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# CONNECTION OF TERMS BETWEEN INQUIRY ACTIVITIES AND THE MAIN TEXT IN THE LIFE SCIENCE UNIT OF LOWER SECONDARY SCHOOL TEXTBOOKS IN THE REPUBLIC OF KOREA

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**Soo-min Lim**

**Abstract.** *Teachers are highly reliant on textbooks for teaching. In the Republic of Korea, science textbooks help students to understand scientific terms through inquiry activities. However, there is a lack of analysis on whether the inquiry activities suggested in these textbooks appropriately cover the terms included in the main text. Therefore, this study assesses the life science units included in widely used lower secondary school science textbooks in the Republic of Korea by analysing the connection between the terms presented in the inquiry activities and the main text using the NetMiner 4.0 programme. The results reveal that the life science units included in the lower secondary school science textbooks are well structured for learning life science terms through the inquiry activities, as the terms presented in the inquiry activities and the main text are well connected. However, the number of terms included in each unit greatly differs and needs to be supplemented with the optimization of the number of terms per unit. The results provide basic data for the future development of lower secondary school science textbooks. Future research should analyse how the terms used in inquiry activities and the main text are connected in real science classes.*

**Keywords:** *biological terms, connection network, terms connection, inquiry activity, main text*

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## Introduction

Science teachers select teaching - learning materials and conduct classes according to the teaching - learning methods of each teacher based on the curriculum. In science classes in the Republic of Korea, teachers generally choose textbooks as their teaching - learning materials. It can be confirmed from the results of previous studies that 89.9% of science teachers and 85.4% of students in the Republic of Korea depended on textbooks as teaching - learning materials (Choi & Kim, 1996; Lee, 2018; Park et al., 2022). As such, textbooks are used as a means of materialising and delivering curriculum content (Lebrun et al., 2002; Oakes & Saunders, 2004) and occupy an important position in the realisation of the curriculum (Angus, 2004; Rillero, 2010). Textbooks are most of the time source of the basic and objective information that allow teachers to determine the nature and content of many activities that occur during students' learning process (DeLeuil, 1998; Wellington & Osborne, 2001). In general, teachers are highly dependent on textbooks for teaching and learning (Roseman et al., 2001; Schwarz et al., 2008), textbooks play a very important role in carrying out science education in the school field. Nevertheless, science textbooks in many countries have various problems as follows: Not only problems related to the quality of concepts such as concepts presented in textbooks lead to misconceptions, but also simple arrangement of concepts that do not consider the hierarchy of concepts in learning, those that are described as concept-centred rather than inquiry-centred (Kim & Park, 2000; Kook, 2003), and not connecting among concepts described textbooks (Eichinger & Roth, 1991; Staver & Bay, 1989).

Although textbooks have several problems, this study focused on the inquiry activities presented in the textbook. The goals of science education in the Republic of Korea can be summarized as enhancing scientific inquiry ability, acquiring scientific concepts, and cultivating scientific attitudes. In-



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quiry activities have the advantage of acquiring scientific knowledge and inquiry skills by contacting and dealing with specific phenomena as a unique learning method of science subjects (Thorsten et al., 2010). Accordingly, science education curriculum in the Republic of Korea recommends that science teachers guide students to acquire science concepts through inquiry activities (Ministry of Education, 2015). In order to become an inquiry-centred class, textbooks, which are the main teaching - learning materials, must be described as inquiry-centred. However, the current science textbooks in the Republic of Korea are still described as concept-centred rather than inquiry-centred (Suh, 2007).

As the importance of scientific inquiry is emphasised in science education, the analysis of the inquiry activities presented in science textbooks has been steadily conducted. Most of the previous studies have focused on the changes in the inquiry activities presented in textbooks (Kim, 2013; Oh & Jeong, 2012; Park & Jeong, 2019; Park & Kim, 1999), the types of inquiry activities according to the revision of the curriculum (Kim et al., 2017; Kim et al., 2021; Park, 2017), and the purpose of the inquiry activities (Millar, 2010). However, while these studies have analysed the external studies, that is, the types and frequencies of inquiry activities presented in textbooks, they have not analysed which scientific terms are connected through the inquiry activities.

In the Republic of Korea, the structure of science textbooks describes the scientific terms appropriate for the inquiry activities. In other words, science textbooks attempt to help students to understand science concepts by directly experiencing such terms through inquiry activities (Kim et al., 2017). Therefore, to ensure students' effective understanding of science concepts, the textbooks' description of the inquiry activities is very important, and effective learning is possible when the core concepts presented in the main text and in the inquiry activities are properly connected (Kim, 2020). However, while students unilaterally follow instructions from their teachers and textbooks, they lack the awareness of why they are engaging in inquiry activities (Bell et al., 2003; Germann et al., 1996). Moreover, the majority of students fail to combine intellectual aspects with inquiry activities (Penner & Klahr, 1996). If scientific content is not conceptually connected, students will have difficulty structuring the knowledge to achieve an integrated understanding (Brophy, 1992; Staver & Bay, 1989). Therefore, in order for students to easily understand scientific knowledge through inquiry activities through textbooks, it is necessary to properly connect the terms presented in the inquiry activities of textbooks in the main text of the textbook.

Semantic Network Analysis (SNA) analyses the connections between terms in texts to identify relationships between texts using words and terms as the analysis targets (Doerfel & Connaughton, 2009). This method is particularly suitable for the analysis of textbooks since they are mainly composed of text and is often used as an objective research method in the education field (Jung & Choi, 2020). The previous studies have used SNA to analyse the connections between the terms presented in textbooks (Kim et al., 2022; Kwon & Kim, 2018) and to conduct a structural analysis between the terms (Park et al., 2010). Therefore, SNA is a suitable research method for analysing the connections between a textbook's inquiry activities and the terms presented in the main text.

Analyses of the connections between the terms presented in textbooks' inquiry activities and the main text using SNA have already been conducted. For example, Kim (2020) used SNA to analyse the connections between the terms presented in the inquiry activities and the main text of plant-related units in elementary and lower secondary schools in the Republic of Korea. In the plant-related units, the core terms were presented in both the inquiry activities and the main text, while some terms were only presented in the inquiry activities but not in the main text. Therefore, the analysis of other subject units or school levels is required.

The scientific terms learnt in lower secondary schools are based on elementary school terms, which then become the basis for upper secondary school science subjects in the Republic of Korea (Ministry of Education, 2015). Compared with the elementary school science textbooks, there is a sharp increase in the number of terms introduced in lower secondary school textbooks (Kim, 2020; Kim et al., 2011; Lim & Kim, 2015) as well as a relatively large number of inquiry activities presented (Lim & Jang, 2015). However, there is a lack of analysis on whether the inquiry activities suggested in lower secondary school science textbooks are appropriate. Therefore, this study analyses the connection between the terms presented in the inquiry activities and the main text in the life science domain included in the lower secondary school science textbooks.

This study intended to assess whether the inquiry activities suggested in the textbooks are appropriate so as to provide basic data for the future development of lower secondary school science textbooks. The purpose of this study was to assess whether the inquiry activities suggested in the textbook are appropriate, and to provide basic data to increase the connection between the terms presented in the inquiry activities and in the main text in the future development of lower secondary school science textbooks.


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## Theoretical Background

*Lower Secondary School Life Science Domain in Korean Textbooks*

In the Republic of Korea, science subjects are taught to students in grades 3-6 of elementary school, grades 7-9 of lower secondary school, and grades 10-12 of upper secondary school. The Republic of Korea implements a national curriculum in which the science curriculum contains life science subjects for these students (Ministry of Education, 2015). The science curriculum contains subjects including physics, life science, chemistry, and earth science that are to be taught in elementary school, lower secondary school, and upper secondary school alongside the characteristics, goals, content systems, achievement standards, evaluation methods, and guidance instructions for each subject.

In the lower secondary school science curriculum, the life science domain consists of five units: 'Biological diversity', 'Plants and energy', 'Animals and energy', 'Stimulation and reaction', and 'Reproduction and genetics'. These units are revised when the national curriculum is revised. The current units are part of the 2015 revised curriculum that was implemented in 2017. The curriculum previously focused on 'things to be taught' but now emphasises 'what needs to be accomplished' as part of a competency-based curriculum. Accordingly, achievement standards are included for each unit, and the inquiry activities related to the achievement standards are described in detail (Ministry of Education, 2015). Table 1 shows the achievement standards for the life science domain's units in the 2015 revised curriculum.

