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Semantic network analysis of the biotechnology domain in Iranian high school biology textbooks

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Abstract

Textbooks can have a fundamental and positive effect on both learning and teaching. As such, in order to understand how students structure concepts in their minds, it is necessary to analyze the structure in which those concepts presented in textbooks are described. This study examined a network of concepts used in the domain of biotechnology in the Iranian 12th grade biology textbook and investigated the alignment of science concepts used in its sub-domains. The findings of this study suggest that too many concepts, as well as unconnected ones, were used in biotechnology domain, which led to a complicated conceptual network. Therefore, this paper recommends that the number of biology concepts described in the later text books in the biotechnology domain at Iranian high schools should be reduced in order to facilitate a better formation of connections between concepts and their descriptions.

Keywords: semantic network analysis, Iranian biology textbook, biotechnology domain, biotechnology concept's articulation

INTRODUCTION

Textbooks have a fundamental and positive effect on both learning and teaching. Moreover, as time goes by, the importance of the textbook is becoming ever greater (Angus, 2004; Hutchinson & Torres, 1994; Weinburgh, 2003). Therefore, improvements in textbooks will also improve the quality of education. Well-written textbooks that are distributed among schools, teachers and students can impact the development of a country by contributing to an improvement in the quality of education (Lebrun et al., 2002).

Sometimes the inefficiency and inadequacy of the content and its incompatibility with the students' ability to understand make learning difficult, or it produces less expected results (Ginsburg et al., 1998; Kim et al., 2013). Therefore, in preparing an effective and efficient textbook, educational activities and learning experiences should be arranged in a way that reinforce each other.

Learning activities should also be consistent with students' abilities, so that they can create the desired behavioral pattern in the learner (Niknafs & Aliabadi, 2014). In Iran, due to the educational structure and curriculum governing the country's education, textbooks are an important and widely used form of media in the educational structure of the country.

Biology is one of the most important branches of the basic sciences. Therefore, it should be considered when developing content for textbooks in order to achieve the goals set out in the national curriculum of the Iranian education system (Zare & Rezaean, 2020). In biology, the significance of biotechnology is rapidly increasing (Al-Muhammad et al., 2020). Therefore, future students must be equipped to make the right choices about biotechnology (Chen & Raffan, 1999).

In order to accurately understand controversial issues related to biotechnology and to make the right decisions, it is necessary to accurately understand the contents of this subject. Therefore, it is necessary to analyze how biotechnology is described in textbooks that are used as the basic data for students to understand biotechnology.

Previous studies on the biotechnology content of textbooks have analyzed the methods of their content development (Pyo, 2018; Riahi & Rezaeian, 2020), the connection between concepts (Kim, 2013), and visual data (Kim, 2016). In Iran, in particular, such research focused on analyzing the biotechnology content

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Contribution to the literature

- This research examines a network of concepts used in biotechnology unit of Iran 12th grade biology textbook.
- This study investigates the alignment of science concepts used in sub-units.
- In contrast to previous studies analyzing biotechnology contents, this study suggests life science concepts used in biotechnology unit and relationships between them.

Table 1. Comparing textbook in the past with the present

Contents in biotechnology unit of textbook (12th grade high school)	
2008-2018	2019-2021
Genetic engineering	Biotechnology
Genetic engineering in medicine	Genetic engineering
	Protein engineering
Human genome project	Tissue engineering
Genetic engineering in agriculture	Stem cells
	Uses of biotechnology in agriculture and medicine
Genetic engineering in living stock	
	Importance of transgenic animals
	Ethics in biotechnology

presented in textbooks. These previous studies were limited to external analyses, such as the presented visual data, the form of inquiry and the frequency of the presented concepts. Therefore, they were unable to analyze the relational structure between concepts.

Recently, studies have been conducted to analyze the relationship and structure between concepts, particularly concepts using a semantic network analysis (SNA) (Diesner & Carley, 2005; Popping, 2000). SNA is a method to analyze content by making it a target of a text network analysis. In other words, it is a procedure which draws connections between keywords and codifies the relationships, builds a network among the keywords relating to each other, and analyzes the findings (Choi et al., 2017; Lee & Ha, 2012; Paranyushkin, 2011).

The SNA has the advantage of being able to visually grasp the structure of a concept based on the frequency of co-occurrence between words (Jang & Barnett, 1994; Park & Leydesdorff, 2004).

Therefore, by using SNA, we aim to analyze the network between biology concepts described in the biotechnology domain of an Iranian high school 12th grade biology textbook. Biotechnology is divided into 'genetic engineering,' 'protein and tissue engineering,' and 'uses of biotechnology' sub-domains. The concepts connecting these sub-domains will be analyzed. Through this study, we demonstrate that it is possible to analyze how the Iranian concept of biotechnology is stated. We also provide the basic data for the development of new textbooks in the future.

THEORETICAL BACKGROUND

Biotechnology in the Iranian Curriculum

The education system in Iran is divided into 2 main levels: primary education and high-school education. All children spend six years of their lives at primary level from age 6 to12 and attend in high school from age 12 to 18.

The educational policy in Iran has changed a lot over the last decade, and the high school curriculum has also been affected. Therefore, in newer textbooks, the contents of the biotechnology domain have changed as well (**Table 1**).

