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Constructing a Novel Mind Map to Identify Difficult Topics in Biology Using Processing Software

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ABSTRACT This study aims to determine those topics and concepts that biology and science teacher candidates find most challenging to learn in biology lessons. A qualitative case study research method was used to this end. A total of 132 science and biology teacher candidates studying at a state university were asked to write down the ten subjects or concepts they found difficult to learn in biology and the order in which these came to mind. As a result of the content analysis of the collected data, a novel concept map was created using the Processing 3.3.4 software. According to this map, the subjects that teacher candidates found most challenging to learn in biology are circulatory, genetics, respiratory, and energy. Comparably, those subjects they found least challenging to learn were Basic components of living things, Support and movement systems, and Evolution. The results of the novel mind map can help researchers conduct studies on subjects that are difficult to learn in biology. The results of the novel mind map produced by this study will help future research on subjects that are difficult to learn in the field of biology.

Keywords: Biology concepts, Novel mind map, Pre-service teachers

1. INTRODUCTION

Humans interact with many living and non-living entities in their environment. It is essential for education in biology to be in harmony with the environment that humans live in, to be able to understand nature, to recognize living beings and embrace the whole environment, and to be related to the health of human life (Güneş & Güneş, 2005). The developments in science and technology have also affected the field of biology and have shown the necessity of making changes in biology education (İpek et al., 2021). The goal of biology education is to reach the necessary knowledge, skills, and behaviors in the field of biology with scientific thinking and research methods (Ari & Arslan, 2019). A biology curriculum is a written document that answers the questions of "why, what, how, and how much" to be taught to learners regarding the knowledge, subjects, and concepts in the field of biology (İpek et al., 2021). When biology curricula are examined, many abstract concepts, events, and subjects to be learned by the students are included (Çimer, 2011). Up-to-date curricula covering current biology knowledge, technological developments, and new methods are needed to educate individuals with a biological perspective, who are literate in biology (Ari & Arslan, 2019; Özcan et al., 2014). The biology achievements included in the science subject in primary education are taught within the scope of biology from the 9th grade to the 12th grade, separating the science subjects into fields in secondary education.

Studies in the field reveal that students face difficulties in biology lessons due to various reasons (Bahar, 2002; Güneş & Güneş, 2005; Özatlı, 2006; Çimer, 2011; Özcan et al., 2014; Fauzi & Mitalistiani, 2018; Fauzi & Fariantika, 2018; Koç & Sönmez, 2018; Wai & Khine, 2020; Özarslan, 2021). According to these studies, those subjects that primary and secondary school students find most difficult in the field of biology are as follows: animal and plant tissues; regulatory and control systems, life events and ATP energy, genetics, division, human body, the classification of living things, and evolution (Bahar, 2002; Güneş & Güneş, 2005; Özatlı, 2006; Çimer, 2011; Özcan, et al., 2014; Fauzi & Mitalistiani, 2018; Fauzi & Fariantika, 2018; Koç & Sönmez, 2018; Wai & Khine, 2020; Özarslan, 2021). The fact that students face difficulties in understanding abstract and complex concepts in biology can lead to decreased

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success and motivation of these students in biology lessons (Güneş & Güneş, 2005; Özatlı, 2006; Çimer, 2011; Özcan et al., 2014; Fauzi & Mitalistiani, 2018; Fauzi & Fariantika, 2018; Koç & Sönmez, 2018; Wai & Khine, 2020; Özarslan, 2021). Studies have shown that primary and secondary school students struggle most with the following topics in biology: animal and plant tissues, regulatory and control systems, vital events and ATP energy, genetics, division, human body, classification of living beings, and the world of living beings, cells, circulatory system, respiratory system, sense organs, ecosystems, and material cycles (Güneş & Güneş, 2005; Çimer, 2011; Özcan et al., 2014; Wai & Khine, 2020; Özarslan, 2021).