**Table 1**
*Achievement Standards for Each Unit*

| Unit | Achievement Standards |
|---|---|
| Biodiversity | • To understand biodiversity and explain the relationship between the environment and biodiversity in terms of variation.<br>• To understand the concept and classification system of biological species and classify living things at the kingdom level.<br>• To understand the need for biodiversity conservation and investigate and present cases of activities for biodiversity maintenance. |
| Plants and energy | • To understand photosynthesis and explain that plants produce nutrients to obtain the energy necessary for life activities, alongside the factors affecting photosynthesis.<br>• To understand the relationship between the movement of water and transpiration required for photosynthesis and explain the transpiration in leaves in relation to photosynthesis.<br>• To understand respiration in plants and explain the relationship with photosynthesis.<br>• To express the process of the production, storage, and use of photosynthetic products as a model. |
| Animals and energy | • To explain the organic composition of living things.<br>• To explain the process by which food is digested and nutrients are absorbed in relation to the action of digestive enzymes.<br>• To understand the structure and function of the circulatory system and explain the blood circulation pathways.<br>• To understand the structure and function of respiratory organs and explain the principle of respiratory movement using models.<br>• To understand the structure and function of excretory organs and express the process of excreting waste products.<br>• To explain the process by which animals obtain energy through cellular respiration in relation to digestion, circulation, respiration, and excretion. |
| Stimulus and response | • To understand the structure and function of sensory organs (eyes, ears, nose, tongue, and skin) and explain the transmission process to the brain through sensory organs according to the type of stimulus.<br>• To understand the structure and function of neurons and the nervous system and express the process from the stimulus to the response through reaction experiments depending on the type of stimulus.<br>• To understand that hormones are involved in regulating the functions of our body and investigate and present related cases. |
| Reproduction and heredity | • To explain cell division in relation to the growth of an organism.<br>• To understand the relationship between chromosomes and genes and explain the characteristics of mitosis and meiosis, focusing on the behaviour of chromosomes.<br>• To express the development process of an individual from a fertilised egg as a model.<br>• To understand the significance of Mendelian inheritance and investigate and present related genetic phenomena.<br>• To understand human genetic traits and methods of genetic research and express human genetic phenomena using a genogram. |

*Note*. Achievement standards for each unit in the 2015 revised science curriculum. From "Science curriculum (pp. 59-60, 68-70, 78-81)," Copyright 2015 by Ministry of Education.


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*Structure of Science Textbooks*

In the Republic of Korea, lower secondary school science textbooks are authorised textbooks that are used to improve the autonomy of education and guarantee diversity within the national curriculum. Authorised textbooks refer to those that have been tested according to the qualification standards set by the Minister of Education. Lower secondary school science textbooks are developed by the publisher (author) according to the national curriculum and qualification standards, and the committee of the national level (Korea Foundation for the Advancement of Science and Creativity) decides on whether to publish them or not. Currently, lower secondary schools in the Republic of Korea use science textbooks developed by five publishers. Most science textbooks consist of an introduction to the unit, class-related content, a summary of the unit, science stories about scientific issues, and summative evaluations at the end of the unit. Among these, the class-related content includes the introduction, inquiry activities, scientific term explanations, and brief intermediate evaluations (e.g., quizzes) for each class. This study uses class-related content for its analysis. The class-related content contains between 9–16 inquiry activities that correspond to each life science unit (see Appendix). The unit with the lowest number of inquiry activities is 'Plants and energy', and the unit with the highest number of inquiry activities is 'Animals and energy'.

## Research Methodology

*Subject*

The subject of this study was the life science units in the lower secondary school science textbooks. The specific analysis units were as follows: 'Biodiversity' for the 7th grade; 'Plants and energy' and 'Animals and energy' for the 8th grade; and 'Stimulation and reaction' and 'Reproduction and genetics' for the 9th grade. Each unit is subdivided into 2–5 sub-units. The 'Biodiversity' unit consists of three sub-units: 'biodiversity', 'classification of living organisms', and 'conservation of biodiversity'. The 'Plants and energy' unit consists of two sub-units: 'photosynthesis' and 'plant respiration'. The 'Animals and energy' unit consists of five sub-units: 'digestion', 'circulation', 'respiration', 'excretion', and 'relationships between organ systems'. The 'Stimulus and response' unit consists of two sub-units: 'sensory organs' and 'nervous system and hormones'. Finally, the 'Reproduction and genetics' unit consists of two sub-units: 'reproduction' and 'heredity'.

For the science textbook analysis, this study selected three of the five publishers' textbooks that had a high adoption rate. This means that most of the science teachers in the lower secondary schools in the Republic of Korea have agreed with the school boards to use these textbooks in their class. As a result, most students in the lower secondary schools in the Republic of Korea use these textbooks during classes. Among the adopted textbooks, the class-related contents were selected, and the inquiry activities and terms presented in the main texts corresponding to the selected contents were analysed. This study excluded the introduction to the unit, summary of the unit, science stories including scientific issues, summative evaluation, and the end of the unit. In the inquiry activities, this study's subject of analysis was the introductory text, inquiry method, and discussion parts. It excluded the preparations and precautions parts. This is because the terms presented in the preparations and precautions parts are not directly related to each unit, but are related to the general scientific inquiry process.

*Data Analysis*

The terms of the inquiry activities and main text presented in the life science units in the textbooks were transcribed. The terms were divided into inquiry activities and main text terms by using sentences as the unit and were saved as a text file (.txt). The terms were then extracted from the transcribed file using the NetMiner 4.0 programme (http://www.netminer.com), in which the noun form was used as the basis.

The NetMiner 4.0 programme used in this study is one of the widely used software that can analyse and visualize networks (Huisman & Van Duijn, 2005). This programme enables Semantic Network Analysis by extracting terms from unstructured text data and converting them into term-to -term networks. The network structure consists of one-mode and two-mode. one-mode network is a network composed of relationships between entities (nodes) within a group (homogeneous), and a two-mode network is a network composed of relations between entities within two different groups (heterogeneous). As shown in the example in Figure 1 below, using a two-mode network makes it easy to analyse the degree of connection by visualizing the relationship between the terms in two


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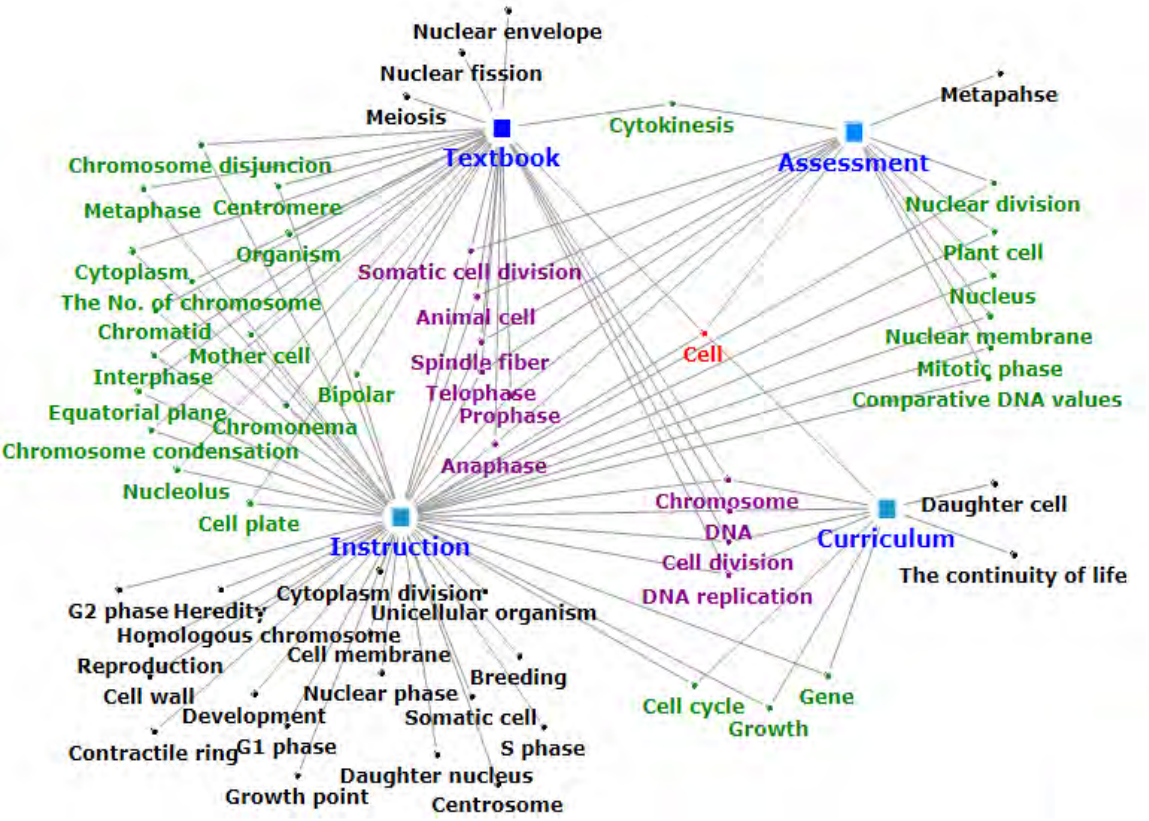
different groups (heterogeneous) of inquiry activity and main text as a network (e.g., conceptual alignment through the connection between concepts presented in curriculum, textbook, instruction, and assessment).

**Figure 1**
*The Example Using Two-mode Network*




*Note*. From "Conceptual alignment between the somatic cell division curriculum, textbooks, instruction, and assessment in high school," by Y. Kim et al., 2021, *Journal of Biological Education*, p12. https://doi.org/10.1080/00219266.2021.1884585.

The extracted terms were pre-processed to leave only meaningful life science terms. A pre-processing step consists of cleansing, control operation, and removal (Lee, 2014). During the pre-processing step, this study used cleaning (e.g., spacing and changing the form of parts of text) as well as control operations to adopt appropriate terms (e.g., synonyms) and then removed meaningless terms. In the control operation and removal operation for adopting an appropriate term, if the extracted term is not a controlled term, an appropriate term is adopted by controlling synonyms, analogues, broad terms, and narrow terms, in particular, if there is no dictionary of controlled terms such as thesaurus, control with appropriate terms with the help from experts in the relevant field.

