JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

ALIGNMENT OF CONCEPTS OF MEIOSIS AMONG CURRICULUM, TEXTBOOKS, CLASSROOM TEACHING AND ASSESSMENT IN UPPER SECONDARY SCHOOL IN REPUBLIC OF KOREA

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Abstract. *If the concepts used in curriculum, textbooks, classroom teaching, and assessment are not consistent, students may have difficulty in understanding the concepts of science correctly and this may lead to the formation of misconceptions. The purpose of this study is to measure the alignment of science concepts by analyzing the semantic networks of curriculum, textbooks, classroom teaching, and student assessment with respect to the contents on meiosis as covered in Life Science I. The semantic network method using the NetMiner 4.0 program was applied. 11 concepts were extracted from the curriculum commentary. The textbook presented 36 concepts; classroom teaching presented 54 concepts; a total of 23 concepts were presented from assessment. With respect to alignment of relevant concepts, 6 (gamete, chromosome, meiosis, gene, daughter cell and cell division) were linked to all 4 sources (curriculum, textbooks, classroom teaching, and assessment). These concepts are mainly used to explain the process of meiosis. It is concluded that the key concepts of meiosis exhibited alignment in curriculums, textbooks, classroom teaching and assessment. However, there are many concepts used only in textbooks and classroom teaching. The greater number of concepts in textbooks and teaching can become one of the causes of a deficit in learning.*

Keywords: *concepts' alignment, meiosis concepts, upper secondary school, semantic network*

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Introduction

Different approaches to formal school education have been advocated by professionals in education in Republic of Korea. Their efforts, ideas, and research have influenced the directions of education. For instance, education is an intended and planned activity designed to lead learners towards desirable directions (Kim & Kang, 2012). This planned activity expresses itself in the curriculum, learning tools (textbooks), and processes of classroom teaching and assessment. Even though curriculum content is important, everything involved in the curriculum affects the success or failure of education, from textbooks, curriculum, and teachers' understanding of the process, to educational implementation (Bencze & Hodson, 1999; Loucks-Horsley et al., 1998; Parke & Coble, 1997; Powell & Anderson, 2002). Therefore, in order to ensure the successful implementation of a curriculum and to secure continuity, the overall process of curriculum implementation needs to be investigated in detail.

Furthermore, a frontloading alignment is the proper method for examining whether content presented in a curriculum is successfully implemented (Kang, 2006). The idea of frontloading alignment is to examine the consistency of the content as guided in order from the overall outline of the curriculum, as represented in textbooks, then in classroom teaching and finally in assessment. In this study, the frontloading alignment based on concepts was used to measure the alignment among curriculum, textbooks, classroom teaching, and assessment stages.

In this view, if misalignment occurs in the flow of curriculum content through textbooks, classroom teaching or assessment, it wastes students' learning time, reduces intellectual curiosity, and interferes with creative and logical thinking (Blank et al., 2001; Porter & Smithson, 2001). This eventually leads to a failure in achieving educational objectives (Lim & Kim, 2015). Despite such urgent and pressing needs, there is a lack of consensus or awareness regarding the methods currently available through the conceptual framework of frontloading alignment.

https://doi.org/10.33225/jbse/22.21.232

Certain previous studies on alignment have dealt chiefly with the alignments among educational objectives, textbooks, and assessment questions (Kim et al., 2003; Nam, 2010; Lim et al., 2011). Others have examined alignment between curriculum and textbooks (Kim et al., 2011) or between learning objectives and educational materials (Porter, 2002). Yet others have considered alignment between curriculum and classroom teaching on the one hand, and assessment on the other (Kurz et al., 2010; Liu & Fulmer, 2008; Lu & Liu, 2012). Finally, some analyses have focused on the relationship between curriculum alignment and students' academic achievements (Squires, 2012). Studies have often reported that there exists a misalignment between curriculum, classroom teaching and assessment.

However, most studies have analyzed the alignment between national- or state-level curriculum and textbooks, or between the national-level curriculum and national-level achievement assessment questions. There were therefore limitations in analyzing the alignment of the curriculums that operate in the classroom; moreover, these studies had the limitation of lacking substantial evidence because they analyzed curriculum as plan rather than as teachers' goals, perceptions, and realities. That is, these studies lacked analysis of actual educational situations in the classroom and failed to analyze the alignment between educational content and assessment. There is a need to analyze the alignments for, e.g., science content as presented in curriculum content and textbooks, classroom teaching, and assessment. In this study, therefore, the alignment of science concepts used in curriculum materials, textbooks, classroom teaching and assessment was analyzed.

