The Suitability and Characteristics Analysis of Key Science Inquiry Activities in the 2015 National Science Curriculum in Korea

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Abstract

The suitability and characteristics of middle school inquiry activities in the 2015 National Curriculum of Science in Korea were studied from the perspective of eight science teachers with rich experience in teaching science inquiry activities. In-depth interviews revealed problems teachers experienced while conducting inquiry classes. Problems were classified into five categories: inquiry level, method, tool, inquiry result, difficulty in guidance, and safety. Based on this analysis, strategies for an inquiry improvement plan are suggested, including that quantitative inquiry requiring
numerical interpretation of data obtained from the process of inquiry should be emphasized. Concrete guidance of inquiries should be provided for non-major science teachers to help them instruct inquiries more easily. Institutional improvement is needed to develop curriculum activities and the improvement of science lab and classroom environments are necessary for conducting inquiry activities utilizing technology. The results of this study can contribute to the development of science inquiry activity programs.

초록
본 연구는 2015 개정 중학교 과학 교육과정에 제시된 탐구의 현장 적절성과 특성을 탐구 수업 지도 경험이 풍부한 8인 과학 교사들의 시각을 바탕으로 연구하였다. 심층 인터뷰를 통해 탐구 수업 진행 과정에서 경험한 문제점이 드러났다. 문제점들은 탐구 수준, 방법, 도구, 탐구 결과, 지도의 어려움, 안전의 다섯 범주로 나누어 분석되었다. 분석 결과로, 탐구의 과정에서 발생하는 결과를 수리적으로 해석하는 정량적 탐구가 강화될 필요가 있다고 제안되었다. 둘째, 해당 영역 비전공 교사도 수월하게 이해할 수 있는 탐구지도 방법이 구체적으로 제시될 필요가 있다. 셋째, 탐구 과정 그 자체에 대한 경험을 강조하는 활동을 위한 제도적 인 개선과 과학기술 현장의 변화 방향과 변화 속도에 대응하는 탐구 활동 수행을 위한 학교 및 교실 환경의 개선이 필요하다. 본 연구의 결과는 과학교과 교육과정에서 제시하고 있는 역량의 중점은 지원하는 과학 탐구 활동 프로그램과 탐구 수업 방법의 개발에 기여할 수 있을 것이다.

Keywords
middle school science inquiry – 2015 Korean national science curriculum – inquiry improvement plan – teacher recognition

1 Introduction

As society becomes more complex and evolves rapidly, the purpose of education has shifted from knowledge to competency, as recognized by an increasing number of national curricula (OECD, 2003; Lee & Shon, 2019). The 2015 revised national curriculum in Korea (hereafter, the 2015 national science curriculum) includes five competencies in science subjects: scientific thinking, science inquiry, scientific problem-solving, scientific communication, and scientific participation and lifelong learning abilities. Students are guided to
develop these competencies through inquiry-based learning activities (MOE, 2015). Inquiry-based methods have been widely used by teachers in the context of science education (Lee & Shea, 2016; Yoon et al., 2013) and have long been utilized as a traditional pedagogical method involving students’ activity in the process of problem solving using their thinking skills (Buckner & Kim, 2014; Ellis & Bliuc, 2016). Colburn (2000) emphasized inquiry-based learning as creating a classroom environment in which students are engaged in open-ended, student-centered, and hands-on activities. The inquiry process starts from an authentic problem, followed by conceptualization to build up a hypothesis about the problem, an investigation to obtain data through experimentation, and, finally, discussion and conclusion, which covers interpreting and sharing the data (Pedaste et al., 2015).

The Korean national science standards have customarily included key (i.e., mandatory) inquiry in relevant subjects in an effort to lead teachers to utilize science inquiry actively in the classroom. The key inquiry section of the 2015 national science curriculum mandates implementation of core competency education in the classroom by including technology and data-driven methods such as AR/VR, cell phone apps, sensor-based measurement, and utilization of public data through the internet. These tools allow students access to data that are measured in real time and/or have an authentic context. Additionally, integrated science units were introduced in each grade of middle school in order for students to have experience in solving real-life problems through self-directed inquiry activities that incorporate competency-oriented activities such as data search, presentation, discussion, analysis of authentic real-time data, and so on (Park et al., 2019).

The concept of science in the 2015 curriculum may not differ much from the previous one, but the methods leading the relevant inquiry activities were new and unfamiliar to most teachers. The change in emphasis to include inquiry activities in the 2015 national science curriculum could cause teachers to have difficulties implementing the new activities. For example, utilization of new technology and data-driven inquiry involves barriers for teachers in general, and simultaneous implementation of such new approaches throughout the country could cause problems in the classroom. To understand these challenges, there have been several studies examining the suitability of the 2015 national science curriculum. Lee et al. (2020) found that while the curriculum did not change significantly in terms of form and content, the inquiry activities designed to cultivate competencies were not being well performed in the field. Jeong (2020) noticed difficulties faced by teachers in inquiry classes caused by the changes requiring teachers to utilize new technologies. Another study on middle school science teachers reported a contradictory result, noting
that the number of inquiry activities presented in the new textbooks were either insufficient or excessive (Joo et al., 2020). These studies indicate that the focus of core competency education utilizing new technology in the 2015 national science curriculum has not been properly implemented in schools. The utilization of new tools and new inquiry inevitably involves difficulties in the school field. This is not just a problem with science education in Korea, as the shift in education from knowledge to competencies is increasingly a global trend – more and more countries are emphasizing digital literacy and educational programs fostering future competency – all of which require integration of disciplines and the adoption of new technologies (Rönnebeck et al., 2018). Sooner or later, many countries will face the problems Korean science teachers are facing now.