In previous versions of biology textbooks, in the biotechnology domain, the definition and process of genetic engineering was explained, followed by its uses in medicine, agriculture, and life stock. Along with this, the human genome project (HGP) was discussed. However, in the new biology textbook, the HGP has been removed, and other contents have increased.

After the introduction of biotechnology, the new textbook explains genetic engineering, protein and tissue engineering, and then stem cells. After this, it indicates the uses of biotechnology in agriculture and medicine, and the importance of transgenic animals. Finally, ethics in biotechnology is discussed more extensively–in the previous textbook, ethics in biotechnology was only explained in a few sentences.

In the revised science curriculum, the topic of genetic engineering is mentioned in the science text books of two grades: 8th and 12th. The 8th grade science textbook presents basic concepts in genetics, such as the different features in people, new features in organisms and the definition of a gene, DNA, chromosome, gene transferring and mitosis.

The contents in the biotechnology domain of the 12th grade high school is more difficult and varied. The important concepts that are used in the biotechnology domain are as follows: gene splicing, DNA recombination, nuclear replacement, cell fusion, screening, protein engineering, tissue culture, stem cells, monoclonal antibody, gene therapy, LMO, and biotechnology ethics.

NetMiner Software

Programs that analyze language networks include NetMiner, KrKwic (Korean Key Words in Context), and

UCINET. In this study, NetMiner was used. NetMiner is one of the network analysis tools, developed by CYRAM in Korea, and is software that can analyze and visualize networks. The program can analyze unstructured text data using the linguistic network analysis function. It automatically extracts words from unstructured text data and enables network analysis between extracted words. In addition, since visualization and analysis are organically combined, exploratory analysis is possible.

The network data structure consists of 1-mode and 2-mode. 1-mode analyzes the relationship between entities (nodes) within the same group (homogeneous), and 2-mode analyzes the relationship between entities within two different groups (heterogeneous) (Lee, 2012).

NetMiner provides the analysis results as a visualization map, allowing you to intuitively understand the results. In order to increase the intuitive understanding of the visualization map, there is an advantage in that the color, size, shape of nodes, and the thickness; and direction of links are displayed differently on the visualization map to display various information possessed by the network.

RESEARCH PROCEDURES AND METHODS

Analysis Target

The Iranian revised high school 12th grade biology textbook (Al-Muhammad et al., 2020) was selected as the subject of this study. The 'New biotechnologies' unit of the biology textbook was chosen for analysis. The Iranian textbook consists of chapter introductions, texts, figures, tables, images, questions and activities, and additional data on the margent of a few pages. In this study, only texts presented in textbooks were analyzed. Therefore, the introduction of the chapters, figures, tables, images, questions and activities, and additional data presented in the pages were excluded from the analysis.

Data Analysis

From the Iranian high school biology Persian textbook, the biotechnology domain was selected and then translated to English. For pre-processing of biotechnology concepts in sentence units, a single file was created by integrating the textbook's biotechnology concepts and the contents of the text into sentence units. The concepts of the text were extracted by the NetMiner program. There were 402 concepts extracted through the preprocessing process through the concept extraction and synonym processing. Among these concepts, those that have no scientific significance or whose Eigenvector value was 0 were first removed.

The secondary concept selection was commissioned by five biology education experts. All five experts have doctoral degrees and have experience in analyzing SNA.

Table 2. Examples of frequency and eigenvector centrality of selected concepts of ethics in biotechnology sub-domain

Concept	Frequency	Eigenvector centrality
Biosafety	2	0.000001
Law	1	0.000001
Application	1	0.408245
Benefit	1	0.408245
Biotechnology	3	0.707102
Ethical	1	0.408245
Issue	1	0.001914
Research	5	0.002706
Side effect	1	0.001914

Among them, three biology teachers have more than 10 years of work experience. In the secondary concept selection, it was requested that we exclude concepts judged to have no scientific or life-scientific significance. The request form was collected from four experts, and the final analysis concept was selected by removing the concept selected as meaningless by more than two experts. As a result, 99 biology concepts were selected as meaningful and 303 concepts were removed from the list. The selected concepts were visualized using the NetMiner program. The networks of the four sub-domains of the biotechnology domain of the Iran high school biology textbook were visualized as a 1-mode network, and the linkage analysis between the middle units was visualized as a 2-mode network (Kim et al., 2022; Kim & Kwon, 2016; Lim et al., 2021). Furthermore, by analyzing the networks of the top 20% of the appearance frequency, we analyzed how the main concepts are connected. **Table 2** provides frequency and eigenvector centrality.

RESULTS

This study analyzed the conceptual network of the biotechnology domain of the Iranian 12th grade biology textbook using SNA and analyzed the linkages between four sub-domains. The presentation of the results suggested a conceptual network for biotechnology and its four sub-domains, and a network for core concepts that were the top 20% in frequency. We looked at the concept that connects the 4 sub-domains.

Network Analysis

Genetic engineering domain

The 42 concepts from the 'genetic engineering' sub-domain were extracted for an analysis of the network (**Figure 1**). The frequency of concepts was highest for 'DNA' (40 times), followed by 'bacteria' and 'gene' (17 times each), 'enzyme' and 'biotechnology' (16 times each), 'genetic engineering' and 'cell' (12 times each), and 'circular DNA' (11 times).