The results of those studies conducted with class teachers and science and biology teacher candidates indicate that the most difficult topics for teacher candidates in biology are plant and animal cells, plant and animal tissues, bacterial cells, protozoa, genetics, and genetic engineering, meiosis and mitosis divisions, botany, the immune system, utilization, and prokaryotes and eukaryotes cells (Bahar, 2002; Özatlı, 2006; Fauzi & Mitalistiani, 2018; Fauzi & Fariantika, 2018; Koç & Sönmez, 2018; Wai & Khine, 2020). Having sufficient knowledge and pedagogical knowledge in the field will make biology lessons more effective for learners (Öztaş & Özay, 2004). It is important to identify those topics that biology teacher candidates—who will teach biology in secondary schools and who are the architects of future generations—struggle with in order to avoid any gaps or incorrect learning in their field knowledge and to take various precautions during their university education. An analysis of the current situation is important to address any deficiencies in teaching biology.

1.1 Mind Maps

A mind map visualizes ideas or information, typically comprising a central concept or topic and branches representing related ideas or details. Mind maps organize and summarize information, brainstorm ideas, and facilitate problem-solving and decision-making. These maps are created using various tools, such as pens and papers, computer software, or online mind-mapping tools. They can mainly be helpful for visual learners or when trying to understand complex or abstract concepts. They can also illustrate relationships between ideas and identify patterns or connections (Balım et al., 2006; Kelepçe, 2021).

Mind maps can be described as a technique that helps support memory and reveals relationships between cognitive processes and thinking about a subject, preparing a presentation, or working on a plan (Balım et al., 2006; Kelepçe, 2021). A central idea, image, theme, or concept is located at the center of a mind map. Those branches emanating from the center show cognitive connections that are related to the mind map's central concept, thought, image, or theme. Mind maps facilitate the expression of thoughts and concepts and information, thoughts, and concepts on a single page (Balım et al., 2006; Aksoy, 2022).

Mind maps were introduced in the 1970s and have subsequently moved into virtual environments through the use and development of technology. Today, mind maps can be easily prepared online and offline (Aksoy, 2022). Computer-supported mind maps can help express ideas and support content with images, making it easier to show relationships among them. The ease of preparing maps with computer support, the ability to make various changes to the maps as desired, and the ability to make edits facilitate access to the map without needing to redraw the map for map users. Further advantages include using computer-supported mind maps in computer presentations and the ability to share the maps with many people simultaneously (Fidan, 2012).

1.2 Processing Software

"Processing program" is a flexible software sketchbook and a language for learning how to code; since 2001, it has supported software literacy in the visual arts and technology. Processing is commonly utilized in classrooms, high schools, computer science programs, and humanities curricula all around the world, and is frequently used in art schools and visual arts programs at universities. College students taught with the "Processing" program starting computing courses at Bryn Mawr College responded to a National Science Foundation-sponsored survey, which showed that students were twice as likely to take another computer science class than those in classes that were taught using a more conventional curriculum. Electronics has also used a processing methodology to teach Wiring and Arduino projects. These projects make it simpler for students to learn how to program robots and a variety of other electronics projects by utilizing a modified version of the processing programming environment.

In their study Determining the Perceptions of Turkish FRC Participants about FRC through Metaphors and Creating a Novel Mind Map, Özgür et al. (2020) propose and use a novel and noteworthy mindmap approach. According to this approach, mind maps are centered on a main concept, which is shown as a circle. Around the main concept, other related concepts are shown, each of which is represented by circles of different sizes and distances from the main concept. In the study, these circles surrounding the main concept and circle represent the priority of participants' responses about the central concept. The size of these circles and their respective concepts represent the strength of participants' responses concerning the central concept, with larger circles showing more participant answers. The relationship between themes is expressed in terms of distance, with larger distances representing weaker relationships. Figure 1 shows the novel mind map Özgür et al. (2020) prepared in their study.