After the pre-processing step, eight people selected the terms: six of them are in-service life science teachers in secondary school and two are professor at the college of Education who teach pre-service life science teachers. All of them have doctoral degrees in life science education. All in-service life science teachers had more than 10 years of experience working in secondary schools. Among the eight people who requested concept selection, terms that were judged to be meaningless in terms of life science by more than five people, more than half of them, were excluded from the analysis. Among the selected terms for the analysis, which are terms meaningful in life science, any term with an eigenvector centrality index of zero (as derived using the NetMiner 4.0 programme) was excluded from the analysis since it was meaningless (Kim & Kwon, 2016; Kwon et al., 2018). Eigenvector centrality index is an index used to analyse not only the number of connected terms, but also how important and influential terms connected to this term are on the network (Bonacich, 2007). Therefore, it is mainly used when selecting core terms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on the network, and in this analysis, the term with an eigenvector centrality index of zero was excluded. Through these processes, this study could finally select the terms to be analysed (Table 2).

**Table 2**
*Number of Selected Terms*

| Unit | Number of Terms |
|---|---|
| Biodiversity | 51 |
| Plants and energy | 29 |
| Animals and energy | 106 |
| Stimulus and response | 87 |
| Reproduction and heredity | 68 |

The final selected terms were visualised using the NetMiner 4.0 programme. The visualisation divided the life science terms presented in the inquiry activities and the main text into units so as to confirm the connections between the units. An analysis of the sub-units was first performed, followed by an analysis of the units. The connections between the terms in the units were visualised in the form of a two-mode network. Then, the term networks and connections between the terms in the inquiry activities and the main text were analysed.

## Research Results

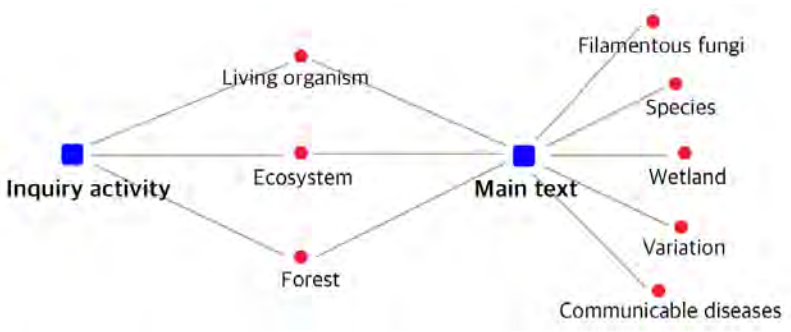
*The Connection Networks at the Sub-Unit Level*

*'Biodiversity' Unit*

Figure 1 presents a connection network that visualises the connections between the terms presented in the inquiry activities and the main text for each sub-unit. There are eight terms in the 'biodiversity' sub-unit (Figure 2a). Three terms connect the inquiry activities and the main text: 'living organism', 'ecosystem', and 'forest'. Five terms appear only in the main text: 'filamentous fungi', 'species', 'wetland', 'variation', and 'communicable diseases'. Through examples of representative ecosystems, such as 'forests', the interactions between living organisms in the environment and other living organisms are investigated in the inquiry activities.

Meanwhile, the main text includes the term of 'variation' as a cause of biodiversity and 'communicable diseases' as explained by the necessity of biodiversity. Therefore, although the terms of 'living organism', 'ecosystem', and 'forest' are connected with the main text and inquiry activities, the inquiry activities on the causes and necessity of biodiversity presented in the main text are insufficient.

**Figure 2**
*The Connection Networks at the Sub-unit Level between the Terms Presented in the Inquiry Activities and the Main Text of the 'Biodiversity' Unit*




*a. 'Biodiversity' sub-unit*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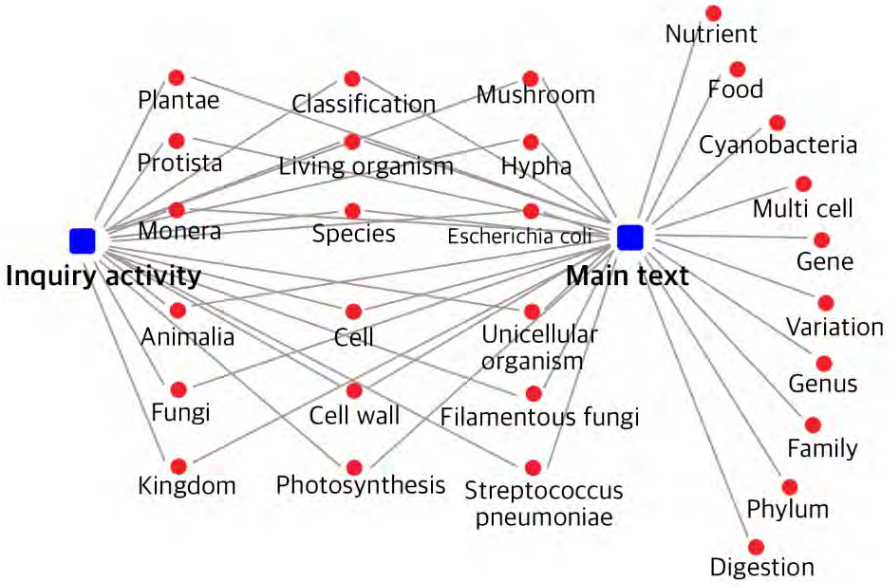
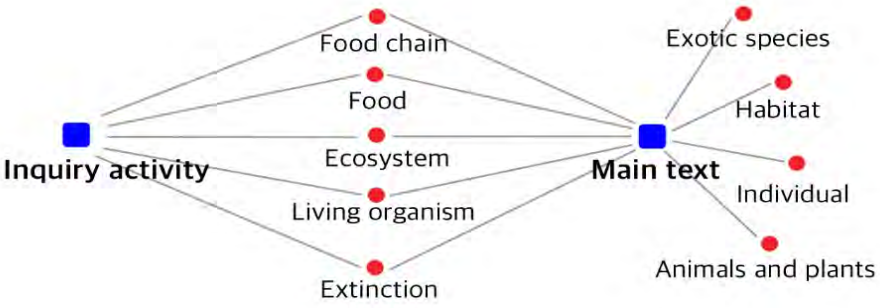



*b. 'Classification of living organisms' sub-unit*




*c. 'Conservation of biodiversity' sub-unit*

There are 28 terms in the 'classification of living organisms' sub-unit (Figure 2b), and 18 terms connect the inquiry activities and the main text, which include 'living organism', 'plantae', 'protista', 'animalia', 'fungi', 'cell', and so on. As such, the terms that connect the inquiry activities and the main text correspond to the 'kingdom' term; for example, 'plantae', 'protista', 'monera', 'animalia', and 'fungi'. Example terms correspond to species of living organisms, such as 'Streptococcus pneumoniae', 'E. coli', and 'filamentous fungi'. Terms of the classification criteria are also presented; for example, 'cell wall', 'photosynthesis', 'hypha', and 'unicellular organism'. This is because the learning goal for the classification of life sciences for lower secondary schools in the Republic of Korea concerns classification at the 'kingdom' level (Table 1). Meanwhile, 10 terms only appear in the main text, which include 'digestion', 'cyanobacteria', 'variation', 'gene', 'food', and so on.

There are nine terms in the 'conservation of biodiversity' sub-unit (Figure 2c), and five terms connect the inquiry activities and the main text, which include 'food chain', 'food', 'ecosystem', 'living organism', and 'extinction'. These terms can explain the effects of biodiversity on the ecosystem's equilibrium. However, four terms only appear in the main text: 'habitat', 'exotic species', 'individual', and 'animals and plants'. Among these, terms such as 'habitat' and 'exotic species' correspond to terms that cause the decline of biodiversity.

Overall, in the 'Biodiversity' unit, there is a relatively high number of connections between the terms presented in the inquiry activities and the main text. Moreover, the main text explains the terms of life science based on the terms used in the inquiry activities and provides additional examples.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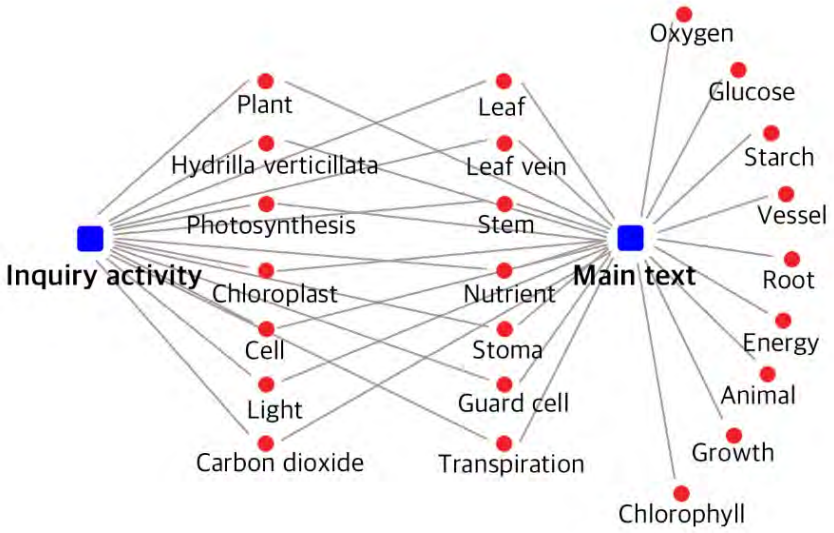
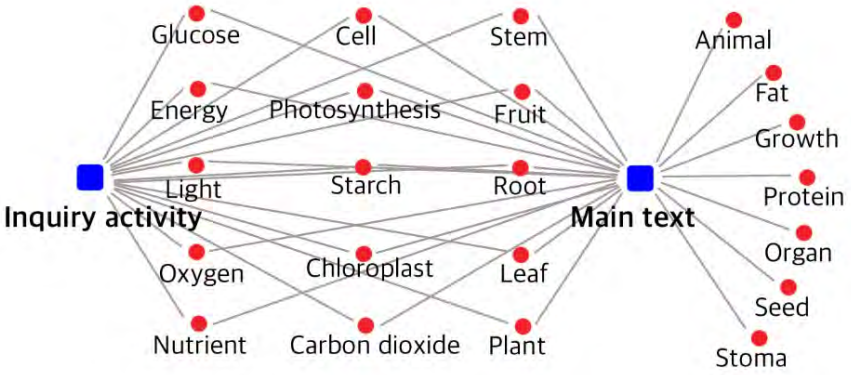
*'Plants and Energy' Unit*

Regarding the 'Plants and energy' unit, the 'photosynthesis' sub-unit explains the process of photosynthesis, the place of photosynthesis, the products of photosynthesis, the environmental factors that affect photosynthesis, and transpiration. The relationship between respiration and photosynthesis and the process of the production, storage, and use of the products of photosynthesis are explained by understanding respiration in the 'plant respiration' sub-unit.

