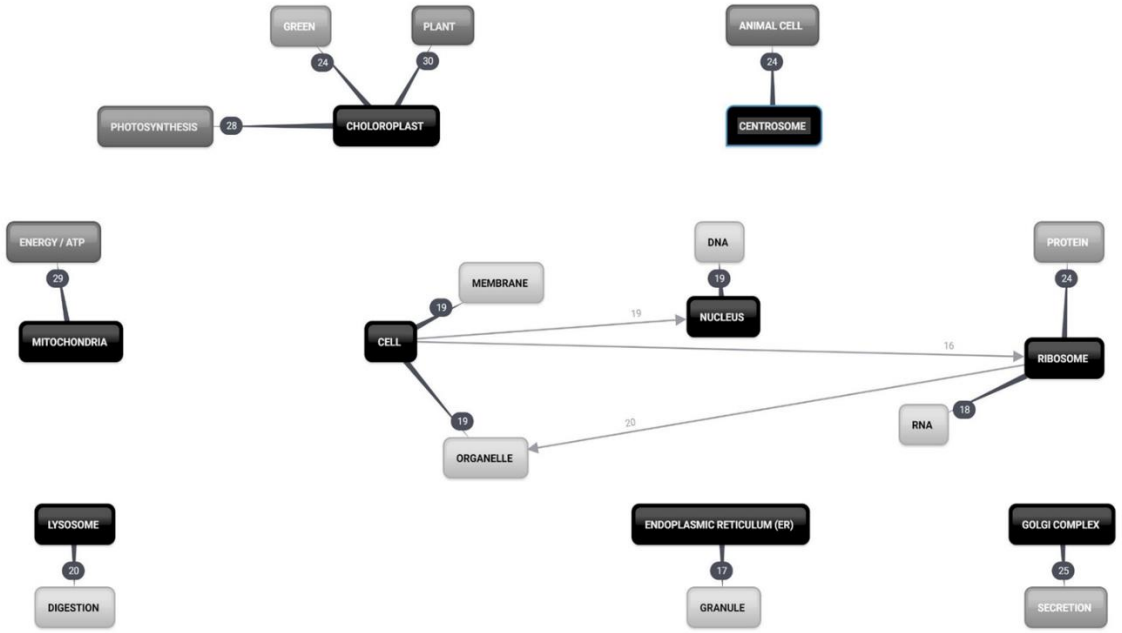

Figure 4. Pre-Test Concept Network (Cut-off Point: 20-16)

When the concept network presented in Figure 4 is examined, it is observed that the cell, nucleus, lysosome, and endoplasmic reticulum are included in the concept network at the determined cut-off point. At the 20-16 cut-off point, it is observed that preservice teachers have a cognitive structure in which the lysosome key concept is associated with digestion, the endoplasmic reticulum key concept is associated with the granule, the nucleus key concept is associated with DNA, the cell key concept is associated with the membrane, ribosome, organelle, and nucleus, and the ribosome key concept is associated with RNA and organelle. The concept network for the 15-11 cut-off point is presented in Figure 5.

When the concept network in Figure 5 is examined, it is observed that the peroxisome key concept is not added to the structure at the specified cut-off point. It can be stated that preservice teachers have a cognitive structure in which the centrosome key concept is associated with the centriole, the mitochondria key concept is associated with the organelle, the chloroplast key concept is associated with food and chlorophyll, the cell key concept is associated with the mitochondria, Golgi, cytoplasm, living beings, and its constituents at the 15-11 cut-off point. Furthermore, preservice teachers associated the nucleus key concept with the cell centre, management, RNA and membrane, the ribosome key concept with synthesis and cell, the Golgi key concept with packaging and organelle, and the endoplasmic reticulum key concept with carrying at the relevant cut-off point. After the General Biology course, the Word Association Test was applied to preservice science teachers again, and the concept networks created in line with the frequency table obtained from the data analysis are shown in Figures 6-9, respectively.