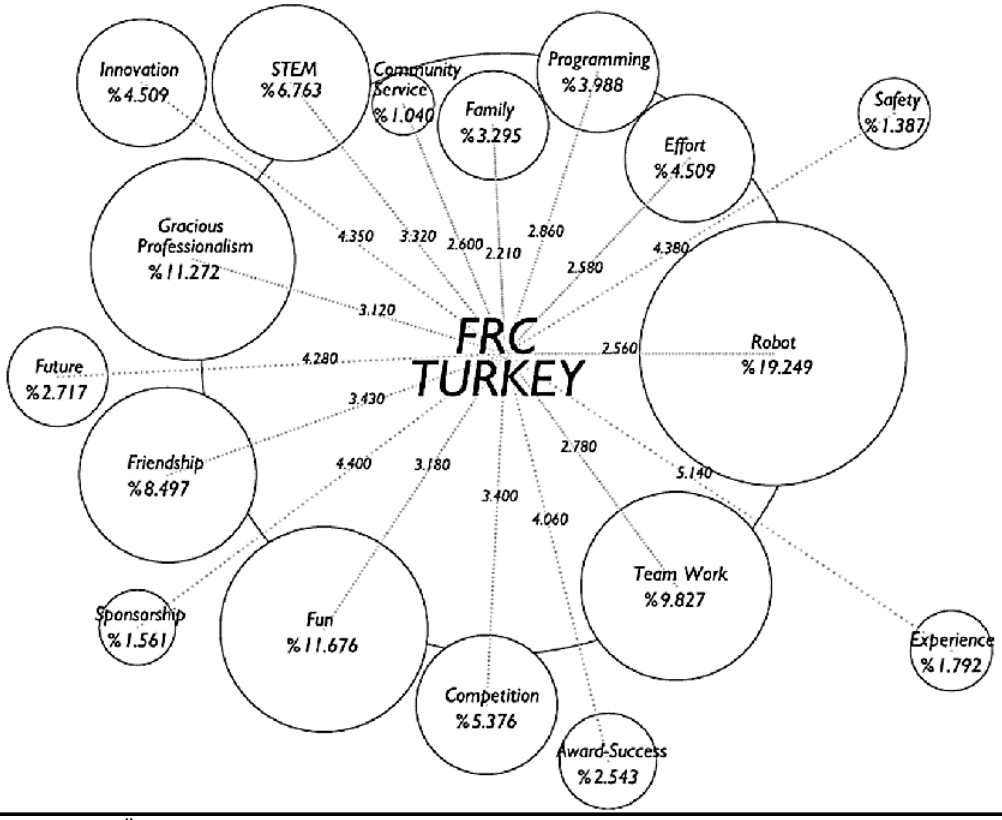

Figure 1 Novel mind map by Özgür, et al. (2020)

Özgür et al. (2020) used the Processing 3.3.7 software to obtain the mind map after collecting data on the main concept. The program calculated and determined the distances and sizes of the various sub-concepts about the central concept using the original code written by Özgür et al. (2020); this resulted in the novel mind map depicted in Figure 1. This approach shows the relationship between the participants' responses and the central concept. It can be used to analyze those studies aimed at revealing the cognitive structures of individuals, such as word-association tests (Özgür et al., 2020).

In addition, the novel mind map approach may be advantageous in visualizing data and making it more understandable and interpretable by different researchers. In the present study, the novel mind map approach developed by Özgür et al. (2020) was used to determine those biology topics with which pre-service teachers struggle, facilitating the interpretation of these topics by showing the visual relationship between their cognitive structures. Mind maps are helpful for visualizing those topics and concepts with which pre-service teachers struggle within the field of biology. Several studies in the literature focus on those topics in the field of biology that pre-service teachers find particularly challenging; however, the current study is the first example in the literature that visualizes the current situation regarding this issue.

1.3. Study Aim

This study aims to identify topics in biology that pre-service biology and science teachers find particularly challenging through a novel mind map. To achieve this aim, the following research question was addressed.

- Which biology topics do pre-service science and biology teachers find particularly challenging?

2. METHOD

2.1 Research Design

This study uses a qualitative case study research method. Case studies involve a detailed and in-depth examination of one or more events, occurrences, social groups, or interconnected systems (Büyüköztürk et al., 2008); this research approach is used to see or describe the details of an event or occurrence, allowing researchers to conduct detailed research with rich content. In the present study, the case study method was used to identify in a detailed and holistic manner those topics in biology that pre-service teachers find particularly challenging. The research design flow can be seen in Figure 2.