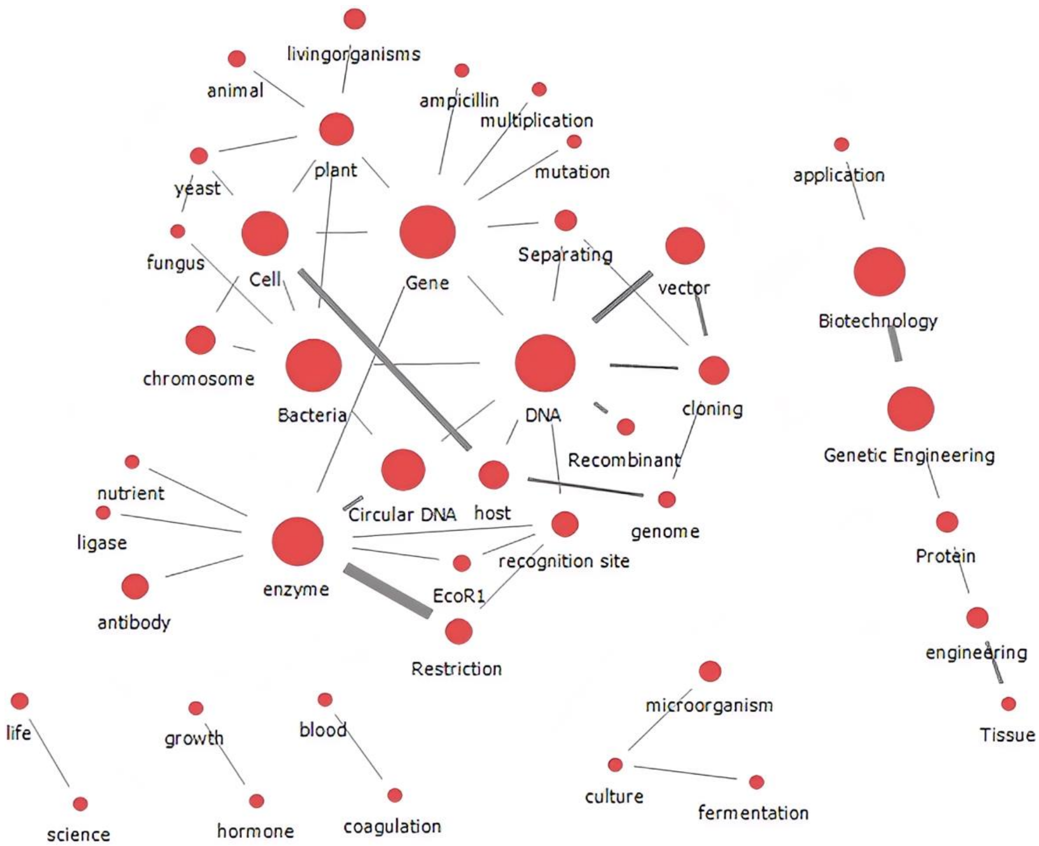

Figure 1. Conceptual network of 'genetic engineering' sub-domain in the Iranian high school biology textbook

The concepts with higher eigenvector centrality were arranged in the order of 'DNA,' 'enzyme,' 'cloning,' 'restriction,' 'gene,' 'host,' 'circular DNA,' and 'cell,' suggesting that they belong to the key concepts in the genetic engineering sub-domain. The concepts related to biotechnology presented in the 'genetic engineering' sub-domain were presented as a network, as shown in **Figure 1**.

'Gene,' 'bacteria,' 'enzyme,' 'DNA,' 'cell,' and 'plant' were located at the center of the network. 'Gene' is connected to 'cell,' 'plant,' 'DNA,' 'enzyme,' 'separation,' 'multiplication,' and 'mutation.' 'Bacteria' is in turn connected to 'chromosome,' 'cell,' 'plant,' 'circular DNA,' and 'DNA.' Moreover, 'Cell' is linked to concepts such as 'chromosome,' 'gene,' 'bacteria,' 'plant,' 'host,' and 'yeast.' The other central concept was 'enzyme,' which was connected to different concepts, such as 'circular DNA,' 'EcoR1,' 'recognition site,' 'restriction,' and 'antibody.' They all form a network. Another network is formed when 'genetic engineering' is connected to 'biotechnology' and 'protein,' and each of them have a relationship with other concepts. On the other hand, 'culture' is connected to 'microorganism' and 'fermentation,' and they form a separated network. Meanwhile, three other separate networks are formed when two concepts, such as 'growth' and 'hormone,' were connected.

In the Iranian biology textbook, 'genetic engineering' is described as the center of DNA cloning. Enzyme, bacteria, and the cell are central concepts in this regard. However, the explanation of genetic recombination technology is not related to genetic engineering or biological engineering concepts but is instead described only as a process focus. In this sub-domain in the Republic of Korean biology textbooks, like Iranian biology textbook, genes and DNA are core concepts, but the concepts described in the textbooks showed a conceptual network connected to each other (Jeong & Jang, 2021).