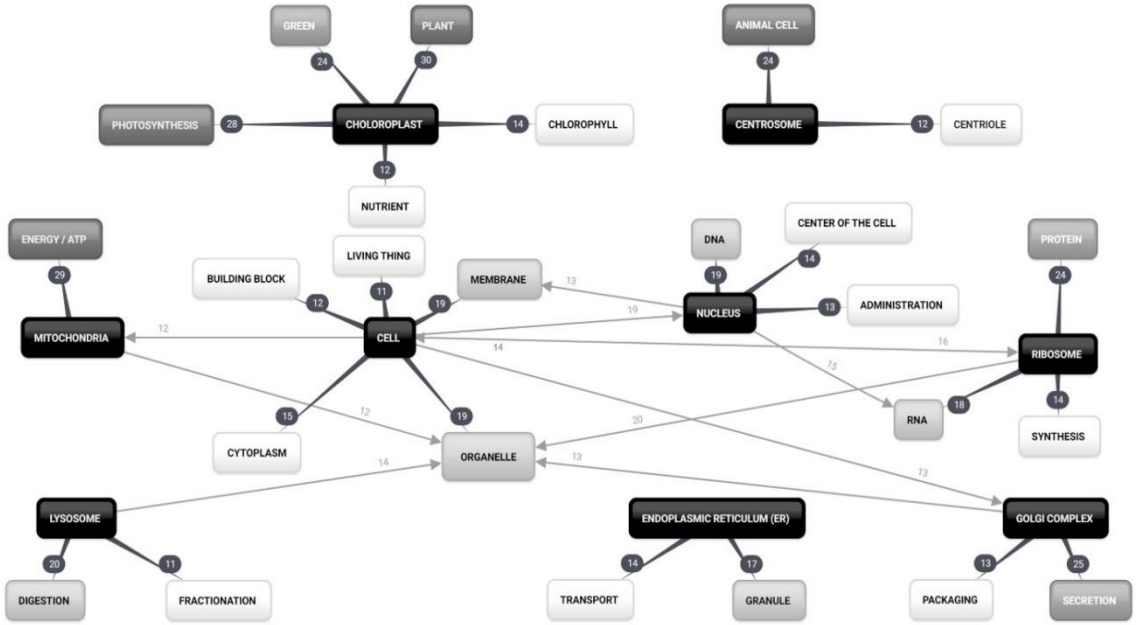

Figure 5. Pre-Test Concept Network (Cut-off Point: 15-11)

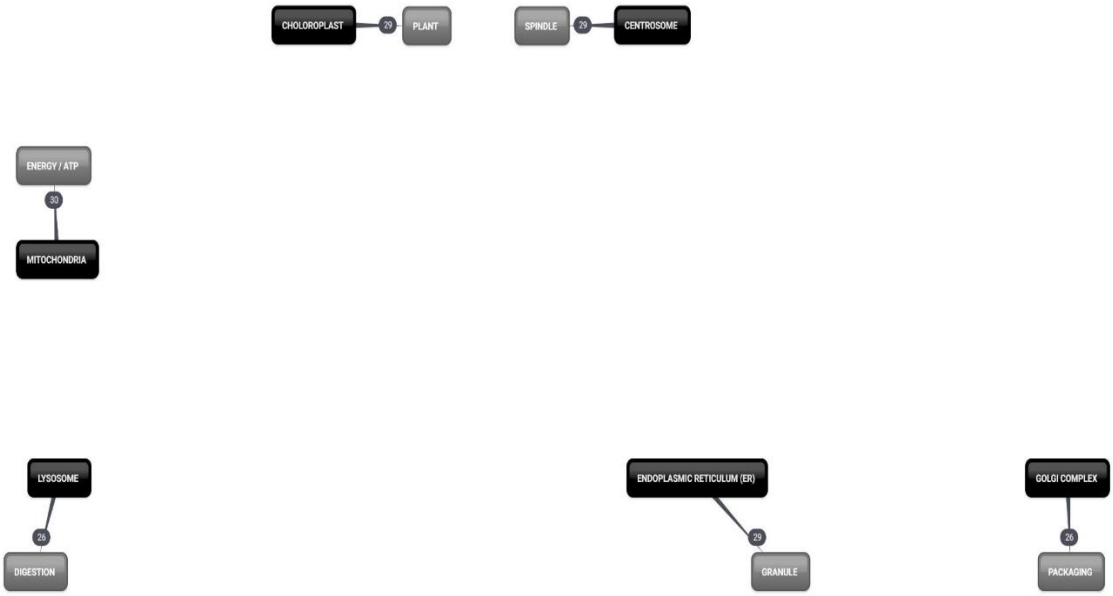

Figure 6. Post-Test Concept Network (Cut-off Point: 30-26)

When the concept network in Figure 6 is examined, it is observed that the key concepts of chloroplast, centrosome, endoplasmic reticulum, Golgi, lysosome, and mitochondria emerge at the cut-off point determined at a very high frequency. It is observed that the chloroplast key concept, among these key concepts, relates to the plant, the mitochondria key concept relates to energy/ATP, the centrosome key concept relates to the spindle apparatus, the lysosome key concept relates to digestion, the Golgi key concept relates to packaging, and the endoplasmic reticulum key concept relates to the granule. The concept network for the 25-21 cut-off point is presented in Figure 7.

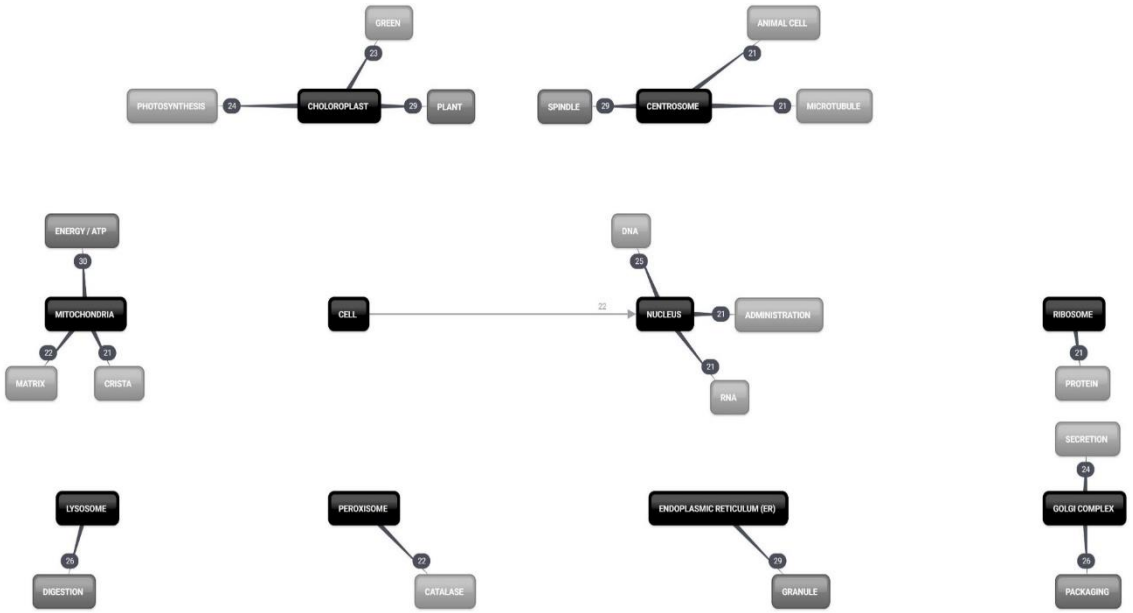

Figure 7. Post-Test Concept Network (Cut-off Point: 25-21)