2.2 Study Group

In the academic year 2021-2022, a total of 132 pre-service teachers studying biology and science teaching at Necatibey Faculty of Education at Balıkesir University participated in the study. Of the participants, 95 were female, 14 were male, and 23 did not specify their gender.

2.3 Data Collection Tools

The data collection tool used in this study was a word association test prepared by the researcher. Word association tests (WATs) are used to reveal an individual's

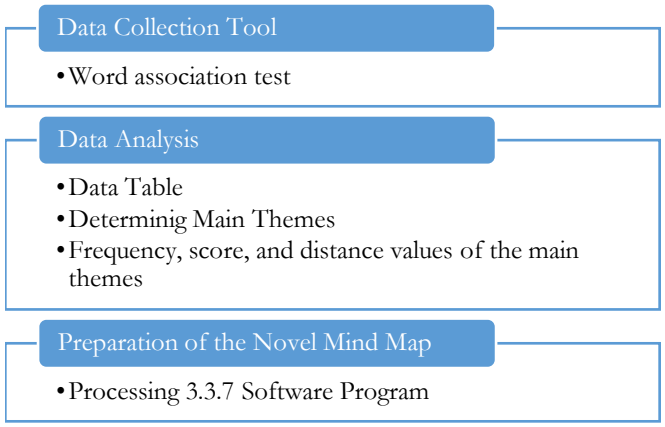

Figure 2 Research design flow

cognitive structure and analyze those concepts and relationships in their long-term memory within this cognitive (Bahar, 2002). When using WATs, participants are asked to associate, without limitation, other concepts that the stimulus or key concept brings to mind and write these down as answers as quickly as possible (Bahar & Özatlı, 2003; Ekici & Kurt, 2014). The number and quality of the responses given by the participants to the key concept can be determined in the evaluation of WATs, and the cutting point technique or mind map can be used thereafter (Bahar & Özatlı, 2003). Özgür et al. (2020) indicated that WATs may be their study's most appropriate data collection tool for the novel mind map approach. Therefore, in this study, the participants were asked to write, in order of appearance in their minds, the ten concepts or topics in biology that they struggled with within approximately one minute.

2.4 Data Analysis

The study data were collected through WAT and evaluated using content analysis. Content analysis allows similar data to be grouped under specific themes in a way that the reader can easily understand (Ekici & Kurt, 2014). A novel mind map was then created based on the analyzed data. The Processing 3.3.7 Software Program was used to implement this novel mind map, a new evaluation approach. Here, a central topic is placed in a circle, and other identified themes occupy circles of their own, each linked to the central theme and varying in size and distance from the central theme. This process enables the creation of a model through the use of content analysis. In preparing the map, the novel mind map preparation steps prepared by Özgür et al. (2020) were adapted to the present study. The following sequence was followed in the data analysis:

- Making a Table 1 using WAT Data: The words written down by the participants in the WATs were entered into an MS Excel spreadsheet and ordered. The resulting data set comprised a total of 746 words. Four words that were not related to biology were removed from the set, leaving a data set of 742 words for the analysis. The remaining 742 words comprised the frequency of the concepts, with the area of the central circle and topic of the novel mind map used in the present study, "difficult topics in biology," corresponding to the size of all 742 words.
- Determining Main Themes; The large number of participants' WAT responses made it difficult for each word to be included in the novel mind map. Therefore, words in the data set were grouped under more general and comprehensive concept headings, known as main themes. In this way, 20 main themes were identified. The validity and reliability of the novel mind map were ensured according to the rule that the main theme to be included in the map must represent at least 1% (7) of the total number of concepts (742) (Özgür et al., 2020).
- Identifying the frequency, score, and distance values of the main themes: Once the concepts had been identified and grouped according to 20 main themes, the frequency, score, and distance values of these central themes were calculated. Frequency values determine the area of each circle on the map, while the distance values of each circle (the distance of each circle from the main topic and circle) were calculated according to the ratio of score values. Accordingly, each circle's location was determined based on its distance from the central circle.
- Calculation of the frequencies of the main themes: In the study, all those words written down by the participants related to biology; accordingly, the frequency of all main themes constituted the total frequency value, that is, the size of the circle of the central concept "difficult topics in biology". The frequency of the main themes was formed by the frequencies of those concepts collected under each main theme heading. For example, if participants wrote down eight responses relating to the topic of evolution and one response relating to divergent evolution, convergent evolution, Darwin, adaptation, and types of evolution, these concepts would be