Protein and tissue engineering sub-domain

A total of 32 concepts were extracted from the 'protein and tissue engineering' sub-domain in the biotechnology domain of the biology textbook. The frequency of concepts is the highest in 'protein' (19 times), followed by 'cell' (17 times), 'stem cell' (12 times), 'tissue' (11 times), 'amino acid' and 'engineering' (9 times each). The concepts with higher eigenvector centrality were arranged in the order of 'engineering,' 'tissue,' 'protein,' 'body,' and 'fetal.' These concepts were found to be the key concepts of the conceptual network for 'protein and tissue engineering' sub-domain.

Figure 2 exhibits the conceptual network used in the 'protein and tissue engineering' sub-domain. In the conceptual network for "protein and tissue engineering" sub-domain, the 'cell,' 'tissue,' 'protein,' and 'stem cell' take center stage. The 'tissue' was connected to a variety of concepts, such as 'engineering,' 'stem cell,' 'protein,' 'body,' and 'culture.' The 'cell' was linked to the

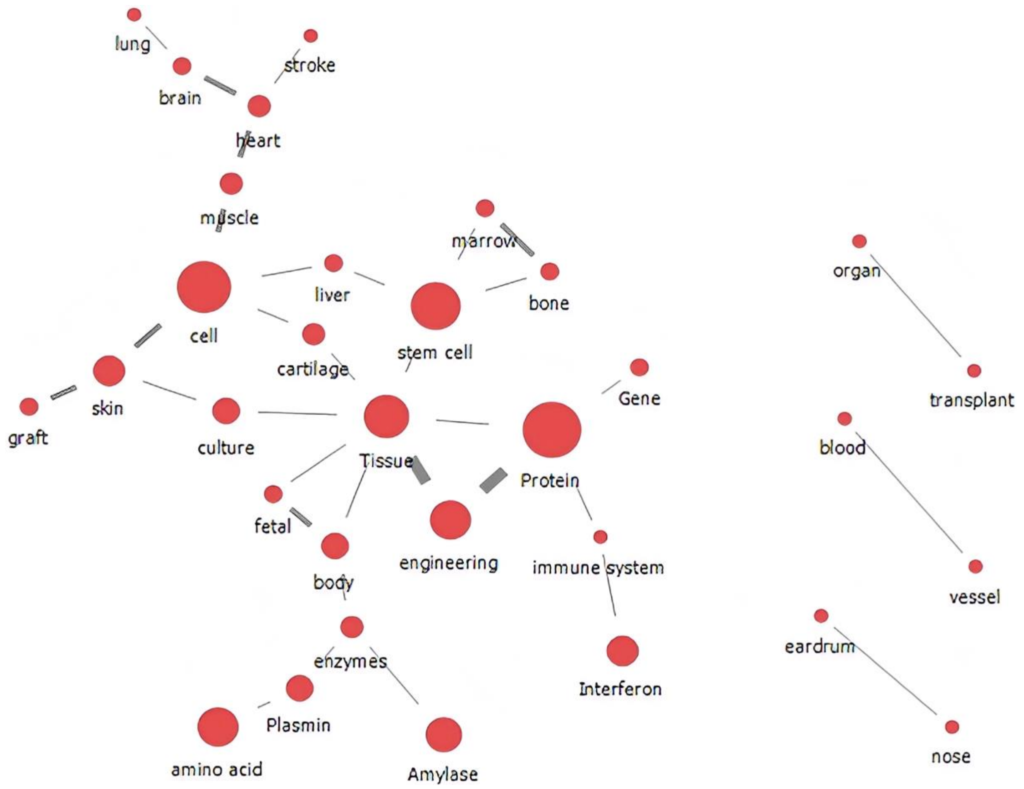

Figure 2. Conceptual network of 'protein and tissue engineering' sub-domain in the Iranian high school biology textbook

concepts of 'skin,' 'liver,' 'muscle,' and 'cartilage.' 'Protein' was connected to concepts like 'engineering,' 'immune system,' 'gene,' and 'tissue.' The concept 'stem cell' was linked to the concepts of 'marrow,' 'bone,' 'liver,' and 'tissue.' Meanwhile, the connection between the 'organ,' and 'transplant,' and the connection between 'blood' and 'vessel,' and the connection between 'eardrum' and 'nose' were separate from other networks.

The Iranian textbook describes the use of amylase, interferon, and plasmin as a method to increase protein stability. Tissue engineering describes examples regarding the use of this technology, such as stem cells and tissue engineering, mature stem cells, and embryonic stem cells. Therefore, 'cells,' 'stem cells,' 'proteins,' 'tissues,' and 'engineering' were located at the center of the network. Many organs such as 'liver,' 'heart,' 'brain,' 'marrow' and 'bone' were used in this sub-domain; these are necessary components in process of tissue engineering (George & Ravindran, 2010).

Uses of biotechnology sub-domain

According to the conceptual network of 'uses of biotechnology' sub-domain, a total of 43 concepts were extracted from the 'uses of biotechnology' sub-domain in the biotechnology domain of the biology textbook. The concept related to 'uses of biotechnology' was presented as a network shown in **Figure 3**.

The concept with the highest frequency was 'gene' (15 times), followed by 'recombinant' and 'body' (12 times each), 'DNA' and 'insulin' (nine times each), 'plant' and 'disease' (eight times each). The concepts with higher eigenvector centrality were arranged in the order of 'gene,' 'therapy,' 'body,' 'plant,' 'disease,' 'lymphocyte,' and 'toxin', respectively. This perspective presents the key concepts in the conceptual network of the 'uses of biotechnology' sub-domain.