When the concept network in Figure 7 is examined, it is observed that the ribosome, cell, nucleus, and peroxisome are included in the concept network at the determined cut-off point and all key concepts are included in the concept network. At the 25-21 cut-off point, preservice teachers have a cognitive structure in which the chloroplast key concept is associated with photosynthesis and green, the centrosome key concept with the microtubule and animal cell, the ribosome key concept with protein, the Golgi key concept with secretion, and the peroxisome key concept is associated with catalase. Furthermore, preservice teachers associated the nucleus key concept with DNA, RNA, and management, and the mitochondria key concept with the crista and matrix at the relevant cut-off point. It was observed that the first connection between the key concepts was established between the cell and nucleus key concepts at this cut-off point. The concept network for the 20-16 cut-off point is presented in Figure 8.

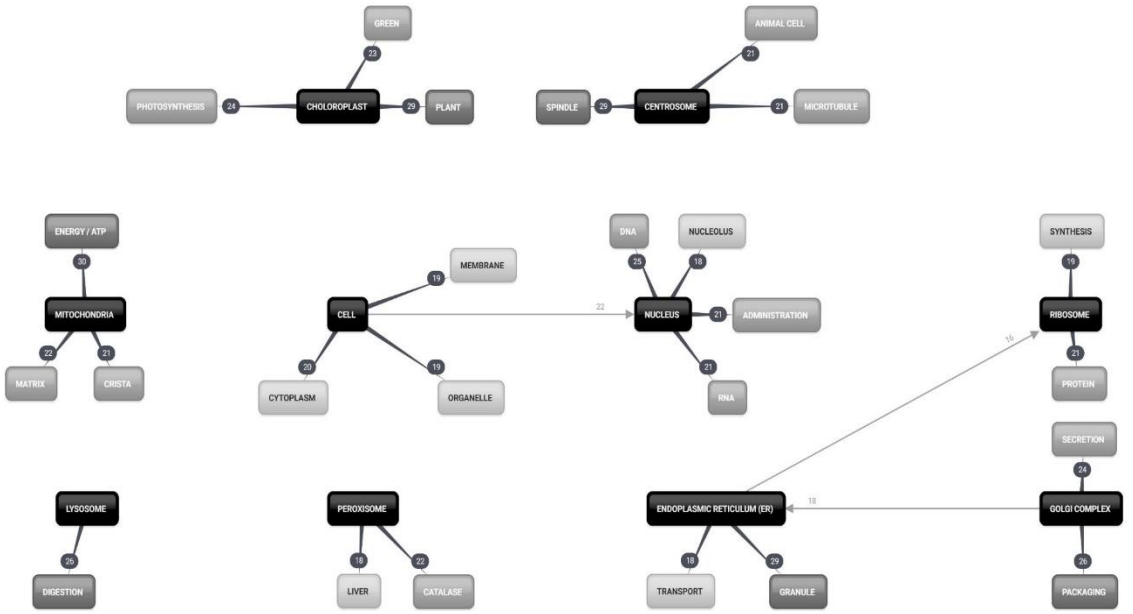

Figure 8. Post-Test Concept Network (Cut-off Point: 20-16)

When the concept network in Figure 8 is examined, it is observed that at the 20-16 cut-off point, preservice teachers have a cognitive structure in which the peroxisome key concept is associated with the liver, the endoplasmic reticulum key concept with the ribosome and transport, the cell key concept with the membrane, cytoplasm and organelle, the Golgi key concept with the endoplasmic reticulum, the nucleus key concept with the nucleolus, and the ribosome key concept is associated with synthesis. At this cut-off point, it was also observed that a connection was established between the Golgi key concept and the endoplasmic reticulum key concept, and between the endoplasmic reticulum key concept and the ribosome key concept. The concept network for the 15-11 cut-off point is shown in Figure 9.