To analyze the alignment of such concepts, a semantic network analysis (hereafter referred to as SNA) was used as a theoretical framework. SNA enables visual text analytics by expressing hidden structures, based on an analysis of connected forms shared between the concepts. It has an additional advantage in that the frequency of a particular concept's occurrence can be calculated to easily identify its role in the structural relationship of concepts (Doerfer & Barnett, 1994; Jang & Barnett, 1994; Kim & Kwon, 2016; Lim & Kim, 2015). In this study, SNA was used to analyze the alignment of science concepts used in curriculums, textbooks, classroom teaching and assessment.

Meanwhile, students are not accustomed to the definition of concepts related to genetics, and these concepts are highly dependent on each other (Kim et al., 2006). Hence, it is not easy for students to accurately understand the relation between concepts in the process of learning genetics (Kindfield, 1994; Knippels et al., 2005). In addition, it is difficult to connect the relationship between alleles and the movement of chromosomes during meiosis (Knippels et al., 2005; Stewart & Dale, 1989; Tolman, 1982). Thus, students often do not understand the mechanisms of chromosomal behavior at meiosis, the relationship between chromosome and gene, and the relevance to chromosomes of DNA (Hafner & Stewart, 1995; Stewart, 1982; Stewart & Dale, 1989).

Looking at the current science curriculum in Korea, students learn about cellular organization and chromosomes, and the basic principles of inheritance and evolution, in lower secondary school. This learning is followed in upper secondary school by study of somatic cell division and meiosis. Despite the repetitive learning process, students have a lot of misconceptions and find it difficult to understand concepts of cell division, especially meiosis (Hwang & Lee, 2000).

In this context, the language network of curriculum, textbooks, classroom teaching and assessment was analyzed by using the SNA with respect to meiosis as covered in upper secondary school curriculum in Korea. The alignment of scientific concepts across curriculum materials, textbooks, classroom teaching and assessment was analyzed with focus on 'Life Science I'. This study was intended to contribute to reveal causes of students' difficulty in learning about the biological concept of meiosis.

Theoretical Background

Curriculum and Textbooks

In Republic of Korea, "the national curriculum" refers to the documented national-level curriculum, which is officially announced by the Ministry of Education and includes a national-level curriculum plan and curriculum commentary. This national curriculum undergoes revision every six to seven years. When the curriculum plan is revised, the curriculum commentary is developed to explain the curriculum content. The curriculum commentary presents rationales for setting up units, learning contents, the flow of units, and notable points for each unit (Ministry of Education, Science and Technology, 2011a). The 2009 Revised Science Curriculum has been applied in upper secondary schools since 2015.

The subjects related to life science in upper secondary school in Republic of Korea are Life Science I and II. Life Science I features a unit on meiosis, dealing with the "cell and the continuity of life." The curriculum objective

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

concerning meiosis is "to understand the continuity of life by relating chromosomal behaviors at meiosis to genes." The curriculum commentary prescribes that the behavior of chromosomes should be associated with genes to explain meiosis. This unit is designed to further deepen the "reproduction and generation" unit included in the ninth-grade curriculum; it is further linked to genes and genetic expression in Life Science II (Ministry of Education, Science and Technology, 2011b).

Textbooks developed as a core part of the curriculum must obtain authorization from the Ministry of Education. The authorization criterion for science textbooks requires that the educational content reflect what is prescribed in the curriculum. In addition, materials should be selected according to the level of the learner and the capacity to spark interest among students, along with topics easily connected with or applied to everyday life. It also requires learners to perform self-directed learning. Subject areas for upper secondary are to be reviewed by members of a committee for each course of study (Shim, 2011a). Meanwhile, there are textbooks published by six publishing companies, based on the 2009 curriculum, for Life Science I.

Alignment

Curriculum alignment refers to the degree to which classroom teaching and assessment are in agreement with the objectives of the curriculum. In particular, it is important to make sure that curriculum content is consistent across textbooks, classroom teaching and assessment (Lim et al., 2014). This is because a lack of alignment causes education to be inefficient and to lose its original purpose (Liu & Fulmer, 2008). It also acts as a deterrent to the field application of curriculum contents (Coenders et al., 2008; Roach et al., 2008). In other words, when there is a lack of curricular alignment, and misalignment occurs, the inefficiency of education rises, and the concept being taught varies. Therefore, curricular alignment is very important (Lim et al., 2011)

An alignment index and a contents map have been used to analyze curricular alignment. For the alignment index, the SEC model developed by Porter (2004) was used as a measure of two dimensions: topics, and categories of cognitive demand. The contents map is a representation of topics and performance expectations as contours in two or three dimensions (Porter, 2002).

Lim et al. (2011) analyzed units on digestion and circulation using the alignment index, while Kim et al. (2015) carried out a similar analysis, also providing a contents map, regarding upper secondary school units on the cell and the continuity of life. Lim et al. (2014) also used the contents map, to analyze "stimulation response" in Republic of Korea's curriculum for lower secondary school. However, these studies focused only on comparisons between curriculum and lesson plan, and between educational objectives and assessments. In other words, the previous study failed to analyze the textbooks used in the classroom, the teachers' teachings, and the actual assessment items.