The concepts 'gene,' 'recombinant,' 'body,' and 'enzyme' were located at the center of the network. 'Gene' was connected to different concepts, such as 'therapy,' 'plant,' 'disease,' 'body,' and 'lymphocyte.' 'Body' was connected to the concepts 'gene,' 'cell,' 'growth,' 'insect,' and 'pathogen.' 'Recombinant' was linked to the concepts of 'animal,' 'plant,' 'DNA,' and 'agriculture.' The concept 'enzyme' was linked to the concepts of 'immune system,' 'insect,' 'transplant,' and 'injection.' Furthermore, the connection between the 'vaccine,' and 'hepatitis' and the connection between 'HIV' and 'infection' were separate from other networks.

In Iranian biology textbooks, the use of biotechnology is explained with specific examples of how it is being used in agriculture and medicine. It also describes the importance of transgenic animals. The high thickness between 'gene' and 'therapy' shows that gene therapy was used the most in the biotechnology sub-domain. 'Gene,' 'enzyme,' and 'recombinant' have a key role in this sub-domain.

Ethics in biotechnology sub-domain

In all, nine concepts relating to the 'ethics in biotechnology' sub-domain were extracted from the biotechnology domain in the biology textbook. The highest frequency belongs to 'research' (five times), followed by 'biotechnology' (three times), and 'biosafety' (two times). The concept with the highest

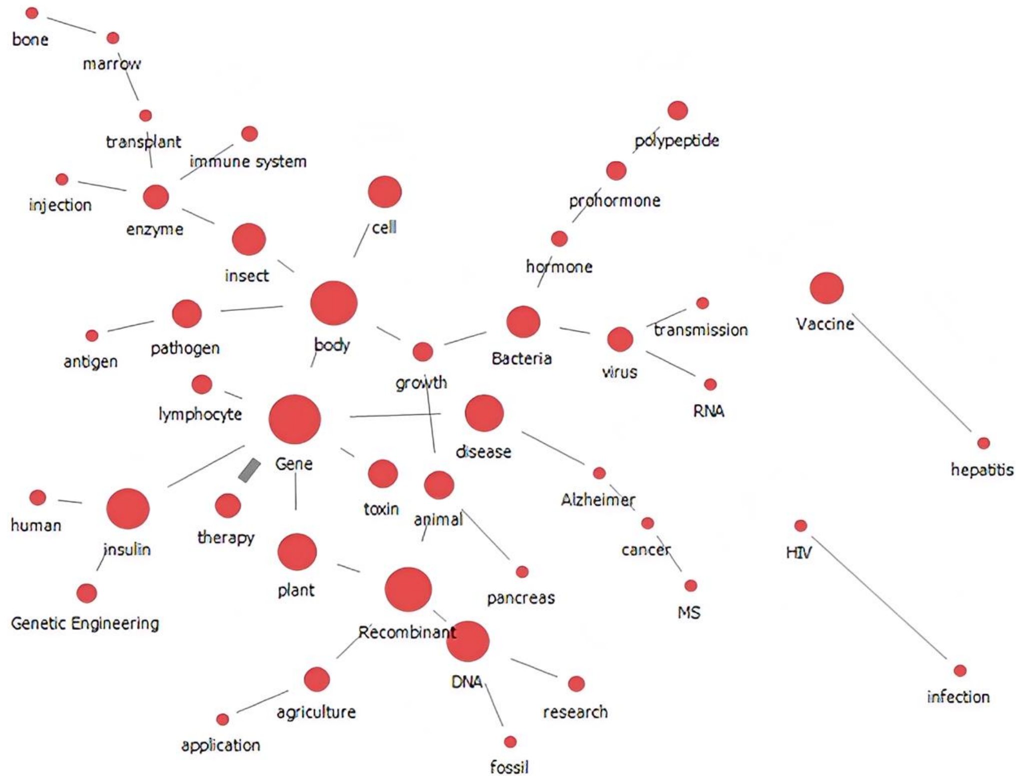

Figure 3. Conceptual network of uses of biotechnology sub-domain in the Iranian high school biology textbook

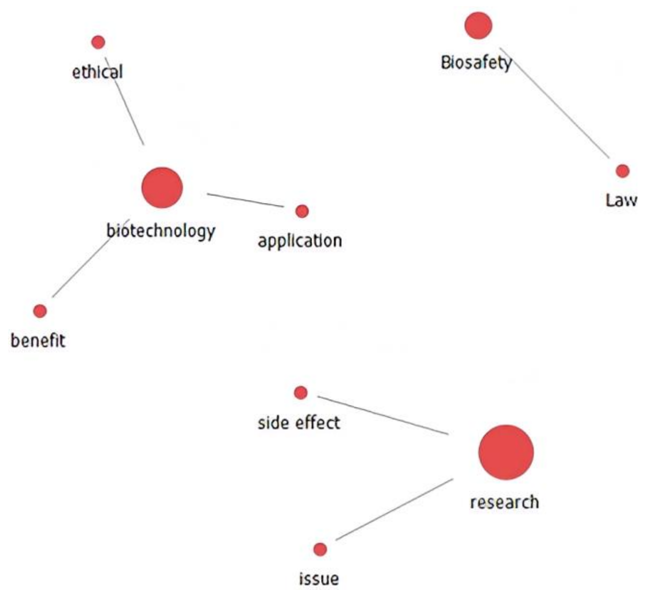

Figure 4. Conceptual network of ethics in biotechnology sub-domain in the Iranian high school biology textbook

eigenvector centrality was 'biotechnology', and then 3 other concepts that had equal eigenvector centrality were 'ethical,' 'benefit,' and 'application.' It seems that these concepts were the key concepts of the conceptual network for ethics in biotechnology sub-domain.