**Figure 3**
*The Connection Networks at the Sub-unit Level between the Terms Presented in the Inquiry Activities and the Main Text of the 'Plants and energy' Unit*




*a. 'Photosynthesis' sub-unit*




*b. 'Plant respiration' sub-unit*

There are 23 terms in the 'photosynthesis' sub-unit (Figure 3a). There are 14 terms that connect the inquiry activities and the main text, which include 'photosynthesis', 'leaf', 'plant', 'light', 'transpiration', and so on. The connected terms are 'leaf' and 'plant', where photosynthesis takes place; the environmental factors that affect photosynthesis are 'light' and 'carbon dioxide'; and the terms that relate to transpiration are 'transpiration', 'stoma', and 'guard cell'. Meanwhile, nine terms are only presented in the main text, for example, 'oxygen', 'glucose', 'starch', 'growth', 'chlorophyll', 'root', and so on. Terms that correspond to the product of photosynthesis, such as 'oxygen', 'glucose', and 'starch', and terms related to water, such as 'root' and 'vessel' (i.e., elements necessary for photosynthesis), are presented.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There are 22 terms in the 'plant respiration' sub-unit (Figure 3b). Although the 'plant respiration' sub-unit has the theme of plant respiration, terms related to photosynthesis are mainly presented. This is because these terms focus on the relationship between plant respiration and photosynthesis rather than on plant respiration itself. There are 15 terms that connect the inquiry activities and the main text, which include 'photosynthesis', 'plant', 'light', 'leaf', and 'chloroplast'. Meanwhile, seven terms are only presented in the main text, for example, 'animal', 'growth', 'fat', 'protein', 'organ', 'seed', and 'stoma'.

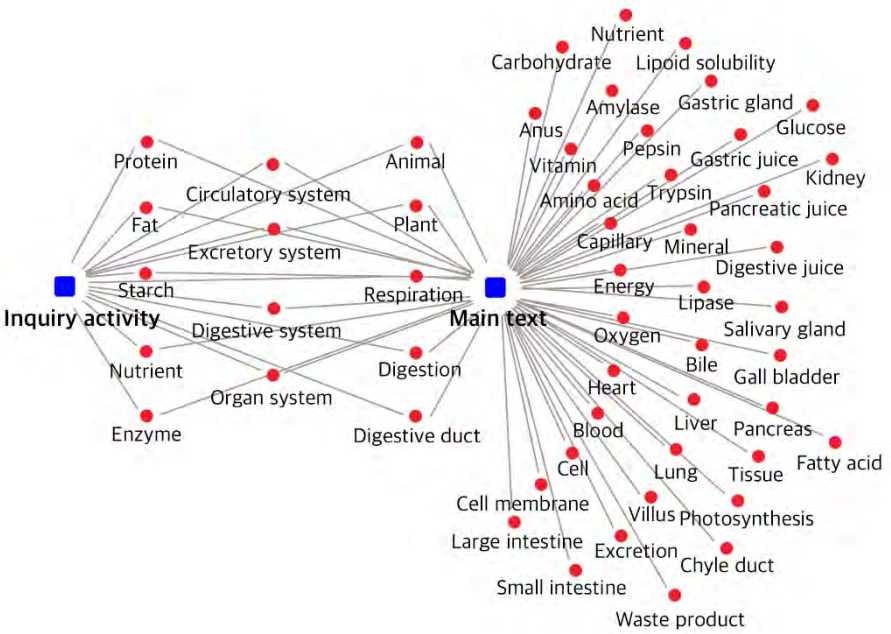
Overall, the 'Plants and energy' unit shows a high number of connections between the terms presented in the inquiry activities and the main text, like in the 'Biodiversity' unit. This means that terms that include the relationship between photosynthesis and respiration are explained in the main text after the inquiry activities are performed.

*'Animals and Energy' Unit*

Regarding the 'Animals and energy' unit, the 'digestion' sub-unit explains the organic building of living organisms, nutrients, digestive enzymes, and digestion. The 'circulation' sub-unit explains the heart and blood vessels that belong to the circulatory system, the structure and function of blood, and the circulation path of blood. The 'respiration' sub-unit explains the structure and function of the respiratory tract and the principle of respiratory movement, and the 'excretion' sub-unit explains the structure and function of the excretory organs and the excretion process of waste products. Finally, the 'relationships between organ systems' sub-unit explains the process of obtaining energy through cellular respiration in relation to digestion, circulation, respiration, and excretion.

There are 53 terms in the 'digestion' sub-unit (Figure 4a). There are 14 terms that connect the inquiry activities and the main text, which include 'digestion', 'enzyme', 'nutrient', 'fat', 'protein', and so on. These terms are nutrient-related terms, such as 'protein', 'fat', and 'starch', and organ system-related terms, such as 'digestive system', 'circulatory system', and 'excretory system'. Meanwhile, 39 terms are only presented in the main text; for example, 'cell', 'amylase', 'bile', 'glucose', and 'pancreas'. These terms correspond to digestive enzymes, such as 'pancreatic juice', 'trypsin', 'pepsin', and 'lipase'; digestive organs, such as 'pancreas', 'large intestine', and 'small intestine'; and the absorption process of digested nutrients, such as 'villus', 'capillary', and 'chyle duct'.

**Figure 4**
*The Connection Networks at the Sub-unit Level between the Terms Presented in the inquiry Activities and the Main Text of the 'Animals and energy' Unit*




*a. 'Digestion' sub-unit*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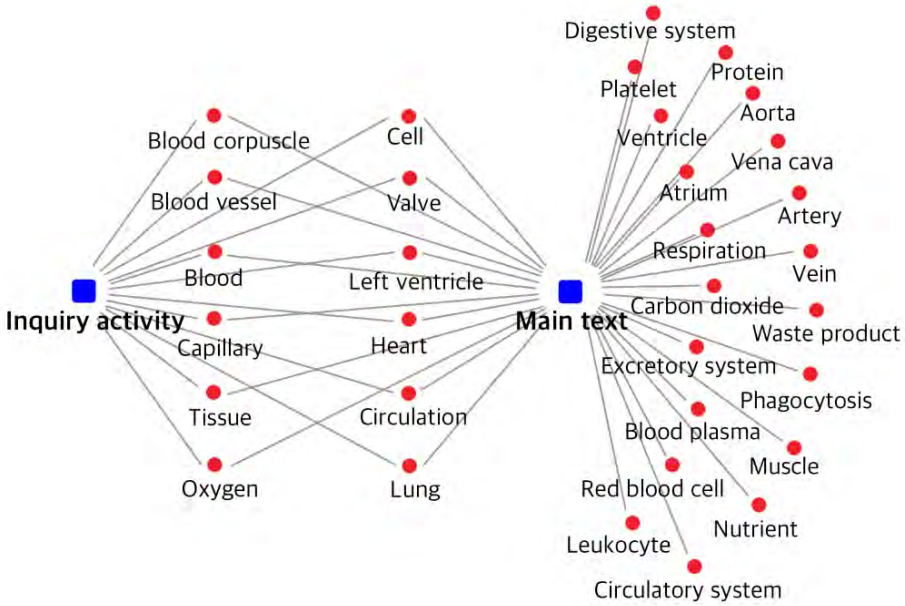
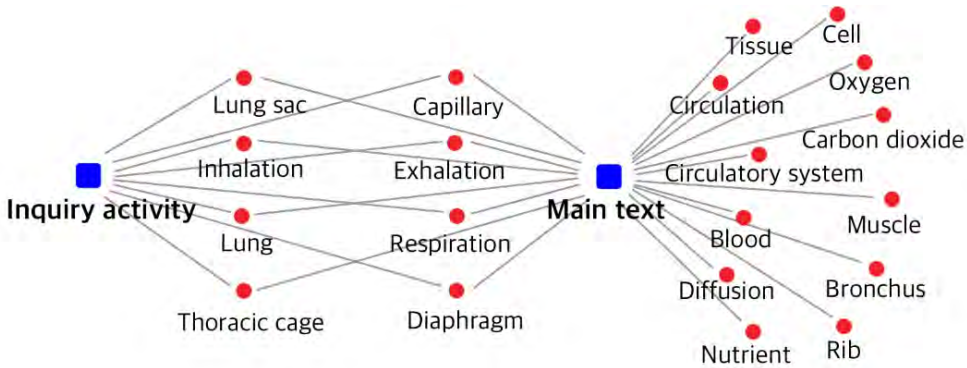
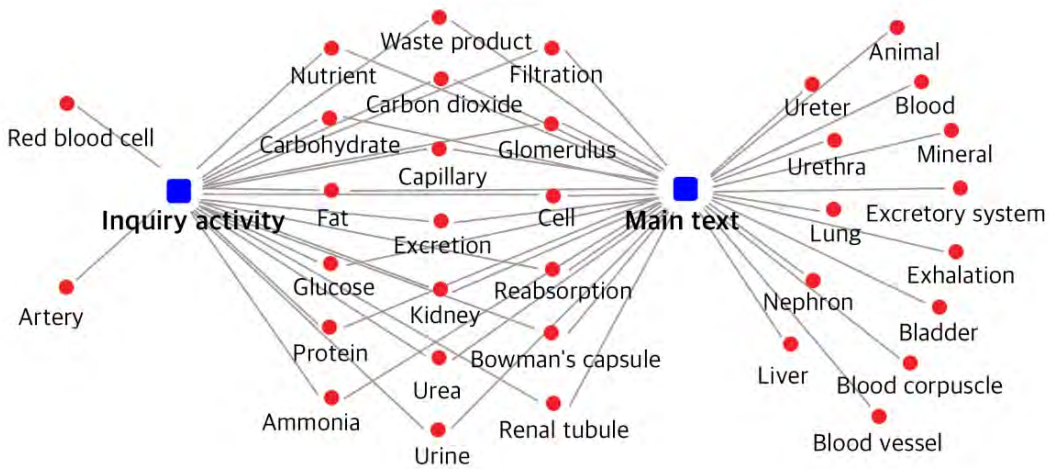