Semantic Network

A semantic network analysis examines the relationship between components so as to identify the structure of a system. It enables semantic interpretations due to the existence of the symbolism of interrelationships between key words (Wasserman & Faust, 1994). In addition, it analyzes and visualizes forms of connection between concepts, making it easy to specify abstract semantic structures. Thus, it is a method in which social network analysis is applied to language. It is also an analytical method that can identify the relationship between each concept based on the shared symbolic meaning (Lee & Ha, 2012; Shim, 2011b). Centrality approaches to the concepts' relationships, generated by representative indicators measured in the SNA, are divided into degree centrality, closeness centrality, betweenness centrality and eigenvector centrality.

Degree centrality is used as a method to determine which concepts exist in a central position in the structure of a concept. Closeness centrality indicates how close one concept is to another, and the distance between each concept and the others is a core element. Betweenness centrality represents the strength of the intermediary role of a concept in the network. Eigenvector centrality gives weight to the importance of a connected partner, representing the degree to which a concept has relationship with other concepts at higher levels of centrality for the entire network (Doerfel & Connaughton, 2009). Both the key concepts using eigenvector centrality and the size of node are mainly examined in this study.

https://doi.org/10.33225/jbse/22.21.232

Research Methodology

Analysis Target

The curriculum alignment was analyzed by using the semantic network for meiosis in Life Science I. The concept related to meiosis in the 2009 Revised Science Curriculum Commentary was used to identify the network of concepts. The concept of meiosis was selected because it is the concept that upper secondary school students in Republic of Korea had the most difficulty and high psychological hierarchy in learning among genetic-related concepts (Lim, 2019). Two upper secondary schools offering Life Science I were selected to analyze these concepts as used in their classroom teaching and assessment. The classroom teaching concerning meiosis during the unit on cells was recorded to analyze the concepts used in the classroom. The assessment questions related to the concepts of meiosis in written examinations were selected for the analysis for assessment.

Classroom Teaching

The two upper secondary schools were located in a city with a population of 2.5 million. Both were public schools, and the students' academic achievement levels were in the top 30% for the Republic of Korea. The two teachers who gave the classes were men. One had four years of classroom experience, and the other had nine.

Each meiosis lesson lasted 50 minutes, with a teacher-centered approach. Each teacher delivered the curriculum contents in a manner that explained the process and significance of meiosis. Their explanation, during "Meiosis 1," focused on the process of meiosis, which involves the formation of bivalent chromosomes. In "Meiosis 2," each teacher explained the generation of four daughter cells without replication of genetic materials, along with changes in the amount of DNA. They also explained genetic diversity in the significance of meiosis. Finally, both teachers gave explanations through a comparison of meiosis and mitosis.

Data Collection

Textbooks, recorded classes, and the teachers' assessment questions were collected to analyze alignment based on the 2009 Revised Curriculum in the Republic of Korea. The recordings of the actual classes were transcribed to collect the concepts used in the classroom. Both teachers used written questions for students' assessment. Of the 48 questions, six were applicable to meiosis. The questions were focused on the two units, and 31 out of 48 questions were about the cell and the continuity of life. The unit regarding the cell and the continuity of life is a medium unit concerning chromosomes, mitosis, meiosis, and heredity. Four questions were based on the chromosome unit, 11 questions on mitosis, six on meiosis, and ten on heredity. The six questions, which are all multiple-choice questions, were analyzed in this study because this study focused on the biological concept of meiosis. Conducting research by providing evaluation questions that have already been used is subject to exemption as research conducted in relation to practice within the scope of the school's curriculum in accordance with Article 2 of the Elementary and Secondary Education Act and Article 2 of the Higher Education Act (KoNIBP, 2018). In addition, the provided evaluation questions were used only for research, and consent was obtained after notifying the school, students, and parents that the students' personal information was not collected or recorded.

Data Analysis

The sentences related to meiosis, as collected from the curriculum commentary, classroom teaching, and assessment were transcribed to analyze the semantic network. The transcribed statements were converted into a text file (text.txt) and then preprocessed it using NetMiner 4.0 so as to select only the relevant concepts. For this stage, we excluded other concepts except for related concepts, and unified synonyms such as "meiosis 1" and "heterotypic division", and "meiosis 2" and "homotypic division".

After thus reorganizing and selecting the concepts, we visualized each of the semantic networks as a 1-mode network, organized for curriculum, textbooks, classroom teaching and assessment. On the other hand, each was visualized as a 2-mode network in order to analyze the alignment across curriculum, textbooks, classroom teaching and assessment (Jeong et al., 2019; Kim & Kwon, 2016). Table 1 provides the frequency and example of the eigenvector centrality of concepts used in the curriculum network in Figure 1.