The bioethics sub-domain describes ethical, social, and biological safety aspects, national regulations, and national efforts related to biotechnology. It also emphasizes the importance of monitoring the side effects and risks of the use of new products and technologies related to biotechnology. But, in the concept network, the concepts of ethics, side effects, and laws are not connected. Thus, supplementation is required (**Figure 4**).

Biotechnology domain

With respect to the biotechnology domain, a total of 99 concepts were used in the Iranian biology textbook for the 12th grade of high school. The concepts related to biotechnology, presented as a network, are shown in **Figure 5**. The concept with the highest frequency was 'DNA' (48 times), followed by 'cell' (35 times), 'Gene' (34 times), 'Biotechnology' (30 times), 'Protein' (27 times), 'Bacteria' (25 times), and 'enzyme' (23 times). The concepts with higher eigenvector centrality were arranged in the following order: 'engineering,' 'Tissue,' 'Protein,' 'Gene,' 'body,' 'cell,' 'therapy,' 'enzyme,' 'DNA,' and 'plant.' This aspect presents the key concepts in the conceptual network of the biotechnology domain.

'Biotechnology,' 'Gene,' 'bacteria,' 'enzyme,' 'DNA,' 'cell,' 'body,' 'Tissue,' and 'plant' are located at the center of the network. 'Biotechnology' is linked to the concepts 'Genetic engineering,' 'animal,' 'agriculture,' 'plant,' 'application,' 'ethical,' and 'benefit.' 'Gene' is connected to concepts such as 'cell,' 'plant,' 'DNA,' 'enzyme,' 'separation,' 'multiplication,' and 'disease.' 'Bacteria' is in turn connected to some concepts, such as 'chromosome,' 'cell,' 'plant,' 'circular DNA,' and 'DNA.' 'Cell' is linked to concepts such as 'chromosome,' 'gene,' 'bacteria,' 'plant,' 'host,' 'body,' and 'yeast.'

The other central concept was 'enzyme,' which was connected to different concepts, such as 'circular DNA,' 'EcoR1,' 'recognition site,' 'restriction,' and 'antibody.'

Figure 5. Conceptual network analysis of biotechnology domain in an Iranian high school biology textbook

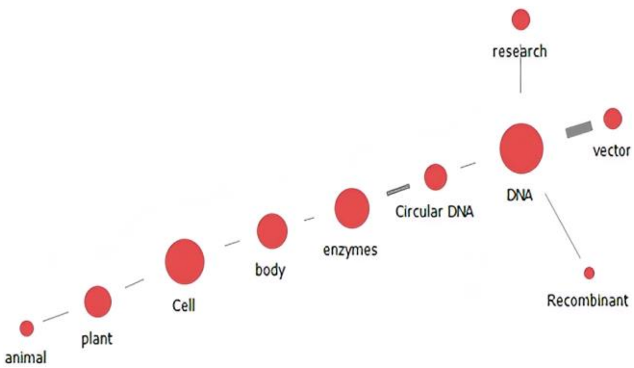

Figure 6. Top 20% conceptual network analysis of the frequency of biotechnology domain in Iranian high school biology textbooks

'DNA' is linked to a variety of concepts, like 'recombinant,' 'recognition,' cloning,' 'vector,' 'separating,' 'circular DNA.' 'Body' is connected to concepts such as 'Gene,' 'cell,' 'enzyme,' 'fetal,' 'growth,' 'pathogen,' and 'insect.' They all form a network. Another network is formed when 'blood' is connected to 'vessel,' and 'coagulation.' On the other hand, six other separate networks are formed when two concepts, such as 'HIV' and 'infection,' are connected.

Conceptual Network of Key Concepts

In total, 10 concepts that composed the top 20% in terms of frequency of the biotechnology domain were extracted from the biotechnology domain in the high school 12th grade Iranian biology textbook. The frequency for each concept was the highest in 'DNA' (47 times), followed by 'cell' (35 times), 'enzyme' (23 times), 'body' (16 times), 'plant' (14 times), and 'circular DNA' (11 times). The concepts with a higher eigenvector centrality were arranged in the order of 'DNA,' 'vector,' 'circular DNA,' 'recombinant,' 'research,' and 'enzyme,' suggesting that these concepts correspond to key concepts in the biotechnology domain. The concept with the highest frequency ('DNA'), was included in the key concept with the highest eigenvector score. However, 'vector,' which had a low frequency, was found to be one of the concepts that played an important role in the biotechnology domain, as a concept with high eigenvector centrality.

The concepts extracted from the curriculum constitute a network centering on 'DNA,' which is presented in **Figure 6**.