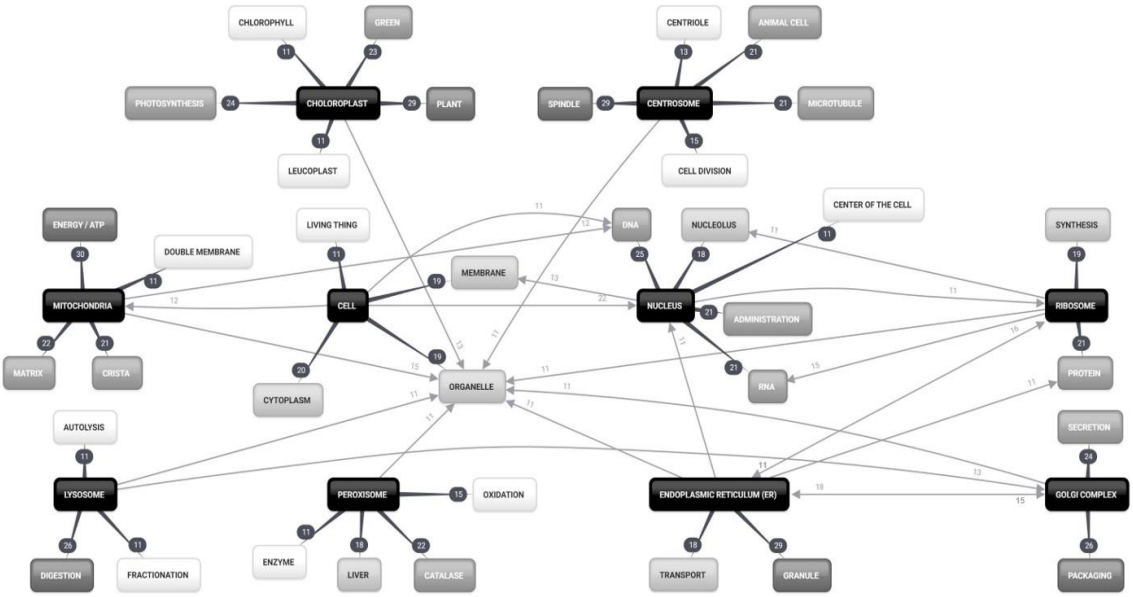

Figure 9. Post-Test Concept Network (Cut-off Point: 15-11)

When the concept network in Figure 9 is examined, it can be stated that at the 15-11 cut-off point, preservice teachers have a cognitive structure in which the centrosome key concept is associated with organelle, cell division and centriole, the mitochondria key concept with the double membrane, DNA and organelle, the chloroplast key concept with leucoplast, organelle and chlorophyll, the lysosome key concept with autolysis, digestion, Golgi, and organelle, and the peroxisome key concept is associated with enzyme, oxidation, and organelle. Furthermore, at the relevant cut-off point, preservice teachers associated the nucleus key concept with the ribosome, cell centre and membrane, the ribosome key concept with the nucleolus, RNA, endoplasmic reticulum and organelle, the Golgi key concept with organelle, the endoplasmic reticulum key concept with the nucleus, organelle, protein and Golgi, and the cell key concept with a living being, DNA, and mitochondria. One year after the General Biology course, the Word Association Test related to the cell and its organelles was applied to preservice science teachers again, and the concept networks created in line with the frequency table obtained from the data analysis are shown in Figures 10-13, respectively.

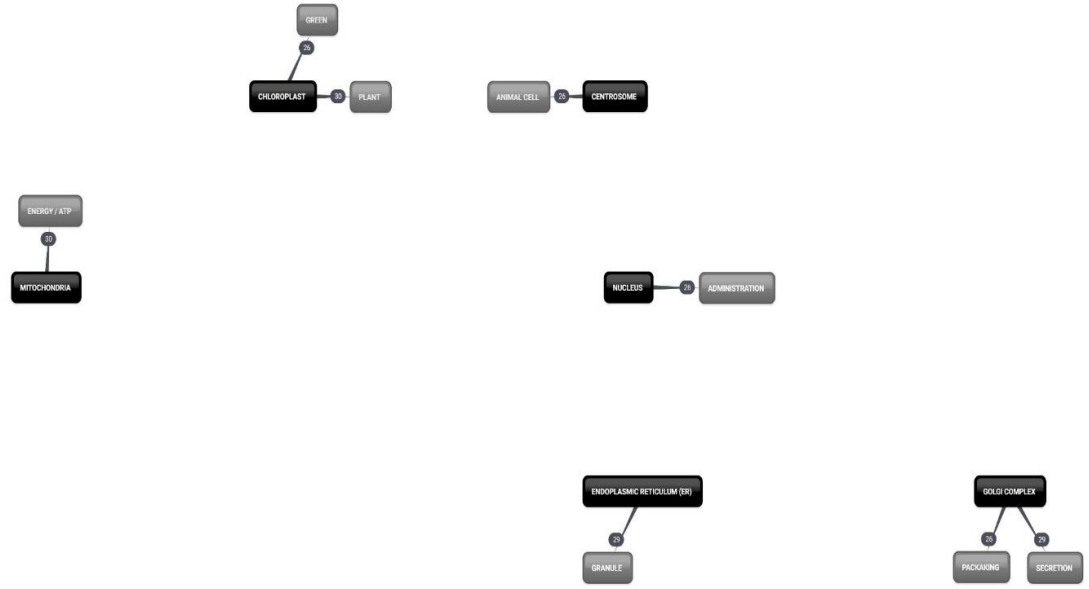

Figure 10. Retention Test Concept Network (Cut-off Point: 30-26)

When the concept network in Figure 10 was examined, it was observed that the key concepts of chloroplast, centrosome, endoplasmic reticulum, Golgi, nucleus, and mitochondria emerged at the determined cut-off point at a very high frequency. It is observed that, among these key concepts, the chloroplast key concept is associated with green and plant, the mitochondria key concept with energy/ATP, the centrosome key concept with the animal cell, the nucleus key concept with management, the Golgi key concept with secretion and packaging, and the endoplasmic reticulum key concept is associated with granule. The concept network for the 25-21 cut-off point is presented in Figure 11.