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 1
Examples of Frequency and Eigenvector Centrality: Concepts Used in the Curriculum

Concept	Frequency	Eigenvector centrality	Concept	Frequency	Eigenvector centrality
Meiosis	3	.550	Fertilization	1	.244
DNA replication	1	.063	Chromosome	2	.443
Chromosome separa-tion	1	.021	Genetic material	1	.168
Continuity of life	1	.097	Gene	2	.292
Gamete	2	.445	Offspring	1	.097
Cell division	1	.329			

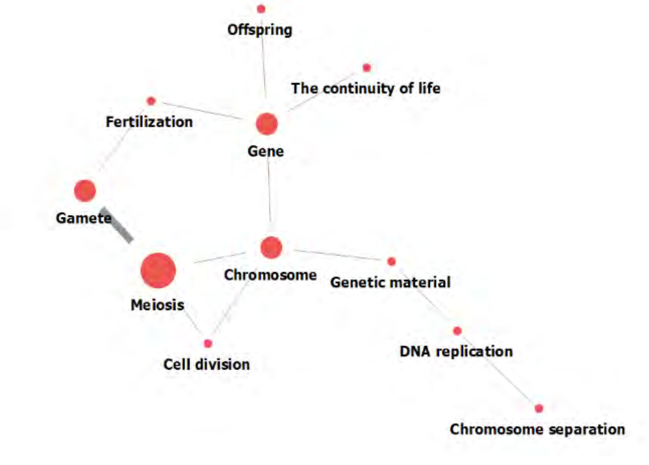
Research Results

Network

Curriculum

The eleven concepts from the curriculum commentary were extracted for the analysis of network. The frequency was highest for "meiosis" (three times), followed by "chromosome," "gene," and "gamete" (twice each). Concepts with higher eigenvector centrality were arranged in order as follows: "meiosis," "chromosome," "gamete" and "cell division." The concepts extracted from the curriculum form a network structure based on "gene" and "chromosome," in which "gene" is linked to "chromosome," "fertilization," "offspring" and "continuity of life," while "chromosome" is linked to "meiosis," "cell division," "gene," and "genetic material." (Figure 1)

Figure 1
Semantic Network of Concepts Used in the Curriculum



The curriculum requires teachers to introduce meiosis, and the various aspects of its process, outcomes, and significance, based on the concept of the chromosome (Ministry of Education, Science and Technology, 2011b). In line with this requirement, the "chromosome" was found at the center of the curriculum network. In this network, the concepts that represent the meiosis process include "gene," "chromosome," "meiosis," and "cell division." These

https://doi.org/10.33225/jbse/22.21.232

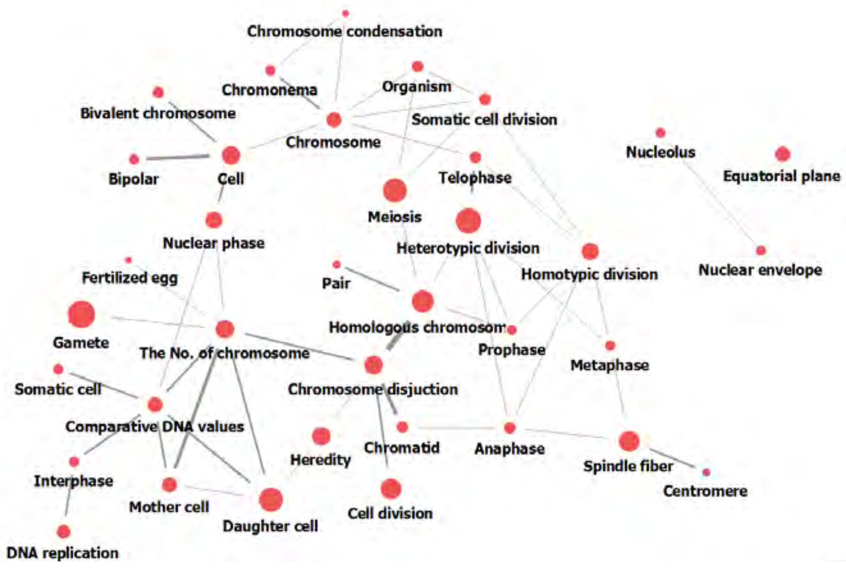
exhibited higher relative importance and were emphasized over concepts representing the outcomes and significance, such as "offspring" and "continuity of life."

Textbooks

A total of 36 concepts related to meiosis was extracted from the textbook. The frequency was highest for "gamete" (15 times), followed by "heterotypic division" (13 times), "daughter cell" (11 times), "meiosis" (11 times), and "homologous chromosome" (10 times). We arranged the concepts with higher eigenvector centrality in order, thus: "number of chromosomes," "comparative DNA values," "chromosome disjunction," "mother cell," "daughter cell," and "homologous chromosome."