*b. 'Circulation' sub-unit*




*c. 'Respiration' sub-unit*




*d. 'Excretion' sub-unit*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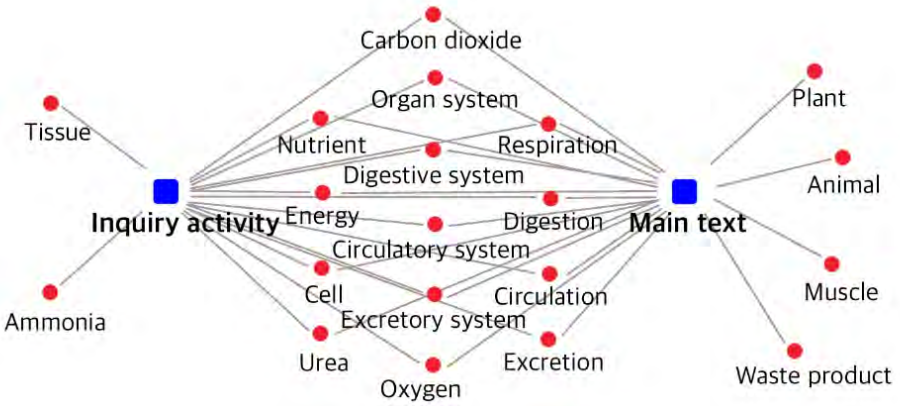


*e. 'Relationships between organ systems' sub-unit*

There are 32 terms in the 'circulation' sub-unit (Figure 4b). There are 12 terms that connect the inquiry activities and the main text, which include 'circulation', 'blood', 'heart', 'lung', 'blood vessel', and so on. Meanwhile, 20 terms are only presented in the main text; for example, 'aorta', 'vena cava', 'atrium', 'ventricle', 'respiration', and so on. Regarding the terms that connect the inquiry activities and the main text, only 'blood corpuscle' among the terms corresponding to the components of blood appears connect the inquiry activities and the main text, while its terms of 'blood plasma', 'red blood cell', 'leucocyte', and 'platelet' are only presented in the main text. This is because students mainly discover blood corpuscles, such as red blood cells, leucocytes, and platelets, as a result of the inquiry activities for observing blood. However, it is not possible to clearly understand the functions of the composition components of blood through inquiry activities that only focus on the observation of blood corpuscles. This is a limitation because only the functions of blood plasma (e.g., as 'waste products' and 'protein') and the terms that belong to the functions of blood corpuscles (e.g., 'phagocytosis') are presented in the main text.

There are 20 terms in the 'respiration' sub-unit (Figure 4c). There are eight terms that connect the inquiry activities and the main text, which include 'lung', 'respiration', 'capillary', 'lung sac', 'thoracic cage', and so on. There are 12 terms presented in the main text, which include 'cell', 'tissue', 'oxygen', 'carbon dioxide', 'blood', and so on. The terms connected in the inquiry activities and the main text correspond to terms used when organically presenting changes in the diaphragm, lung, and thoracic cage during inhalation and exhalation. However, terms such as 'circulation', 'cell', 'oxygen', 'carbon dioxide', 'tissue', and 'diffusion', which are presented only in the main text, are related to gas exchange in the body and are not used in the inquiry activities. The terms related to the principle of respiratory movement are presented in the inquiry activities; however, these terms cannot be acquired through inquiry activities because they do not represent the gas exchange that occurs in the body. Meanwhile, the terms of gas exchange presented only in the main text mainly relate to diffusion and are explained in the "Properties of gas' unit in the 7th grade; thus, they are excluded from the 'Animals and energy' unit in the 8th grade.

There are 34 terms in the 'excretion' sub-unit (Figure 4d). There are 19 terms that connect the inquiry activities and the main text, which include 'kidney', 'urine', 'renal tubule', 'waste product', 'filtration', and so on. There are 13 terms presented only in the main text; for example, 'urethra', 'blood', 'nephron', 'blood vessel', and so on. The terms presented only in the inquiry activities are 'red blood cell' and 'artery'. The terms that connect the inquiry activities and the main text include 'ammonia' and 'urea', which are substances that form through the excretion process of digested nutrients, such as 'fat', 'carbohydrate', 'glucose', and 'protein'. Moreover, the 'glomerulus', 'Bowman's capsule', and 'renal tubule' terms are presented, which represent the structure of the kidneys (i.e., an excretory organ) and the 'filtration' and 'reabsorption' terms (i.e., the formation process of urine). The terms presented only in the main text include 'lung' and 'exhalation' (related to the respiratory system) and 'ureter', 'bladder', and 'urethra' (related to the excretory organs). 'Red blood cells' appears only in the inquiry activities and is used to explain the reabsorption process, while 'artery' is used to represent changes in the blood entering the renal artery.

There are 20 terms in the 'relationships between organ systems' sub-unit (Figure 4e). There are 14 terms that connect the inquiry activities and the main text, including 'respiration', 'cell', 'circulation', 'excretion', and so on. These terms correspond to digestion, circulation, respiration, and the excretion process to obtain energy through cellular respiration, which is an achievement standard for lower secondary schools (Table 1). Meanwhile, the terms that are


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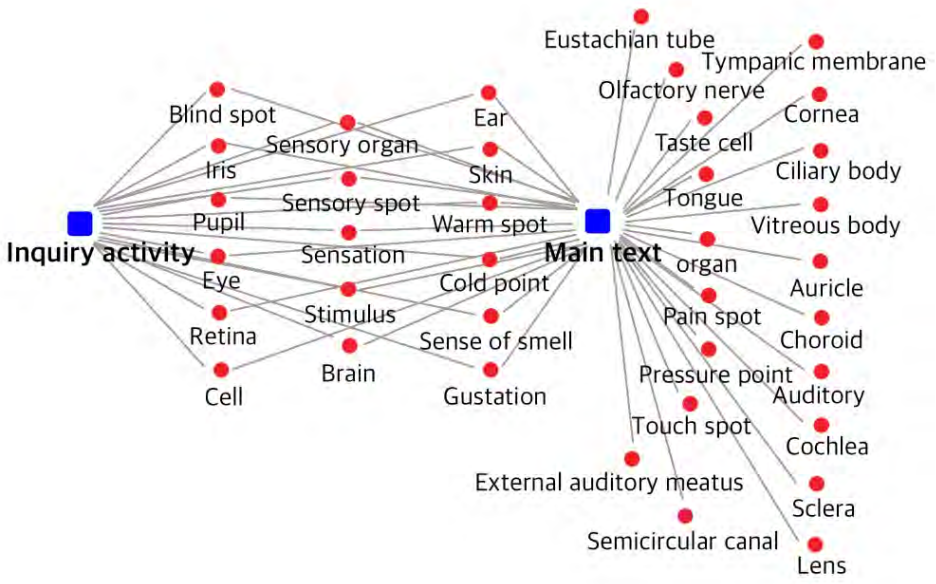
presented only in the main text include 'animal', 'plant', 'muscle', and 'waste product', where 'muscle' is a term related to tissue that directly utilises energy formed through cellular respiration, 'waste product' is a term that is presented in the transport of products through cellular respiration, and 'plant' is a term that is presented for comparison with plant respiration. The terms that are presented only in the inquiry activities include 'tissue' and 'ammonia', where 'tissue' is presented in the main text of the 'respiration' sub-unit, while 'ammonia' connects the inquiry activities and the main text in the 'excretion' sub-unit.

The 'Animals and energy' unit has more terms in the textbook than the other units. This corresponds with the results of Seo et al.'s (2020) study on the connections between the animal-related terms presented in the curriculum and textbooks according to the revised curriculum in the Republic of Korea. The inquiry activities in the 'Animals and energy' unit are mainly described in terms of the structure of organs and include 'observing organs composing organ systems', 'recognising structures of blood vessels and heart', 'expressing excretory processes', and so on. Moreover, because this sub-unit emphasises learning about the interaction between digestion, circulation, respiration, and excretion in relation to cellular respiration (Seo et al., 2020), the processes and functions of digestion, circulation, respiration, and excretion are presented as focal points alongside their interactions. Therefore, there is a relatively larger number of presented terms compared to the other sub-units.