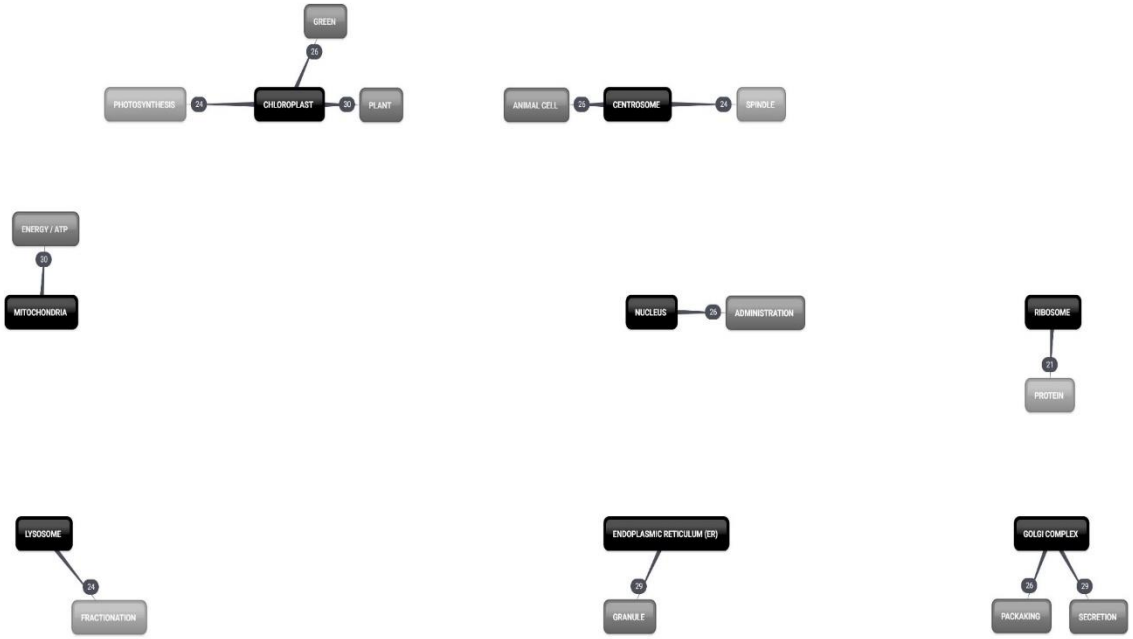

Figure 11. Retention Test Concept Network (Cut-off Point: 25-21)

Upon examining the concept network in Figure 11, it is observed that the ribosome and lysosome are included in the concept network at the specified cut-off point. At the 25-21 cut-off point, preservice teachers have a cognitive structure in which the chloroplast key concept is associated with photosynthesis, the centrosome key concept with the spindle apparatus, the ribosome key concept with the protein, and the lysosome key concept is associated with digestion. The concept network for the 20-16 cut-off point is shown in Figure 12.

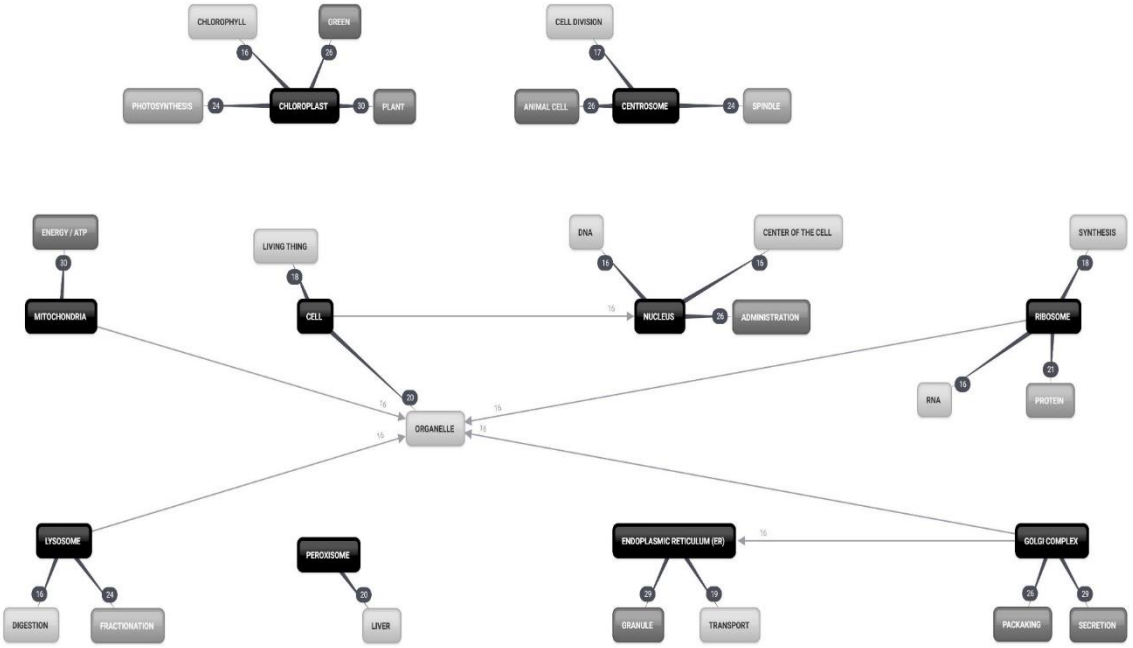

Figure 12. Retention Test Concept Network (Cut-off Point: 20-16)

When the concept network in Figure 12 is examined, it is observed that the cell and peroxisome are included in the concept network at the specified cut-off point and all key concepts are included in the concept network. At the 20-16 cut-off point, preservice teachers are observed to have a cognitive structure in which the chloroplast key concept is associated with chlorophyll, the centrosome key concept with cell division, the ribosome key concept with synthesis, RNA and organelle, the Golgi key concept with the endoplasmic reticulum and organelle, and the peroxisome key concept is associated with the liver. Furthermore, preservice teachers associated the nucleus key concept with DNA and cell centre, the mitochondria key concept with organelle, the endoplasmic reticulum key concept with transport, the lysosome key concept with digestion and organelle, the cell key concept with a living being, organelle and nucleus. The concept network for the 15-11 cut-off point is shown in Figure 13.