'DNA' is connected to 'vector,' 'circular DNA,' 'research,' and 'recombinant.' The concepts 'circular DNA,' 'enzymes,' 'body,' 'cell,' 'plant,' and animal,' respectively are connected to each other in a line. The

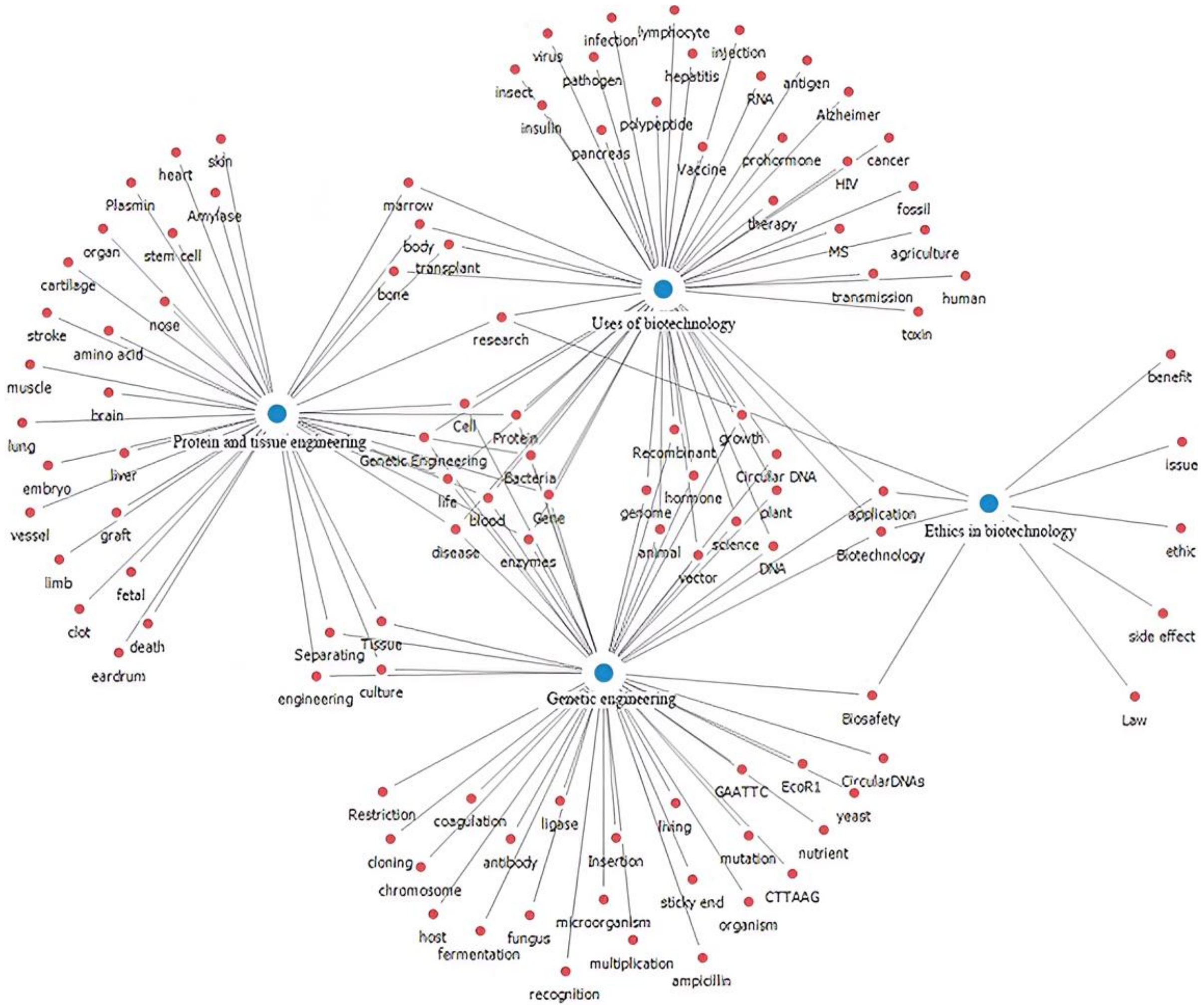

Figure 7. Analysis of the concept of connection of four sub-domains of biotechnology domain in the Iranian high school biology textbook

high thickness of the link between 'DNA' and 'vector,' and between 'circular DNA' and 'enzymes,' illustrate that these concepts were used together many times.

Analysis of the Connection Concept between Sub-Domains

Figure 7 shows the alignment between the concepts used in the four sub-domains of the biotechnology domain: genetic engineering, protein and tissue engineering, uses of biotechnology, and ethics in biotechnology. There is no concept that connects the 4 sub-domains. In all, two concepts were used together in genetic engineering, uses of biotechnology, and ethics: 'application' and 'biotechnology.' One concept was used in protein and tissue engineering, uses of biotechnology, and ethics in biotechnology sub-domains: 'research.' Nine concepts were employed in the genetic engineering, protein and tissue engineering, and uses of biotechnology sub-domains: 'cell,' 'protein,' 'bacteria,' 'gene,' 'enzymes,' 'blood,' 'life,' 'disease,' and 'genetic engineering.'