Table 1 WAT answers and scores of participants 73 and 77

Scores	Pre-service teacher no: 73	Pre-service teacher no: 77
	Nervous system	
0	Chemosynthesis	DNA
1	Energy transfer	Circulatory system
2	Meiosis	Classification
3	Endocrine	Inheritance
4	system	Excretory system
5	Circulatory	Nervous system
6	system	Meiosis
7	Excretory system	Mitosis
8	-	Cell transitions
9	-	Photosynthesis/respiration
	-	

collected under the central theme of evolution; together, these would determine the frequency of this central theme. Accordingly, the frequency of evolution's central theme would be 13. This process was carried out for each of the study's 20 main themes, determining the size of all circles on the mind map.

- Calculation of the scores of the main themes: The total score of each concept comprising the main themes was then calculated to determine the distance between these main themes and the central concept. The score value of the concepts refers to the numerical value given to each concept as written by the participants according to the ranking of their WAT responses, with given scores ranging from 1 to 10. For this calculation, values from 0 to 9 are given to the WAT answers according to this ordering and ranking (Özgür et al., 2020).
  - For participant 73, the Nervous system scored 0; chemosynthesis scored 1; energy transfer scored 2; meiosis scored 3; the endocrine system scored 4; the circulatory system scored 5; and the Excretory system scored 6.
  - For the participant 77, DNA scored 0; Circulatory System 1; classification 2; inheritance 3; excretory system 4; nervous system 5; meiosis 6; mitosis 7; cell transitions 8; and Photosynthesis/respiration 9.
  - According to these values, the circulatory system's total score was calculated as 6 (5+1). This scoring was then undertaken for all concepts in consideration of the order of participant responses, resulting in a total score value for each related concept. Subsequently, the concepts were grouped under the main themes to which they were related, thereby forming the total score value of each theme.
- Calculate the distance of the main themes to the central theme: The total frequency and score values of those concepts belonging to the main themes were then determined according to their respective total frequency and score values. The distance between the primary and central themes was then found by dividing the total score value and the total frequency of the main themes (Özgür et al., 2020). This process calculated the distance value of the main themes from the central theme, "difficult topics in biology."
- Preparation of the Novel Mind Map: As a result of the data analysis, the main themes, frequency and distance values of the main themes and the novel mind map of the study began to emerge. Özgür et al. (2020) wrote a code and used the Processing 3.3.7 Software Program to make the mind map of their study easier to prepare; the researchers included the frequency, distance values, and concepts of their study into the code, ran the Processing 3.3.7 Program, and created a new novel mind map based on "difficult topics in biology." If necessary, subheadings should be used.

3. RESULT AND DISCUSSION

The recent study investigated biology concepts most challenging biology and science teachers found and created a new "difficulties in biology" novel mind map. A total of 132 science and biology teacher candidates participated in the study. All participants were asked to write down the first 10 concepts/topics that came to mind regarding those topics they found most challenging. The participants were given approximately one minute to do this as part of a WAT and were asked to give suggestions to determine in what order they came to mind. Some participants completed the required 10-word list of topics within the specified time. A total of 746 words were collected and analyzed, and four words were removed because they had no relation to biology. The researchers then analyzed the remaining 742 words. These words were grouped into broader main theme titles that included themselves. This process determined a total of 20 main themes; these central themes and their related words are shown in Table 2.