"Chromosome," "number of chromosomes," "homologous chromosome" and "homotypic division" were located at the center of the network. "Chromosome" is linked to "mitosis," "chromonema," "cells and continuity of life." "Number of chromosomes" is linked to "chromosome disjunction," "comparative DNA value," "daughter cell," "mother cell" and "fertilized egg." In addition, "homologous chromosome" is linked to "prophase," "chromosome disjunction," "meiosis" and "heterotypic division." "Homotypic division" is linked to "metaphase," "anaphase," "telophase" and "mitosis." (Figure 2)

Figure 2
Semantic Network of Concepts Used in the Textbook



Of the three categories identified this way (chromosome, number of chromosomes, and homologous chromosome), division and significance of meiosis was presented in the curriculum. The process of meiosis is explained in connection with the concepts "chromosome," "homologous chromosome" and "homotypic division." The outcomes and significance of meiosis are explained in terms of the central concept of "number of chromosomes." That is, although the concepts related to meiosis were not connected to each other in the curriculum, these concepts were connected in the textbook.

Classroom Teaching

A total of 54 concepts from the recorded lectures relating to meiosis was extracted from classroom teaching. The number of these concepts showed a marked increase in comparison with the curriculum and textbook. The concept with the highest frequency was "chromosome" (116 times), followed by "number of chromosomes" (101 times), "gamete" (90 times), "gene" (60 times) and "prophase" (47 times). The concepts with higher eigenvector centrality were arranged in order from "prophase" to "heterotypic division," then "metaphase," "cytokinesis," "homotypic division," "telophase" and "homologous chromosome."

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 3
Semantic Network of Concepts Used in the Classroom Teaching

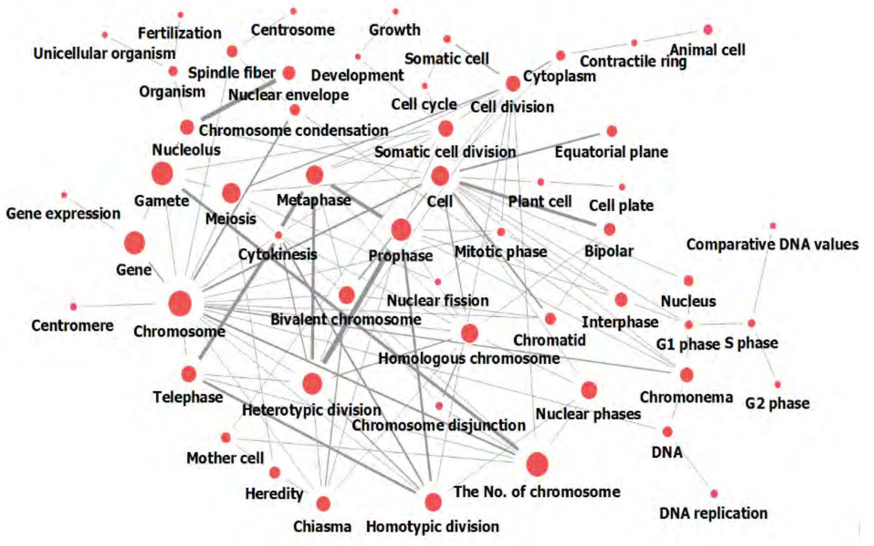


Figure 3 shows networked concepts extracted from the lectures on meiosis. The teachers' teachings about meiosis were focused on cells, chromosomes, and the number of chromosomes. They linked discussion of cells to the model of a plant cell, with interphase and chromosome. The discussion of chromosomes showed links to concepts such as heterotypic division, homotypic division, nuclear fission, chromosome condensation and anaphase. The process of meiosis was explained based on the chromosome concepts. The number of chromosomes was linked to chromosomes, gametes, and mother cells. Thus, the teachers gave explanations about meiosis with a focus on the number of chromosomes, showing that their lectures exhibited similar patterns to the conceptual network shown in the textbook.

In class, the teachers explained the process of meiosis first and then the significance of meiosis. To explain the process, they presented concepts related to the behavior of chromosomes, such as organelles, chromosomes, and homologous chromosomes. As for the significance of meiosis, the explanations focused on the concepts of chromosomes and comparative DNA values. Even in the curriculum, organelles, chromosomes, and homologous chromosomes are repeatedly explained in relation to meiosis, as the concepts to be recycled from previous teachings.

Of the numerous concepts extracted from the lectures, the largest number of concepts was related to the process of meiosis. This is because of the increasing number of concepts associated with organelles, as organelles were prescribed to be presented for explanations.

There was a prominent tendency to explain the process and outcomes of meiosis in relation to chromosomes. That is, the frequency of "chromosomes" and "number of chromosomes" was very high, and in addition to these concepts, "gamete," "homologous chromosome" and "bivalent chromosome" appeared in close spatial proximity on the graph.