When the concept network in Figure 13 is examined, it is stated that at the 15-11 cut-off point, preservice teachers have a cognitive structure in which the centrosome key concept is associated with organelle, cell, mitosis, meiosis and centriole, the mitochondria key concept with a double membrane, matrix, crista, plant and animal cell, the chloroplast key concept with nutrients and organelle, the lysosome key concept with the cell and enzyme, and the peroxisome key concept is associated with the enzyme, digestion, and organelle. Moreover, at the relevant cut-off point, preservice teachers associated the nucleus key concept with cell, nucleolus, and membrane, the ribosome key concept with mRNA, tRNA, and rRNA, the Golgi key concept with cell, the endoplasmic reticulum key concept with the nucleus, organelle, protein, and ribosome, and the cell key concept with plant, animal cell, cytoplasm, building block, DNA, membrane, and mitochondria.

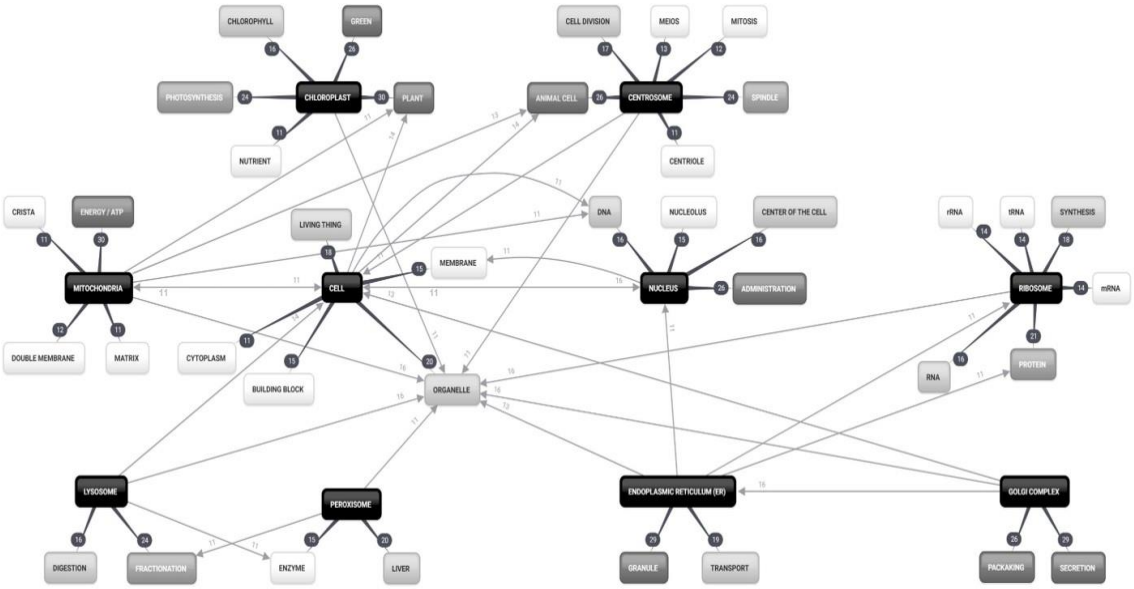

Figure 13. Retention Test Concept Network (Cut-off Point: 15-11)

4. Conclusion

In the present study, preservice science teachers' cognitive structures related to the cell and its organelles were examined through the WAT before, after, and one year after the General Biology course, and the discussion was made according to the final cut-off point (15-11). It was determined that the preservice teachers' cognitive structures related to the cell and its organelles before the lecture process were structured as four separate clicks ("chloroplast", "centrosome", "mitochondria-cell-nucleus-ribosome-lysosome-Golgi" and "endoplasmic reticulum"). This structure demonstrates that preservice teachers could not perform meaningful learning about the cell and its organelles during their pre-undergraduate education process and they could not perceive the functioning of the cell in a holistic way. Furthermore, it was observed that the peroxisome organelle, which was given as a key concept, was never added to this structure. This shows that preservice teachers do not have any knowledge about the presence of the peroxisome organelle or its role. This lack of knowledge may have originated from the inadequacy of both textbooks and teachers who conduct science and biology courses up to the undergraduate level (Carlan, Sepel & Loreto, 2014; Suwono et al., 2019). In the study in which they critically examined science textbooks on the basis of biology subjects. Atıcı, Keskin-Samancı and Özel (2007) concluded that the descriptions and representations made in the textbooks on the subject of the cell and its organelles were scientifically inadequate and could lead to misconceptions. It is observed that there are deficiencies regarding the structures and functions of the organelles in the concept network. For example, according to the concept network, it is observed that preservice teachers have knowledge about the presence of the centrosome in animal cells and the fact that it consists of centrioles, while the absence of any knowledge about the function of the centrosome organelle in the cell can be explained by the absence of the related concepts in the structure. This shows that the role of the centrosome in cell division could not be learned in a meaningful way by preservice teachers, and the knowledge, although incomplete, only about its structure and in which cells it is located was put forward. On the other hand, a similar deficiency was observed in the endoplasmic reticulum key concept. While this organelle is expected to be connected with the key concepts of the ribosome, Golgi, nucleus, organelle and cell, it is observed that only the transport and granule response words are included in the structure. Moreover, it was observed that the key concepts of chloroplast, centrosome, nucleus, and endoplasmic reticulum could not be related to the organelle key concept.