Table 2 Main themes and their examples

Main Themes	Examples
The circulatory system	Immunity, immune system, blood circulation
Excretory system	excretory system, urinary system
Digestive system	digestion, digestive system
Supervisory and regulatory systems	Central nervous system, hormonal system, nervous, brain
Photosynthesis	Photosynthesis, photosynthesis-chemosynthesis, chlorophyll
From gene to protein	From gene to protein, genetic code, and protein synthesis
Ecosystem ecology	Ecosystem, ecology, material cycles, food pyramid
From cell to organism	Tissues, histology, animal tissues, systems
Plants	Plant, reproduction in plants, plant parts
Living World	The living kingdom, bacteria, and archaea, invertebrates
Genetic	Crossover, mendelian genetics, heredity, genetics
Evolution	Evolution, Darwin, divergent evolution, convergent evolution
Division	Types of division, meiosis, meiosis, mitosis
Classification of living things	Classification of living things, Latin species names, species and genus concept
Essential components of living things	Vitamin minerals, vitamins, DNA, and genetic code

Table 2 Main themes and their examples (*Continued*)

Main Themes	Examples
Cell	Cell, organelles, animal and plant cell
Respiratory system and energy	ATP synthesis, respiratory system, anaerobic respiration
Support and movement system	Skeletal system, muscular system, bones
Reproductive	Sexual reproduction, female reproductive system, reproductive system
Life science biology	Biochemistry, molecular biology, animal anatomy

As shown in Table 2, all the concepts written by the participants regarding biology were related to the main theme, with similar concepts being grouped under the 20 main themes. After the main themes and the concepts included in these main themes had been determined, the next data analysis stage was carried out. First, the frequency of each word written down by the study participants was determined, after which scores were calculated by considering the order in which the words were written. Consequently, a total frequency and points value were found for each theme; distance values were then calculated by dividing the theme's total points value by their total frequency. The frequency, score, and distance values of each of the main themes are given in Table 3.

Table 3 shows the data relating to the topics that biology teacher candidates struggle with within the field of biology. The list was ordered according to the order of emergence (points) in the minds of the participants. The novel mind map approach, as suggested by Özgür et al. (2020), was used to visualize these data so that they can be more easily understood and interpreted by different researchers. The codes written to visualize the mind map were then adapted to the present study. The codes adapted for the present study are shown in Annex 1. The aforementioned processing software was used to run the codes. This program can be used offline; a screenshot of the program after running the codes is shown in Figure 3.

Some of the lines of code shown in Figure 3 (especially lines 6, 7, and 8) have been adapted for the present study. When the codes adapted for the main theme names, frequencies, and distance values obtained from this study were run using the Processing Program, a novel mind map on the subject of "difficulties in biology" related to the participant's responses was then obtained as shown in Figure 4.

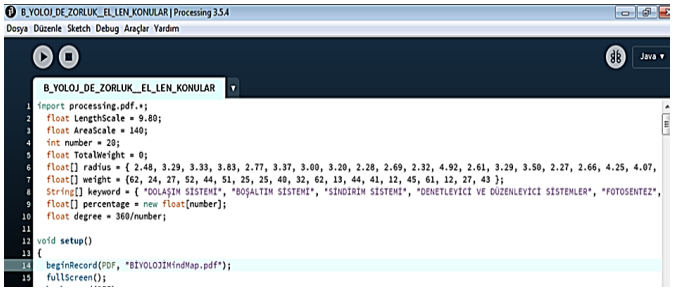

Figure 3 Processing program screenshot

Table 3 Main themes' frequency, score, and distance values

Main Themes	Frequency	Score	Distance
1. Circulatory system	62	154	2.48
2. Excretory system	24	79	3.29
3. Digestive system	27	90	3.33
4. Controller and regulatory systems	52	199	3.83
5. Photosynthesis	44	122	2.77
6. From gene to protein	51	172	3.37
7. Ecosystem ecology	25	75	3.00
8. Cell to organism	25	80	3.20
9. Plants	40	91	2.28
10. Realm of the living	32	86	2.69
11. Genetics	62	144	2.32
12. Evolution	13	64	4.92
13. Division	44	115	2.61
14. Classification of living things	41	135	3.29
15. Basic components of living things	12	42	3.50
16. Cell	45	102	2.27
17. Respiratory system and energy	61	162	2.66
18. Support and movement system	12	51	4.25
19. Reproduction	27	110	4.07
20. Life science biology	43	108	2.51