Even during the classes related to the process in which reproductive cells undergo meiosis, giving rise to daughter cells, the teachers emphasized changes in number of chromosomes, nuclear phases, and comparative DNA values. However, changes in genetic information were not detailed. This may be why students have often failed to perceive the various possibilities of gene combinations in daughter cells. As described above, students have often appeared relatively unaware of differences in genetic information between mitosis and meiosis.

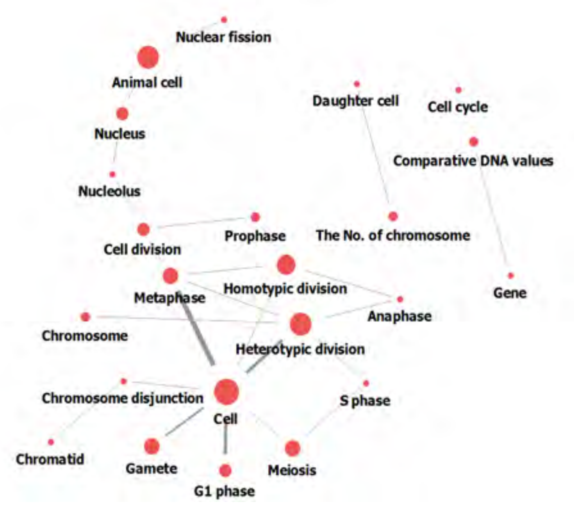
Assessment

The number of concepts extracted from assessments for meiosis was 23. The frequency was highest for "cell" (13 times), followed by "heterotypic division" (6 times), "animal cell" (6 times), "homotypic division" (5 times), "meiosis" (4 times), "gamete" (4 times), and "metaphase" (4 times). The concepts with higher eigenvector centrality were arranged in order from "cell" to "metaphase," "heterotypic division," "G1 phase," "gamete," "homotypic division," and "meiosis."

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

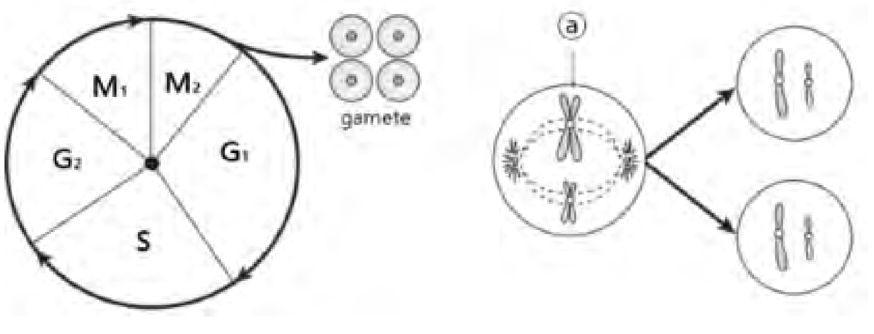
Figure 4
Semantic Network of Concepts Used in the Assessment



In the conceptual network for assessment in meiosis, the network is composed mainly around "cell" (Figure 4). This concept showed links to "G1 phase," "gamete," "chromosome disjunction," "metaphase," "homotypic division" and "heterotypic division." That is, the assessment questions reflected the process of meiosis.

The concepts associated with the outcomes of meiosis, such as "number of chromosomes," "daughter cells," "genes," and "comparative DNA values," were not linked to the process of meiosis. However, in class, these concepts had been connected to "gamete" and to "S phase." This suggests that the process, outcomes, and significance of meiosis were not connected to each other, but instead each stage was divided from the others in assessment. The following Figure 5 is an example of the assessments question.

Figure 5
Example of the Assessment Question



(a) (b)

The figure (a) shows the cell cycle when the reproductive cell of an animal (2n) is formed, and (b) shows a part of the meiosis process that occurs in the animal.

Choose a correct explanation from the following options.

A. (b) is observed in M_2 phase of (a).
B. There is no change in nuclear phase as a result of cell division in (b).
C. The ⓐ cell of (b) has the same number of chromosomes as that of daughter cells made from the result of the M_1 phase.

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

In their meiosis content, the assessment questions showed preparation based on the process and significance of meiosis. With regard to the process, the assessment focused on the stages and their characteristics. Regarding the significance of meiosis, the assessment focused on comparative DNA values and number of chromosomes. This suggests that the curriculum content, designed to explain meiosis in relation to the behavior of chromosomes (reference-curriculum commentary) was faithfully implemented in the assessments.

Alignment

Figure 6 shows alignment among the concepts used in curriculum materials, textbooks, classroom teachings, and assessment questions. There were six concepts in total ("gamete," "chromosome," "meiosis," "gene," "daughter cell" and "cell division") linked across all four curriculum stages. These were the most-used concepts explaining the process of meiosis.