*'Stimulus and Response' Unit*

Regarding the 'Stimulus and response' unit, the 'sensory organs' sub-unit describes the structure and function of the eyes, ears, nose, tongue, and skin sensory organs alongside the transmission process to the brain through the sensory organs. Moreover, this unit explains the structure and function of neurons and the nervous system in terms of the processes by which stimuli are transmitted through neurons and control the body's function via hormones in the 'nervous system and hormones' sub-unit.

**Figure 5**
*The Connection Networks at the Sub-unit Level between the Terms Presented in the Inquiry Activities and the Main Text of the 'Stimulus and response' Unit*




*a. 'Sensory organs' sub-unit*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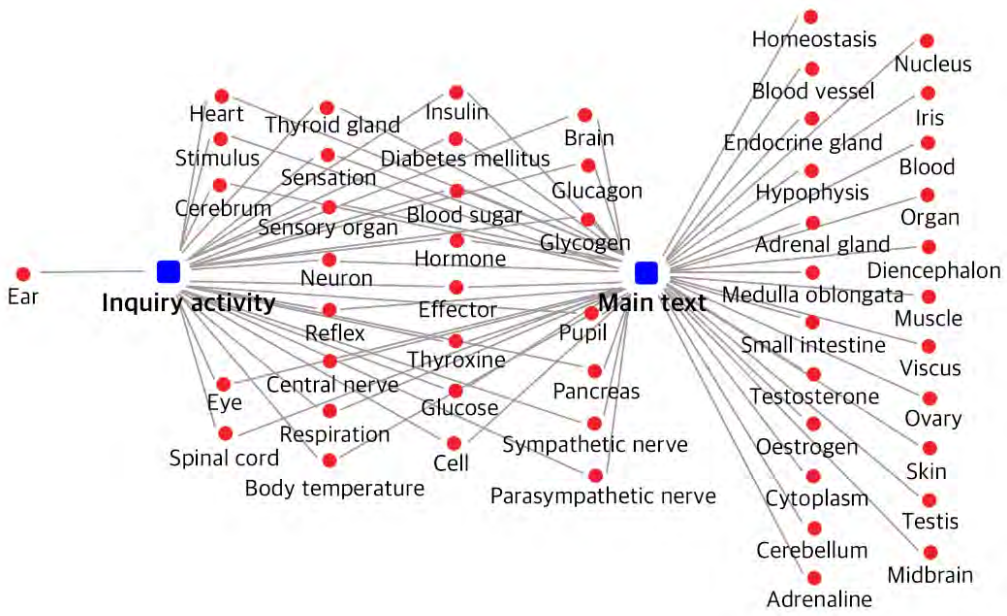


*b. 'Nervous system and hormones' sub-unit*

There are 37 terms in the 'sensory organs' sub-unit (Figure 5a). There are 17 terms that connect the inquiry activities and the main text, which include 'eye', 'skin', 'sensation', 'stimulus', and so on. Meanwhile, 20 terms are only presented in the main text; for example, 'auditory', 'tongue', 'taste cell', 'pain spot', 'organ', and so on. The terms that connect the inquiry activities and the main text mainly represent the transmission process from the sensory organs, for example, 'sensory organs', 'stimulus', and 'brain'. In terms of the sensory organs, eye-related terms, such as 'eye', 'iris', 'blind spot', 'retina', and 'pupil', are the most presented, followed by skin-related terms, such as 'skin', 'warm spot', and 'cold spot'. The nose-, tongue-, and ear-related terms, such as 'sense of smell', 'ear', and 'gustation', are the least presented. Accordingly, most of the activities involved in the inquiry activities concern the processes by which the senses of sight and skin are transmitted to the brain, and name-based learning is conducted using other sensory organs.

There are 52 terms in the 'nervous system and hormones' sub-unit (Figure 5b). There are 28 terms that connect the inquiry activities and the main text, which include 'neuron', 'sensation', 'stimulus', 'sensory organ', and so on. Of these terms, many relate to maintaining blood sugar and diabetes in relation to the maintenance of homeostasis. Terms related to the difference in responses to moving to the cerebrum and spinal cord according to the type of stimulus are also presented. Meanwhile, 23 terms are only presented in the main text (e.g., 'adrenal gland', 'endocrine gland', 'adrenaline', 'testosterone', and so on), while 'ear' is only presented in the inquiry activities. The terms that are presented only in the main text feature aspects related to the brain, endocrine glands, and hormones. 'Ear', which is only presented in the inquiry activities, connects the main text and the inquiry activities via the 'sensory organ' sub-unit and does not overlap the text in the 'nervous system and hormones' sub-unit.

*'Reproduction and Genetics' Unit*

Regarding the 'Reproduction and genetics' unit, the 'reproduction' sub-unit mainly describes the relationship between cell division and growth and mitosis and meiosis. The 'heredity' sub-unit explains Mendelian inheritance, human genetic traits, and research methods of genetic traits using a genogram. There are 33 terms presented in the 'reproduction' sub-unit (Figure 6a). There are 16 terms that connect the inquiry activities and the main text, which include 'cell', 'reproduction', 'chromosome', 'somatic cell', 'fertilised egg', and so on. There are 17 terms that are presented only in the main text; for example, 'nucleus', 'oviduct', 'mother cell', 'heredity', and so on. The 'mitosis', 'meiosis', and 'cleavage' terms connect the inquiry activities and the main text, and the terms that are presented only in the main text correspond to reproductive organs; for example, 'oviduct', 'vas deferens', 'ovary', and 'testis'.


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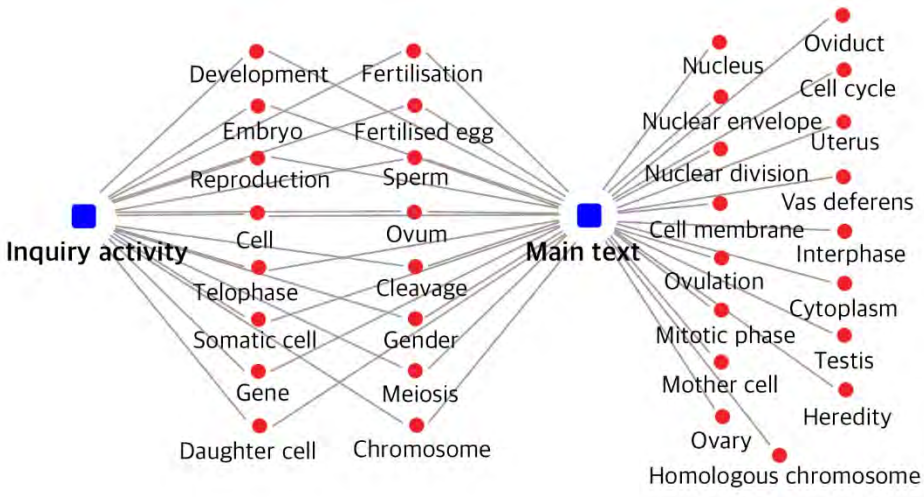
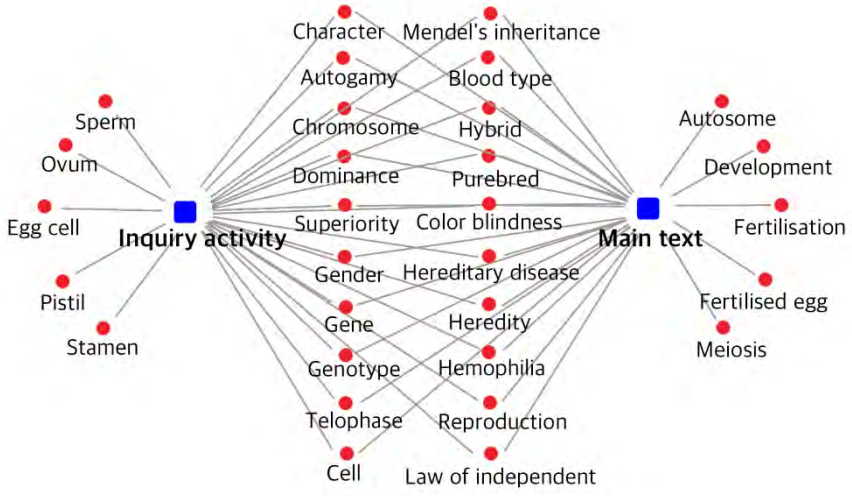
**Figure 6**
*The Connection Networks at the Sub-unit Level between the Terms Presented in the Inquiry Activities and the Main Text of the 'Reproduction and genetics' Unit*




*a. 'Reproduction' sub-unit*




*b. 'Heredity' sub-unit*

There are 30 terms in the 'heredity' sub-unit (Figure 6b). There are 20 terms that connect the inquiry activities and the main text, which include 'reproduction', 'Mendel's inheritance', 'character', 'dominance', 'gender', and so on. The terms that are presented only in the main text include 'autosome', 'development', 'fertilisation', 'fertilised egg', and 'meiosis'. The terms that are presented only in the inquiry activities include 'sperm', 'ovum', 'egg cell', 'pistil', and 'stamen'.