Furthermore, ten concepts, including 'growth,', 'recombinant,' 'circular DNA,' 'plant,' 'hormone,' 'science,' 'genome,' 'animal,' 'vector,' and 'DNA' were used together in genetic engineering, and uses of biotechnology sub-domains. 'Biosafety' was used together in genetic engineering, and ethics in biotechnology sub-domains. A total of four concepts were used together in protein and tissue engineering: 'bone,' 'transplant,' 'body,' and 'marrow.' The uses of biotechnology sub-domain and four concepts, including 'tissue,' 'culture,' 'separating,' and 'engineering' were employed together in genetic engineering, and protein and tissue engineering sub-domains.

When it comes to the alignment between concepts used in genetic engineering, protein and tissue engineering, uses of biotechnology, and ethics in biotechnology sub-domains, the degree of conceptual alignment used in the genetic engineering, protein and tissue engineering, and uses of biotechnology sub-domains were high, while their use in the ethics in biotechnology sub-domain was lower. The concepts used in the biotechnology domain exhibit a higher degree of alignment between genetic engineering and uses of biotechnology than that of alignment between the other sub-domains.

DISCUSSION

Thus far, the concepts used in the biotechnology domain of the Iranian 12th grade biology textbook has been examined using SNA. In comparison to the biotechnology domain of the South Korean biology textbook, there are more concepts related to genetic engineering in the Iranian textbook when compared to other sub-domains (Jeong & Jang, 2021). In other words, the main content of this domain is focused on understanding the concept of genetic engineering. However, the concept of genetic engineering is described as overlapping with previous concepts related to genetics or cell cycle. Therefore, improvement is required.

There are some concepts that are not connected to their related concepts and remain separate. This can make it difficult for students to understand concepts. For example, concepts such as 'culture,' 'organs,' 'vaccines,' 'biosafety,' and 'genetic engineering' are not linked to other concepts. It connects concepts piecemeal and makes it difficult for students to understand the relationships between related concepts (Brophy, 1992; Staver & Bay, 1989). In this domain, Korean textbooks describe similar contents to Iranian textbooks, but the concepts described in bioengineering in biology textbooks are interconnected.

'Plant' in comparison with 'animal' was used more in the network, and it was connected to a variety of concepts that demonstrate usage of 'plant' in the process of teaching genetic engineering. However, 'animal' was only connected to one concept. In genetic engineering, research on animals (such as fruit flies) is centered (Hwang & Lu, 2013; Ormandy et al., 2011), but in the Iranian biology textbook, the explanations are focused on plants.

There are too many concepts presented in the instructions regarding biotechnology in the Iranian 12th grade biology textbook. The reason is that the biotechnology topic is taught only in the 12th grade. However, in other countries, such as Spain, the genetic engineering topic is taught over three years and is mentioned in the biology textbooks of grades 10, 11, 12 (Martínez-Gracia et al., 2003).

According to Martínez-Gracia et al. (2003) and Zeller's (1994) textbook analysis on the biotechnology sub-domain, the textbooks analyzed did not contain a definition or the process of protein or tissue engineering; however, in the Iranian biology textbook it was mentioned. The Iranian textbook mentioned medical applications as well, which mainly emphasized the production of therapeutic substances, insulin being the most popular, followed by vaccines, hormones, and interferon. This is almost the same as most high-school biology textbooks in Spain (Martínez-Gracia et al., 2003) and the Republic of Korea (Jeong & Jang, 2021).

Some biology concepts are described with a heavy emphasis and only a few of those concepts are in the top 20% of frequencies. The top 20% of concepts are not sufficient to understand biotechnology. From a quick glance at the network of biotechnology domain in the Iranian 12th grade textbook, it appears that biotechnology is explained with the help of the concepts 'biotechnology,' 'gene,' 'bacteria,' 'enzyme,' 'DNA,' 'cell,' 'body,' 'tissue,' and 'plant,' which are the terms that have a central position in the network.

CONCLUSION AND SUGGESTIONS

In this study, the relationship among concepts was investigated through the network of concepts used in the biotechnology domain of the Iranian 12th grade biology textbook, using a SNA. This textbook was used to analyze the alignment between the concepts and the conceptual network used in genetic engineering, protein and tissue engineering, uses of biotechnology, and ethics in biotechnology sub-domains. The findings of this study are as follows.

There are some concepts that are not connected to the related concepts in all four sub-domains and thus remain separate. This can make it difficult for students to understand the concepts. The lack of connection between some concepts in the biotechnology domain demonstrated in the network may lead to misunderstanding and some learning difficulties for students.

Some biology concepts are described with a heavy emphasis and a fewer number of concepts appear in the top 20% in terms of frequency. The top 20% of concepts are not enough to understand biotechnology. In the genetic engineering sub-domain, the main concepts are also not interconnected. For example, the concept of 'genetic engineering' is not connected with the other concepts.

Some suggestions based on this study are as follows. It is expected that the number of concepts in the biotechnology domain of the next Iranian biology textbook will be reduced and the concepts that surround the core concepts will be described to form an interconnected network. In addition, it is expected that an analysis will be conducted with regard to how the concepts of fields (genes, DNA, etc.) related to the field of biotechnology in Iranian textbooks are linked. Moreover, it is expected that the textbook biotechnology unit will analyze teacher classes and student acquisition concept networks in countries with conceptual networks (e.g., Korea) and countries without conceptual networks (e.g., Iran).

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