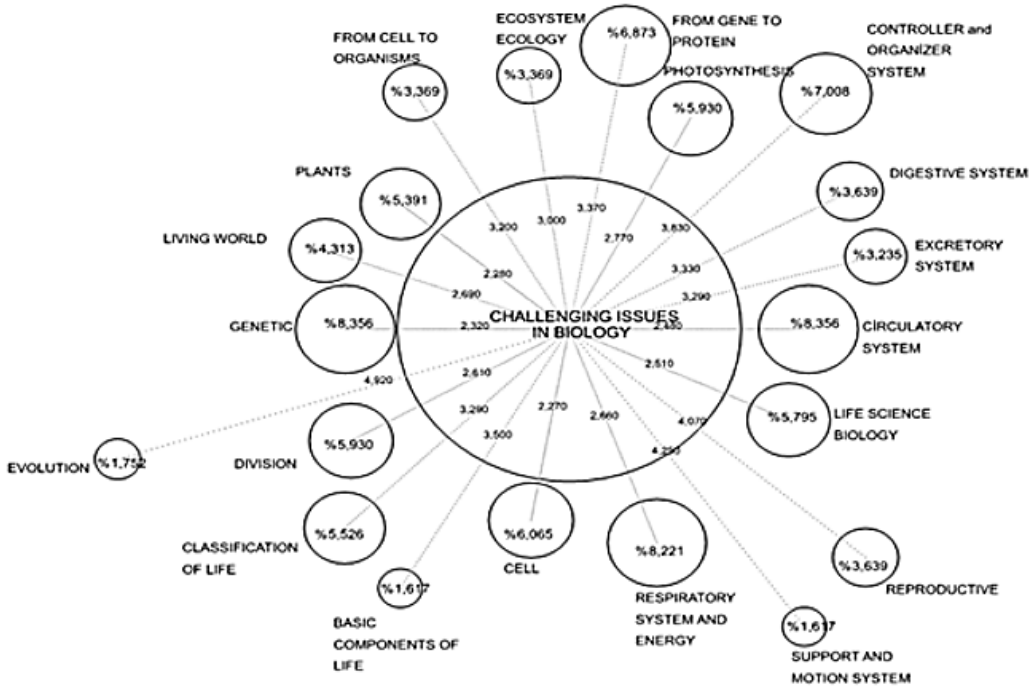

Figure 4 Novel mind map of challenging biology topics according to pre-service biology and science teachers

As can be seen in Figure 4, the central topic of this study is located in the center of the mind map. As can be seen from the Figure, there are shown as circles of different sizes and vary in regard to their distance from the central circle "difficulties in biology", the area of which is equal to the area of all the other circles in the mind map. Therefore, the size of each main theme is represented in visual terms by a circle, its connections with the other circles and themes are also shown. The size of the circle is directly proportional to the frequency with which those concepts make up the main theme. The distance between each main theme/circle to the central topic/theme represents the ranking of those concepts in the main themes, as determined by the order in which they came to mind among participants' responses. For example, when participants were asked to write down those topics with which they struggled most in biology, the more frequently repeated main theme concepts comprised 8.35% of the center concept for the Circulatory system and Genetics concepts and 8.22% of the central concept for the Respiratory system and Energy concept. However, the main theme of those concepts that are higher up in the list, and which were written on the WAT according to the order with which they came into the participants' minds, are those themes that are most closely related to the central concept; examples include cell (2.27), Plants (2.28), and Genetics (2.32). When the map is examined, it is seen that the theme and circle with the largest area, and which is closest to the main circle, is that of Genetics (8.35 in size and 2.32 in distance).

The themes represented by the most prominent circles closest to the map's central are those biology themes that the study group finds most challenging. However, the opposite is also true: the themes with the smallest circle area (Basic components of living things, Support and movement system, evolution) and those most distant from their main themes (Evolution, Support and movement system, reproduction). Support and movement systems (1.61; 4.25) and evolution (1.75; 4.92) represent those biology themes the study group found less challenging. It should be noted that the teacher candidates in the study sample had yet to take the evolution course when the application was made. This shows that evolution is one of the first ten concepts that came to mind when biology was mentioned in this section; research findings should be explained by benefiting from related literature.