The terms that connect the inquiry activities and the main text relate to Mendelian inheritance, human genetic phenomena, and genetic diseases. The term that is only presented in the main text concerns the process of human genetic phenomena. Among the terms that are only presented in the inquiry activities, 'sperm' and 'ovum' connect the main text and inquiry activities in the 'heredity' sub-unit. Moreover, the terms of 'pistil' and 'stamen' are only presented in the inquiry activities, thus have already been taught to the related achievement standard (It is possible to explain the structure and function of roots, stems, leaves, and flowers through observation and experiments on the overall structure of plants) for the 3rd and 4th grades (Ministry of Education, 2015). Therefore, since 'pistil' and 'stamen' are already introduced via the structure of flowers, they are omitted from the main text in the 'Reproduction and genetics' unit.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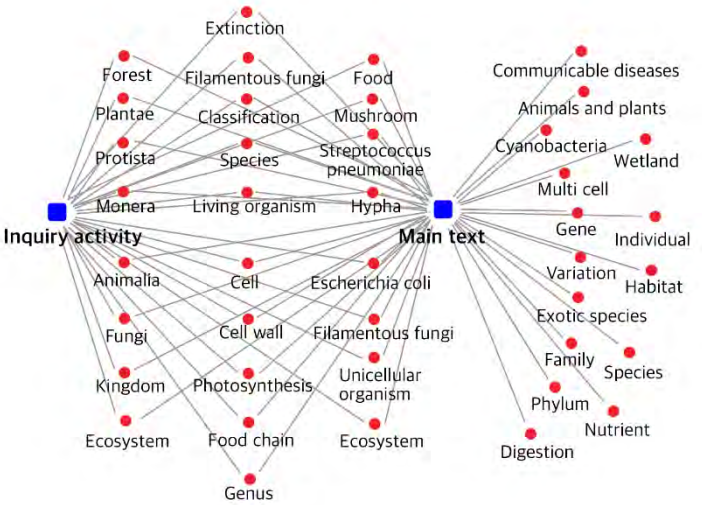
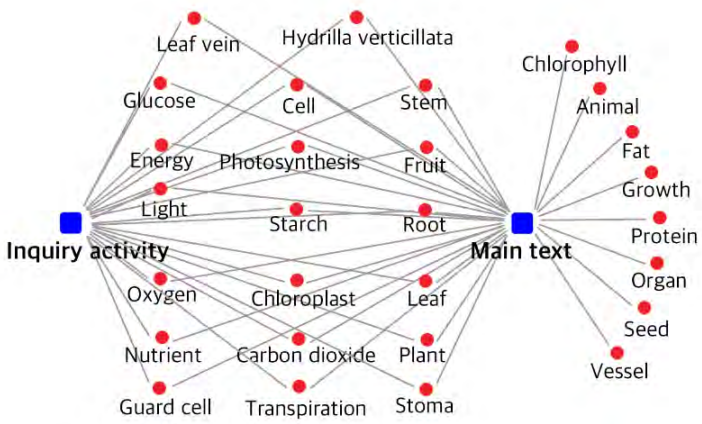
*The Connection Networks at the Unit Level*

This study then visualised the connection networks between the terms presented in the inquiry activities and the main text at the unit level (Figure 7). There are 38 terms in the 'Biodiversity' unit and 24 terms that connect the inquiry activities and the main text, which include 'living organism', 'photosynthesis', 'classification', 'forest', 'cells', and so on (Figure 7a). There are 14 terms that are presented only in the main text, for example, 'variation', 'digestion', 'wetland', 'species', 'individual', and so on.

**Figure 7**
*The Connection Networks at the Unit Level between the Terms Presented in the Inquiry Activities and the Main Text*




*a. 'Biodiversity' unit*




*b. 'Plants and energy' unit*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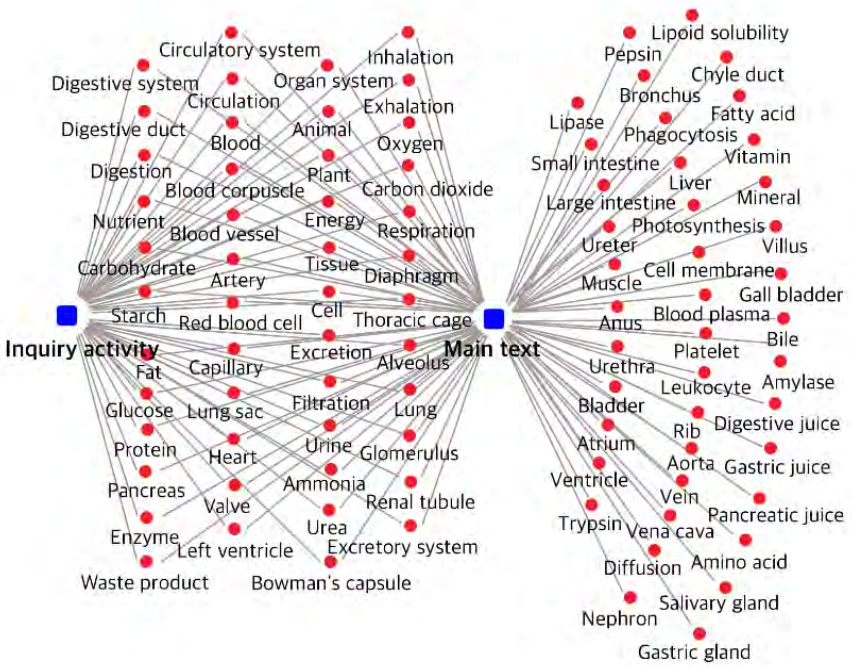
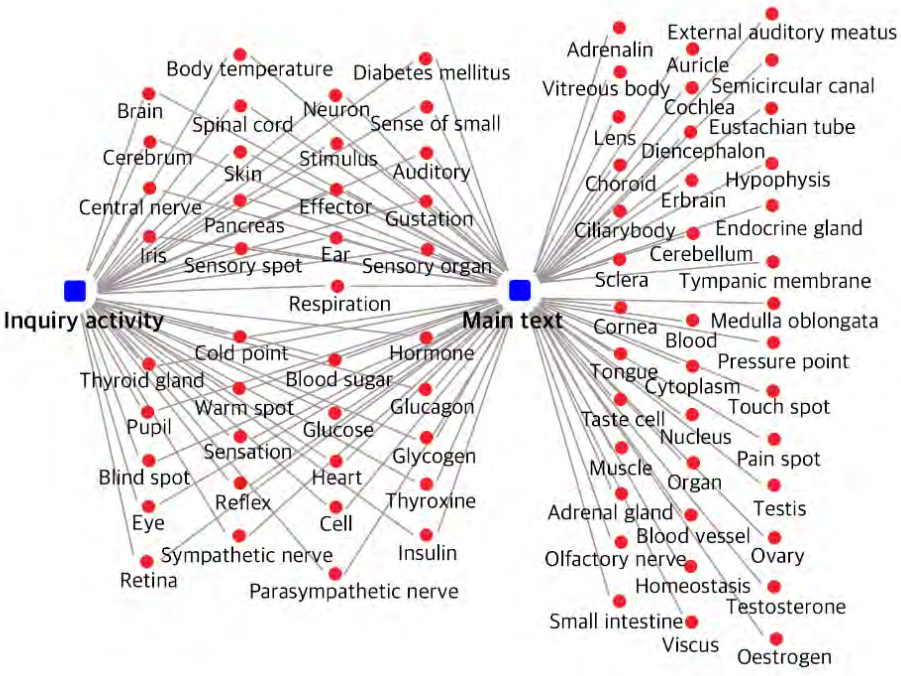



*c. 'Animals and energy' unit*




*d. 'Stimulus and response' unit*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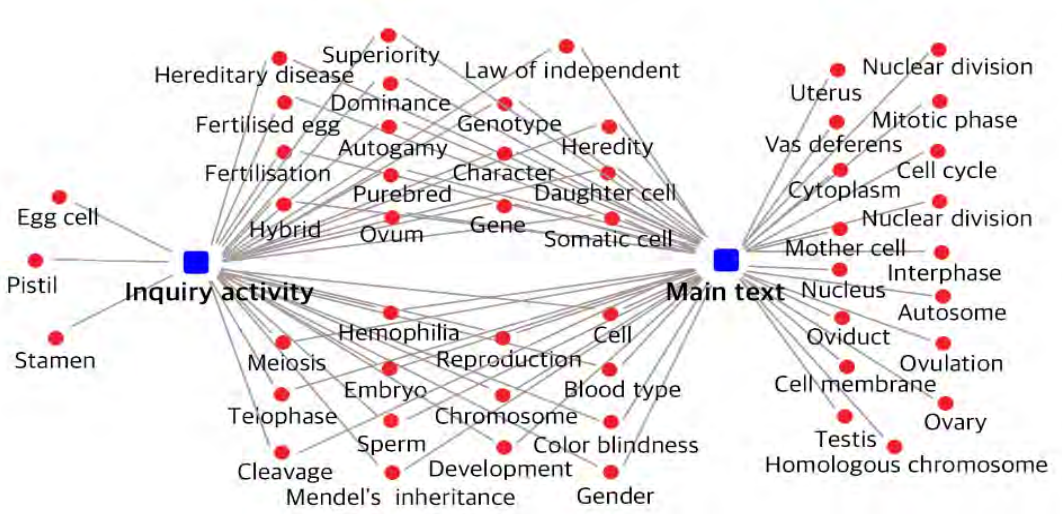


*e. 'Reproduction and genetics' unit*

There are 28 terms in the 'Plants and energy' unit and 20 terms that connect the inquiry activities and the main text, which include 'plant', 'photosynthesis', 'leaf', 'light', 'cell', and so on (Figure 7b). There are eight terms that are presented only in the main text, which include 'growth', 'vessel', 'organ', 'chlorophyll', 'seed', and so on.