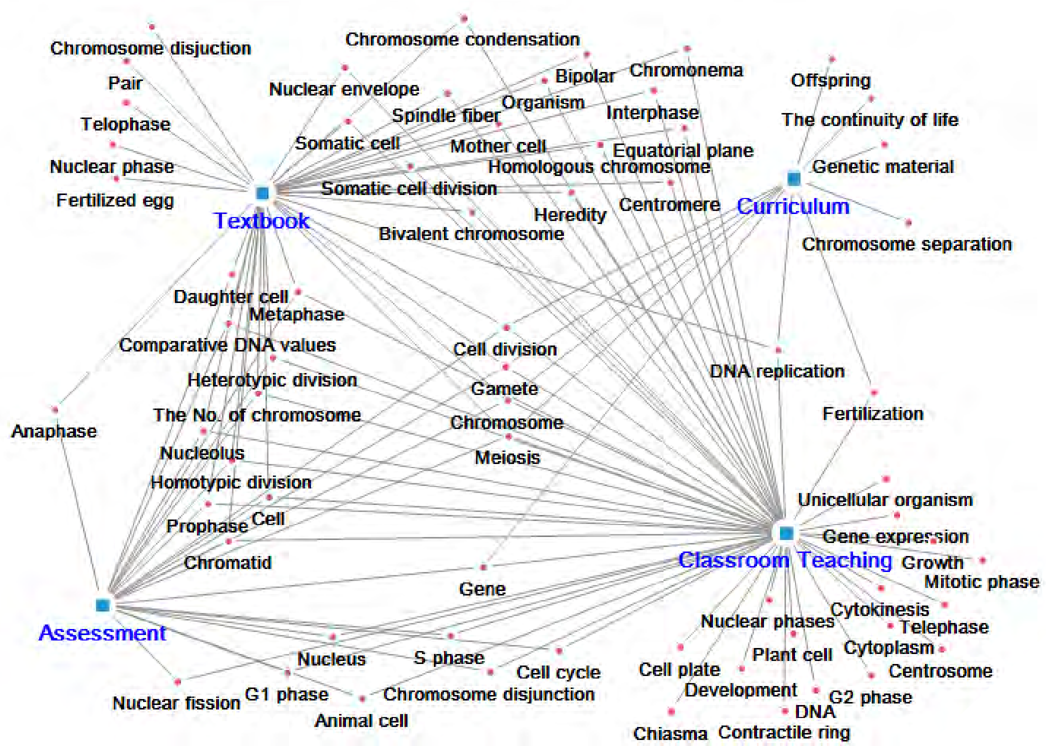
Four concepts appeared consistently in textbooks, classroom teaching and assessment: "gamete," "chromosome," "cell division" and "meiosis." Seven appeared only in classroom teaching and students' assessment, including "cell cycle," "nuclear fission," "animal cell," "S phase" and "chromosome disjunction." Fifteen concepts appeared in both textbooks and classroom teachings, and they included "gene," "mother cell," "homologous chromosome" and "chromosome condensation." The concepts of "gene" and "DNA replication" appeared in curriculum guidelines, textbooks, and classroom teachings.

Meanwhile, many of the concepts appeared only in classroom teaching, and they included 16 concepts, such as "plant cell," "unicellular cell," "centrosome" and "chiasma." Although they were not used in the assessments, most of these concepts were presented in order to explain the process.

In other words, the concepts extracted from the assessments were those that had appeared either in the textbooks or in class. In the assessment stage, teachers were found to have made the assessment questions out of the concepts mentioned in class. However, presenting many concepts in class could contribute to enhance students' understanding of learning. Therefore, it seems that improvements need to be made in class and evaluations based on the concepts used in curriculums, classroom teaching and assessment.

Figure 6

Alignment between the Concepts Used in Curriculum, Textbook, Classroom Teaching, and Assessment



https://doi.org/10.33225/jbse/22.21.232

Discussion

The alignment of concepts in the Republic of Korea's upper secondary school Life Science - curriculum is examined based on curriculum materials, textbooks, classroom teachings and assessments regarding meiosis, using semantic networks. A comparison of the four sources of research data reveals that the number of concepts is much higher in classroom teaching than in the other sources. It seems to be due to teachers' intentions to teach as many concepts as possible, although there is a possibility that the various related concepts are used in class to explain the contents of the presented curriculum (Jeong et al., 2010). However, presenting a large number of concepts to students is likely to be a distraction from learning process (Kim & Kwon, 2016). Therefore, it seems that there is a need to establish guidelines for a desirable degree to which the concepts presented in the curriculum are taught (Jeong et al., 2010; Kim et al., 2009).

The teachers' classroom teachings are based on their respective textbooks. The curriculum guidelines present key concepts in relation to meiosis, according to three categories: Process, outcomes, and significance of meiosis. On this basis, the textbook describes the process, outcomes, and significance of meiosis, with a focus on the concept of the chromosome. Even in the classroom, the meiosis process is explained based on the key concepts presented in textbooks (Figures 2 and 3). Meanwhile, the assessments focus on the process and significance of meiosis, except for outcomes of meiosis, emphasizing chromosomes.