4. CONCLUSION

The area of the circle located in the center of the novel mind map shows us the number of words in the cognitive structures of the participants that relate to the central concept; that is, the area of the central circle is proportional to the number of words presented by the study group relating to the central concept. Additionally, topics and concepts related to the central concept form those circles that spread out from the center into the surrounding areas. The areas of these surrounding circles show how often the participants repeated related concepts; that is, how many participants used a particular word or phrase related to the circle topic per their cognitive structure.

The results of this study concern the responses of 132 teacher trainees when asked to write down the first ten words that came to mind on the subject of "difficult topics in biology." A total of 742 words were collected. The size of the center circle representing these words is shown in Figure 4. When the words that determine the size of the center circle are divided into similar groups, the number of repetitions of each word determines the repetition frequency of that group or central theme. In this way, the sum of the sizes of all the theme circles is equal to that of the size of the central circle. As can be seen from Figure 3, the main themes formed by the most frequently repeated concepts are the Circulatory system (8.35%), Genetics (8.35%), Respiratory system, and Energy (8.22%). This can be interpreted as follows: when asked about complex topics in biology, participants' minds most frequently suggested concepts related to the circulatory system, genetics, respiratory system, and energy.

When considering previous studies on the difficulties students face in biology, Özarslan (2021) found that high-school students struggled with topics such as genetics and the human body. Furthermore, Özcan et al. (2014) studied the difficulties experienced by 8th-grade middle-school students and 12th-grade high-school students' when learning biology. The researcher found that these students struggled most with concepts such as support and movement, the classification of living things, the world of living things in middle school, and topics such as living things and the world of living things in high school. In their study, Güneş and Güneş (2005) found that middle school students struggled with concepts such as genetics, regulatory and control systems, division, and ATP energy. In their study, Koç and Sönmez (2018) investigated concepts trainee teachers struggled with regarding the cells and organelles and determined that concepts such as prokaryotes, eukaryotes, and centromeres were most challenging. In consideration of all these studies, it can be concluded that when students plan their careers in the field of biology, they may face difficulty with the aforementioned topics and may need to pay extra attention to them during their university education. Examining a novel mind map (Figure 3) obtained from previous studies makes comparing and interpreting the results easy. As can be seen from the map (Figure 3), the fact that genetics and systems are among those biology topics that teacher trainees struggle with also supports the results of the aforementioned studies.

The novel mind map approach introduced by Özgür et al. (2020) not only provides benefits in terms of seeing the relationships between concepts but also shows the priority of these concepts in the cognitive structures of the participants. The reason why, in the present study, teacher trainees were asked to write down those biology topics that came to mind, and to order these topics in terms of the readiness with which they came to mind, was to determine and reveal the priority and importance of these concepts in the cognitive structures of these individuals. By examining the novel mind map prepared in the present study, it is possible to interpret the cognitive priority and importance given to biology concepts by the study group; the distance between theme circles and the center of the map determines this. According to the novel mind map prepared for complex topics in biology (Figure 3), we can say that when teacher trainees are asked about difficult topics in biology, the following main themes are foremost in their minds: Cells (2.27), Plants (2.28), Genetics (2.32).

Fauzi and Mitalistiani (2018) conducted a study with both high school students and biology department students and found that the topics students struggled with most were genetics, the immune system, and metabolism. In another study, Turkish and Scottish students were asked to determine which biology topics they found to be most challenging; these results were then compared, and it was found that both groups struggled with topics such as genetics and cell division (Bahar, 2002); all these studies show that not only teacher trainees but all students struggle with similar topics in biology. This finding supports the results of the present study.

This study identified those topics in biology that teacher trainees struggle to find most challenging. It represented these topics using the novel mind map method, a new field approach. The map allows the difficult topics to be seen as a whole. Also, it shows the repetition frequency and importance of the concepts in the cognitive structure of the trainees in generalized holistic terms. Researchers aiming to study those biology topics that teacher trainees struggle with most can, therefore, identify complex topics and more deeply investigate the reasons behind each of them.

Furthermore, they can try alternative methods and techniques for teaching these topics, work with different sample groups, and compare them. Researchers who want to use the novel mind map approach in prospective studies can conduct studies with different disciplines, subjects, and sample groups. Comparative studies can be done using a novel map. In addition, the novel mind map approach can be used in qualitative analysis and longitudinal studies.

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