There are 91 terms presented in the 'Animals and energy' unit and 49 terms that connect the inquiry activities and the main text, which include 'cell', 'respiration', 'tissue', 'circulation', 'blood', and so on (Figure 7c). There are 42 terms that are presented only in the main text, which include such as 'gastric juice', 'large intestine', 'blood plasma', 'vein', 'urethra', and so on.

There are 78 terms presented in the 'Stimulus and response' unit and 39 terms that connect the inquiry activities and the main text, which include 'sensory spot', 'neuron, 'stimulus', 'sensory organ', 'cell', and so on (Figure 7d). There are 39 terms that are presented only in the main text, which include 'endocrine gland', 'medulla oblongata', 'homeostasis', 'oestrogen', and so on.

Finally, there are 50 terms presented in the 'Reproduction and genetics' unit and 30 terms that connect the inquiry activities and the main text, which include 'gene', 'heredity', 'cell', 'reproduction, 'chromosome', 'somatic cell', and so on (Figure 7e). There are 17 terms that are presented only in the main text, which include 'nuclear division', 'mitotic phase', 'cytoplasm', 'interphase', 'autosome', and so on. The terms that are presented only in the inquiry activities include 'egg cell', 'pistil', and 'stamen'.

In sum, even at the unit level, the connections between the terms in the inquiry activities and the main text are generally well established. The main text includes all the terms presented in the inquiry activities alongside additional terms to help students' understanding. However, some units contain terms that are not presented in the main text but are included in the inquiry activities. Therefore, additional research on the terms presented only in the inquiry activities is needed.

## Discussion

This study analyses five life science units in the lower secondary school science textbooks in the Republic of Korea to assess the connections between the terms in the inquiry activities and the main text. The results reveal that many terms connect the inquiry activities and the main text; thus, the two can be considered well-connected, as the science textbooks consist of learning terms through inquiry activities and rearranging terms through the main text. However, some terms that are presented in the inquiry activities in the 'Reproduction and genetics' unit (e.g., 'egg cell', 'pistil', and 'stamen') are not presented in the main text; thus, they have no connection. In the cases in which terms are presented only in the inquiry activities and not in the main text, additional research is needed on how these instances affect students' acquisition of terms.


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On the other hand, as in the 'Animal and energy' and 'Stimulus and response' units, in the connection network at the sub-unit level, there are terms that are presented only in the inquiry activities without being connected to the main text, whereas in the connection network at the unit level, it is connected to the main text with other sub-units. Through this, it is thought that it would be more effective to learn by integrating into a unit rather than learning separately by sub-unit.

The terms presented in the main text and in the inquiry activities of science textbooks are presented without considering the hierarchy of concepts. As an example, terms such as 'root' and 'chlorophyll', which are presented only in the main text of the 'Plants and energy' unit, are recognized as terms with different order. Therefore, it is necessary to consider the order of terms when describing textbooks.

There are few inquiry activities related to social issues. The inquiry activities relate to social issues included in a survey of activities for biodiversity conversation, examples of activities for maintaining biodiversity, and investigations on hormone-related diseases. These inquiry activities occupy a very small proportion of the total 66 inquiry activities; thus, there are insufficient inquiry activities related to social issues. Life science content related to social issues can motivate students as well as interest in life science (Choi & Choi, 2003; Koh & Kim, 2016). Therefore, concrete, and practical inquiry activities and teaching-learning contents related to social issues should be developed and dealt with in the curriculum and textbooks.

In the future, students are expected to be able to apply and respond to various social issues or situations beyond the level of acquiring or understanding terms through learning (Griffin et al., 2012; Park, 2019). However, the inquiry activities presented in lower secondary school science textbooks in the Republic of Korea were insufficient for students' scientific participation and lifelong learning ability (Park, 2019). According to a previous study (Koh & Jeong, 2014), the lower secondary school is the most appropriate school level to develop these competencies based on the cognitive development level of students and the educational reality of the Republic of Korea. Therefore, the development process of the lower secondary school next science textbooks should include sufficient inquiry activities related to social issues, and the terms of the main text should reflect them.

## Conclusions and Suggestions

In the Republic of Korea, science textbooks help students to understand scientific terms through inquiry activities. However, there is a lack of analysis on whether the inquiry activities suggested in life science textbooks appropriately cover the terms included in the main text. Therefore, this study analyses the connection network connections between the terms presented in the inquiry activities and the main text in the life science textbooks issued in the 2015 revised curriculum in the Republic of Korea. The results confirmed that the terms presented in the inquiry activities and the main text in the life science textbooks were well connected. In most of the units, there were few terms that were not connected to the main text and were presented only in the inquiry activities. The unit with the terms presented only in the inquiry activities was the 'Reproduction and genetics' unit, and it was found that only the terms of 'egg cell', 'pistil', and 'stamen' were present.

And looking at the number of terms in terms of being connected to the main text and the inquiry activities, there were more terms being connected to the two domains than the terms presented only in the text of the textbook. This is common to all units. This means that through the main text in the textbook, it is possible to learn the terms learned in the inquiry activities and additional terms that were not presented in the inquiry activities.

However, there were differences in the number of terms presented in the text and the inquiry activities according to each life science unit. For example, the 'Plants and energy' unit had the fewest terms (e.g., 29 terms in the main text, 20 terms in the inquiry activities) while the 'Animals and energy' unit had the most terms (e.g., 106 terms in the main text, 49 in the inquiry activities). This difference in the number of terms could potentially result in the students being biased towards certain terms when learning each life science unit. Therefore, it is necessary to optimize the number of terms for each unit.

The results of this study can provide basic data for the future development of lower secondary school science textbooks. This study's limitation is that it used textbooks to analyse the scientific terms learning processes that occur in real school situations. Therefore, future research should analyse how the terms used in inquiry activities relate to the term learning that is conducted in real science classes.


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## Declaration of Interest

The authors declare no competing interest.

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CONNECTION OF TERMS BETWEEN INQUIRY ACTIVITIES AND THE MAIN TEXT IN THE LIFE SCIENCE UNIT OF LOWER SECONDARY SCHOOL TEXTBOOKS IN THE REPUBLIC OF KOREA
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## Appendix

*List of Inquiry Activities by Unit*

| Unit | Sub-unit | Inquiry activities |
|---|---|---|
| Biodiversity | Biodiversity | • Compare biodiversity.<br>• Compare the characteristics of clam shells.<br>• What are the reasons for the different appearance and characteristics of foxes? |
| | Classification of living organisms | • Classify creatures.<br>• Categorise different living things into order levels.*<br>• A species is a group of organisms with what characteristics?<br>• Which organisms belong to the prokaryotic, protist, and fungal kingdoms?<br>• How can we classify the living things around us? |
| | Conservation of biodiversity | • Discover the impact of sea otters on marine ecosystems.<br>• Investigate examples of activities to conserve biodiversity.*<br>• Discover why biodiversity is declining.<br>• Discover the benefits of biodiversity around you.<br>• What are some examples of activities to maintain biodiversity? |
| Plants and energy | Photosynthesis | • Explore the substances needed for photosynthesis.<br>• Explore the places and products of photosynthesis.*<br>• Environmental factors that affect photosynthesis.*<br>• Transpiration of water.<br>• Explore the relationship between water movement and transpiration.<br>• Observe guard cells.* |
| | Plant respiration | • Can you check the respiration of plants?<br>• Express the relationship between respiration and photosynthesis.<br>• Express the process of the production, storage, and use of nutrients made through photosynthesis. |
| Animals and energy | Digestion | • Compare plant and animal characteristics.<br>• Classify the organs that make up the organ system.<br>• Detect nutrients.*<br>• Experiment with saliva digestion.*<br>• How are nutrients digested? |
| | Circulation | • Investigate the structure of the heart.<br>• Observe blood.*<br>• Types and functions of blood vessels.<br>• Schematic representation of blood circulation paths. |
| | Respiration | • Observe a pig's lungs.<br>• Investigate the composition of inhalation and exhalation.<br>• How does gas exchange happen in the body?<br>• Investigate the principles of breathing. |
| | Excretion | • Express the process of excretion.<br>• How is urine produced? |
| | Relationships between organ systems | • Check the energy released by cellular respiration.<br>• Express how organ systems work together.<br>• Digestion, circulation, breathing, and excretion role-playing.* |



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| Unit | Sub-unit | Inquiry activities |
|---|---|---|
| Stimulus and response | Sensory organs | • How do we see objects?<br>• Experiment with vision.*<br>• How do we hear sound?<br>• How does it taste?<br>• Investigate the distribution of sensory points on the skin.<br>• Check your sense of equilibrium. |
| | Nervous system and hormones | • Create a neuron model.<br>• Create a model of the central nervous system.<br>• Investigate the structure and function of the brain using brain models.<br>• How does the response take place depending on the stimulus?<br>• How does the autonomic nervous system work depending on the situation?<br>• Experiment with responses to stimuli.*<br>• Investigate the thermoregulation process.<br>• How do hormones and the nervous system work differently?<br>• Simulate the blood sugar control process.<br>• Investigate hormonal-related diseases.* |
| Reproduction and heredity | Reproduction | • How do living things grow?<br>• Experiment with the relationship between cell surface area and volume.*<br>• Investigate the relationship between chromosomes and genes.<br>• Observe mitosis.*<br>• Compare mitosis and germ cell division.<br>• Express the process of development. |
| | Heredity | • Gene transfer process.<br>• Simulation and application of Mendel's principles of inheritance.<br>• Simulate genetic phenomena.*<br>• Interpretation of pedigree. |

*Note:* * Inquiry activities presented in the curriculum.

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