It is found that the concepts connecting curriculum materials, textbooks, classroom teaching, and assessment are linked by the key concepts of meiosis. That is, the four concepts of "gamete," "chromosome," "cell division" and "meiosis" connect across the four stages of the curriculum. These concepts serve as a key to understanding meiosis. In other words, the process, outcomes, and significance of meiosis can be explained by the behavior of chromosomes, so it appears reasonable to suggest that the content presented in the curriculum is faithfully reflected in textbooks, classroom teaching, and student assessment.

In previous studies that analyzed alignment, a comparison was made between learning goals, textbooks, and assessment questions (Kim et al., 2003; Nam, 2010; Lim et al., 2011), curriculum materials and textbooks (Kim et al., 2011), learning goals and educational materials (Porter, 2002), curriculum, classroom teaching, and assessment (Kurz et al., 2010; Liu & Fulmer, 2008; Lu & Liu, 2012). This is an analysis of the alignment of some fragmented parts of the teaching-learning process, and thus the overall teaching-learning process could not be analyzed. As shown in the study by Squires (2012) that the higher the degree of alignment, the higher the student's achievement. Therefore, it is very necessary to make efforts to increase alignment. In particular, more efforts are needed to increase alignment in the actual class. In this study, it is meaningful that the actual class situation was analyzed, and the alignment was analyzed by visualizing the concepts actually used as networks in detail. As a result of this study, the alignment on meiosis in the Republic of Korea's upper secondary school was relatively high. Nevertheless, students still have difficulties in learning about meiosis and showed low achievement. Further studies are required to analyze these causes.

Conclusions and Implications

In this study, the alignment is analyzed in curriculum materials, textbooks, classroom teaching, and assessment, using SNA with respect to the concepts on meiosis used in the Republic of Korea's upper secondary school Life Science I curriculum, examining the relationship among these concepts.

First, the key concepts of meiosis exhibited alignment across the curriculum. The concepts "meiosis," "reproductive cells," "chromosomes," "cell division" and "gene" appeared at all stages of the curriculum (materials, textbooks, classroom teaching, and assessment). Meanwhile, as the process, outcomes and significance of meiosis are stated separately in the curriculum, textbooks and classroom teaching were found to comply fully within this curriculum. It was also found that the curriculum commentary was faithfully implemented, as meiosis was explained based on the behavior of chromosomes. However, the concepts that are common at all stages were not located at the center of the network in the curriculum stages presented in textbooks and classroom teaching. This is because the question of centrality became unclear as the number of concepts rose. In the textbooks, "heterotypic division," "number of chromosomes," and "daughter cell" were all located at the center, whereas "cell," "chromosome," and "number of chromosomes" were located at the center in both of the studied classrooms.

Second, the drastically increased number of concepts in textbooks and classroom teaching could be one cause of a deficit in learning. Due to an increase in the number of concepts in textbooks and classroom teaching,

https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

the network of concepts became more complicated, possibly making the relation of concepts unclear. Although the concepts were clearly connected to the basis on chromosomes called for in the curriculum guidelines, the concepts appeared to be unclear due to the complicated network in textbooks and classroom teaching. Therefore, it is likely that students have had difficulties in acquiring the concepts because they need to understand many concepts with complicated network structures. In this regard, there is a need for measures to reduce the number of concepts presented in textbooks and classroom teaching.

The alignment and network of concepts used for meiosis across the curriculum showed numerous concepts that were used only in textbooks and in teachers' teachings. This suggests that the concepts used in the textbooks and classroom teaching should be reduced to increase students' understanding of meiosis.

When teachers teach various scientific concepts in the unit, they need to focus on the key concepts of the unit and reflect the networks of concepts for better classroom teaching and assessment. In particular, within each network of concepts used in classroom teaching and assessment, the key concepts should be located at the center and properly connected with other concepts.

The network of concepts that focus on students' learning was not analyzed in this study. It could be necessary to compare the conceptual status and changes between the concepts used by the teacher in the actual classroom teaching and the concepts acquired by the students after class based on the network of concepts. The key concepts and network could be expected to help us find out issues and problems related to the students' conceptual learning and deficit.

Declaration of Interest

Authors declare no competing interest.

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https://doi.org/10.33225/jbse/22.21.232

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

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Received: *February 08, 2022* Revised: *March 19, 2022* Accepted: *April 09, 2022*

Cite as: Kim, Y.-S., Lee, Y.-H., Lee, H.-Y., & Lim, S.-M. (2022). Alignment of concepts of meiosis among curriculum, textbooks, classroom teaching and assessment in upper secondary school in Republic of Korea. *Journal of Baltic Science Education*, *21*(2), 232-244. https://doi.org/10.33225/jbse/22.21.232

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