On the other hand, in line with the knowledge that preservice teachers have acquired during their pre-undergraduate education, it is observed that they have a conceptual structure regarding the presence of chloroplast in plants and its role in photosynthesis that it contains chlorophyll with green colour pigment and that nutrients are produced as a result of photosynthesis. It can be stated that preservice teachers consider the cell as the smallest structural unit that contains organelles such as the mitochondria and Golgi, has cytoplasm and shows vitality, and the nucleus as a membrane structure located in the centre of the cell, responsible for management and containing RNA. Furthermore, it is observed that preservice teachers have a strong cognitive structure indicating that the mitochondrial organelle is involved in energy/ATP production. Additionally, preservice teachers are observed to have a cognitive structure indicating that the lysosome organelle is an organelle involved in degradation and digestion, the endoplasmic reticulum organelle contains granules and has a function of transport, the Golgi organelle is an organelle responsible for secretion and packaging, and the ribosome is an organelle of the cell that contains RNA and is involved in protein synthesis.

It was determined that the conceptual links in the preservice science teachers' cognitive structures with regard to the cell and its organelles were established more after the General Biology course, the network became more complex, and all key concepts were linked to each other both by themselves and by response words. Moreover, it was observed that the peroxisome organelle, which did not participate in the cognitive structure at all in the pre-test, was added to this structure in the post-test and the liver cells, in which it is mostly located, the oxidation process for its function and catalase, one of the enzymes it contains, were also included in the new structure. After the General Biology course, it can be said that the preservice teachers' cognitive structures related to the peroxisome organelle, which has tasks such as oxygen production, oxidation, and pH balancing, include concepts in terms of features and tasks. The absence of a structure related to the peroxisome organelle in the pre-test concept network can be considered as an indicator that preservice teachers are not aware of the presence of the peroxisome before undergraduate education (Schrader & Fahimi, 2008; Tripathi & Walker, 2016). In their study conducted with preservice science teachers, Önel, Yüce, and Yeşilyurt (2015) aimed to determine the conceptual knowledge levels of preservice teachers about the cell subject. As a result of the analysis of the obtained data, it was revealed that only 3 fourth-grade preservice teachers out of 128 preservice teachers expressed the peroxisome organelle and 98% of the preservice teachers did not express the peroxisome organelle in any way.

Interestingly, it was observed that the knowledge regarding the chloroplast producing nutrients as a result of photosynthesis in the pre-test concept network did not appear in the post-test cognitive structures. On the other hand, the fact that preservice teachers have a conceptual structure containing knowledge that chloroplast is an organelle of the cell and leucoplasts mostly differ from chloroplasts (Sadali et al., 2019) is understood from the connection of the chloroplast key concept established with the organelle key concept and the presence of the leucoplast response word given to this key concept. In the cognitive structures of preservice teachers, there is knowledge about the structure of this organelle rather than the outputs of the photosynthesis event occurring in the chloroplast. However, although photosynthesis has been explained in detail by using both the drama method and analogies in the education given, it is observed that this subject is still not sufficiently understood by preservice teachers. In studies on photosynthesis, it is emphasized that this subject is among the biology subjects that are difficult to understand by students (Orbanić, Dimec & Cencič, 2016; Södervik & Mikkilä-Erdmann, 2015). In the study performed with 292 secondary school students studying in Greece, Marmaroti & Galanopoulou (2006) expressed that students had misconceptions about the structures and organs involved in photosynthesis, parameters in the photosynthesis reaction, factors affecting photosynthesis, the use of photosynthesis products, and they could not learn the photosynthesis subject in a meaningful way.

A similar situation is observed in the ribosome organelle. In the education provided, three-dimensional images of the large and small subunits that make up this organelle created by the X-ray crystallography method were shown, and the regions of the ribosome, the rRNA entering the ribosome structure, the structures of mRNA and tRNA involved in protein synthesis, and how protein synthesis takes place were explained in detail step by step. On the other hand, the ribosome keyword was linked with the nucleolus, the production site of the ribosome, and RNA response words and the organelle

key concept, and only the synthesis and protein response words were given. However, it was expected that preservice teachers would give response words in the form of rRNA, tRNA, mRNA, large and small subunit, E, P and A regions, 60S, 40S and link them with the endoplasmic reticulum and cell keywords. Similar to the photosynthesis subject, it can be stated that the subject of protein synthesis is a subject that students experience difficulty in constructing cognitively (Cavalho, Beltramini, & Bossolan, 2019). In a study carried out with 8 preservice biology teachers, Deveci (2019) stated that preservice teachers' subject matter knowledge of protein synthesis was inadequate and they had misconceptions. In the study conducted with 15 high school students, Cavalho, Beltramini, & Bossolan (2019) indicated that the board game created on the subject of protein synthesis, which is considered to be difficult to perceive, could be effective in creating a protein synthesis model. Although both photosynthesis and protein synthesis are tried to be explained in an enriched way within the scope of the education provided, it is understood that the cognitive structures formed by preservice teachers in their minds with regard to such difficult subjects up to this education level are resistant to change (Ariesta, 2021; Jayanti, 2020).

Apart from these, the fact that the response words given to the key concepts such as centrosome, mitochondria, endoplasmic reticulum, and Golgi in the pre-test increased in the post-test and the relationships of these organelles not only with their structures but also with their functions and other organelles in the cell were comprehended by preservice teachers was understood through the connections they established, and the response words given.

It was observed that the building block response word given by preservice teachers to the cell key concept in the pre-test disappeared in the post-test. Furthermore, it is a surprising finding that although all key concepts, other than the cell key concept, given to preservice teachers have a relationship with the cell, this relationship cannot be established directly by preservice teachers. It was observed that the connections of the key concepts with each other were linked to the cell key concept through the organelle key concept. This can be explained by the inability of preservice teachers to see the general picture (Ormancı, Çepni & Ülger, 2020). In the study conducted by Bozdağ and Ok (2019) with 388 secondary school students, as a result of the analysis of the data obtained through the four-stage test on the cell subject, they stated that students had difficulty in structuring the subject related to the cell's structure and functions cognitively and had a total of 10 different misconceptions regarding the cell subject, including 4 at a strong level and 6 at a moderate level. In a study performed with a total of 1931 students studying in 41 primary schools and 36 high schools in Croatia between 2008 and 2012. Lukša et al. (2016) concluded that students could not learn subjects related to cell divisions in a meaningful way and primary school and high school students had similar misconceptions and incomplete learning, although they were at different education levels.

The concept network formed as a result of the test applied to preservice science teachers for the retention of knowledge one year after the General Biology course was examined, and it was determined that there were some concepts that were in the pre-test but did not appear in the post-test and were revealed again in the retention test. For example, it was observed that nutrient, one of the two important molecules formed as a result of the photosynthesis event, did not appear as the response word in the post-test but was reshaped in the retention test, or the building block response word given in the pre-test to the cell key concept also appeared in the retention test. Although these two concepts did not appear in the post-test, it can be said that they were in the minds of preservice teachers because they were frequently emphasized in science and biology courses. On the other hand, it was observed that many concepts that did not appear in the pre-test emerged in the post-test as a result of the education provided, but some of them were not shaped in the retention test. For example, the leucoplast response word given to the chloroplast key concept, the microtubule response word given to the centrosome key concept, the autolysis response word given to the lysosome key concept, the catalase and oxidation response words given to the peroxisome key concept were in the post-test but were not included in the retention test. Additionally, it is observed that the connections between the nucleus key concept and the ribosome key concept and the key concepts of lysosome and endoplasmic reticulum and the Golgi key concept were not shaped in the retention test. Apart from these, some concepts that did not appear in the concept networks in the pre-test and post-test results but were included in the concept network in the retention test were also encountered. For example, the digestion

response word given to the peroxisome key concept, the connection established between the plant and animal response words given to the mitochondria key concept and the cell key concept, the connection established between the cell key concept and the meiosis and mitosis response words given to the centrosome key concept, the connection established between the enzyme response given to the lysosome key concept and the cell key concept, and the connection established between the Golgi key concept and the cell key concept. While it is expected as a result of the education provided, that the direct connection of all the organelles given to preservice teachers as a stimulus word with the cell will be established in the post-test, it can be stated that this connection is established with only four organelles in the retention test. This may be due to the structuring of knowledge over time. There are many studies in the literature stating that the knowledge learned is structured in mind over time, and if it is reinforced by using it in daily life, it can be organized more easily in the cognitive structure (Agarkar, 2019; Taber, 2019; Vallori, 2014).

It can be said that before the General Biology course, the subject of the concepts associated in terms of structure and function with regard to the cell and its organelles in preservice science teachers' cognitive structures was not structured in their mind in a meaningful way, the concept network in their minds was in the form of four independent clicks, and preservice teachers did not have knowledge about the peroxisome organelle before their undergraduate education. In the retention test conducted after the education provided to preservice teachers and one year later, it was observed that a cognitive structure, which included richer concepts about the cell and its organelles, in which they were interconnected and in which the peroxisome organelle was added to the structure, was formed in the preservice teachers. Furthermore, it is observed that the existing structure did not change much compared to the pre-test concept network for the concepts that organelles such as lysosome and Golgi are related to. Considering the concepts associated with organelles such as mitochondria, centrosome, and peroxisome, it can be said that very effective learning has been achieved in terms of the structure and functions of the specified organelles. It can be stated that, in general, the education provided increases the relationship between the concepts related to the cell and its organelles in preservice teachers and creates a cognitive structure that contains more comprehensive information in terms of the structure and functions of the concepts. On the other hand, in the retention test, it was determined that most of the cognitive structure formed in preservice teachers was preserved, but some detailed and newly learned information was lost from this structure. Although enriched education is given to preservice teachers, it is understood that it is difficult to settle the information that does not settle until they reach the current education level. Therefore, to better understand vitality activities in science lessons starting from the secondary school level, based on the principle of spiralling in education, the course contents should be enriched with techniques such as laboratory practices, context-based approach, drama, and analogy for the structure and functioning mechanism of the cell and its organelles to be taught in a meaningful way. Especially when students get acquainted with the concept of the cell for the first time, it should be explained that the cell is a building block of the organism, the cell membrane, nucleus, cytoplasm, and cell organelles should be given their functions and names without entering into the structures of the cell, and the relationships between DNA, genes, and chromosomes should be established. How and for what purpose photosynthesis and respiration events take place and what their final outcomes are should be explained by being supported by dramas. After this basic information is provided, it is recommended to teach information about the structure and functions of different cell types and organelles by using light microscopy, techniques such as analogies, concept maps, mind maps, and by establishing conceptual networks with applications such as animation and simulation, and to shape the cognitive structure expected to be formed.

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