The efficacy of inquiry-based learning depends on instruction with in-depth pedagogical content knowledge (Nhlengethwa et al., 2021). In this process, the teacher’s role is important for fostering critical thinking, cultivating students’ motivation to learn, guiding students to reach scientific concept understanding, and promoting problem-solving abilities (Tseng et al., 2013). Therefore, from the teacher’s point of view, it is necessary to identify in detail what kind of difficulties exist when conducting the classroom inquiry activities required by the 2015 national science curriculum. Analyzing the difficulties in each inquiry activity can lead to a classroom environment where better instruction and preparation for inquiry activity are possible. Therefore, this study aims to identify the challenges of the 2015 national science curriculum from the teachers’ perspective with a goal of sharing our findings so they may serve as a point of reference for researchers in other countries with similar educational environments that are seeking insights about the challenges of implementing technology-based and data-driven inquiry. The research questions framing this study are summarized as follows:

1. Which inquiry activities do experienced teachers in each grade level perceive as inappropriate?
2. Which criteria do teachers apply when they evaluate the suitability of the inquiry activities included in the textbooks?

2 Research Method

2.1 Structure of the 2015 Revised National Curriculum of Science in Korea

This section is intended to give insights on the science curriculum in Korea based on the 2015 national science curriculum. Once the curriculum revision was publicly announced, science textbooks were developed from 2016 and
new textbooks were implemented in all schools in Korea from 2017 until the present. In Korea, all textbook development is controlled and monitored by the Ministry of Education, so schools can only adopt and use approved textbooks. The 2015 national science curriculum covers science content on motion and energy, material, life, and earth and space, and provides achievement level descriptions for Grades 3 to 12. The curriculum also describes core competencies of science such as scientific thinking, inquiry ability, problem solving ability, scientific communication, participation, and life-long learning ability.

The 2015 national science curriculum for middle school includes 24 subject units for study. Each subject unit includes the content name, a description of subject, achievement standards, key inquiry topics, instruction methods, and evaluation targets (see Figure 1).

FIGURE 1  An example of an illustration of the structure of a subject unit in the Korean science curriculum
The key inquiry topics listed in the curriculum are regarded as mandatory in schools; hence, science textbooks must contain the required inquiry activities. For instance, the subject unit illustrated in Figure 1 lists four achievement standards and two key inquiry topics. Based on this content, science textbooks are required to contain at least two inquiry activities in the relevant subject unit.

In order to foster student competencies, the inquiry activities introduced in the textbooks developed for the 2015 curriculum were increased relative to the activities that appeared in textbooks developed for the 2009 curriculum. In addition, the textbooks for the 2015 curriculum included an increased focus on students’ self-driven inquiry participation. For example, the new curriculum includes a scientific communication competency designed to reinforce students’ involvement in searching and presentation and designing products to solve problems. Also, the number of inquiry activities focusing on problem recognition and variable control to help enhance students’ scientific inquiry abilities increased. However, inquiry activities asking students to draw conclusions based on observations were frequently found in the previous curriculum (Lim, 2018; Kim, 2019). So some aspects of the previous curriculum was unchanged in the revised curriculum, but overall, many changes were made.

Each achievement standard and key inquiry topics included corresponds to 2–3 hours of textbook content coverage in the classroom. While laboratory workbooks are not supplied to Korean middle schools, guides for inquiry activities are introduced that can be used in parallel with the textbooks. Each year, four textbooks are published for middle school science and teachers can select one textbook to adopt for their school. While different types of inquiry activities are presented in each textbook, all of these textbooks present the key inquiry topics addressed in the curriculum. For example, the inquiry topic exploring the relationship between the volume and temperature of gas was introduced using a quantitative measurement method in one textbook and a qualitative observation method with experimental data for students to analyze in a second textbook (see Figure 2). This variation between textbooks which offer teachers various approaches to inquiry activities in the classroom is beneficial in that teachers and schools have some choice about which book to adopt. However, if teachers are not properly prepared to use these textbooks, it can cause difficulties for teachers and students, which can discourage teachers’ use of inquiry-based instruction. Therefore, the field suitability of the inquiry activities in the current curriculum need to be analyzed from the perspective of teachers to understand what kind of suggestions would be helpful for developing the next curriculum revision.
2.2 Research Participants and Research Courses

This study was aimed at finding and categorizing problems that occurred during the application of key inquiry activities in schools in order to provide direction for the future development of inquiry experiments that are better suited for the real classroom context. Generally, teachers rely on the content in the textbooks adopted for use in their schools. As a result, they may not be aware of the kinds of inquiry activities that appear in other textbooks.

In Korea, teachers who have a long career in teaching are sometimes invited to take part in the development and writing of textbooks. In this study, we sought to invite research participants who could accurately grasp the problems of key inquiry activities that occur while teaching students. Teachers who have participated in the development and writing process for preparing new textbooks and inquiry guides are seen as having sufficient pedagogical knowledge about inquiry activities and believed to be able to give insights on inquiry experiments that could lead to developing textbooks and inquiry guides that are better suited for real classrooms. Science teachers with such experience, called leading science teachers, were invited as research participants. These leading science teachers participated in textbook analysis and engaged in interviews to share their insights.

Leading science teachers with rich experience in developing inquiry materials and writing science textbooks and science education materials, with more than 17 years teaching experience, and who have actively participated in teacher research associations for more than 10 years were selected to participate in this study (see Table 1). These teachers reported that they actively used
TABLE 1  Demographics of leading science teachers

<table>
<thead>
<tr>
<th>Code</th>
<th>Major</th>
<th>Teaching experience</th>
<th>Experience with inquiry-related materials</th>
<th>Grades taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Chemistry</td>
<td>17 years</td>
<td>Developed science inquiry materials</td>
<td>8, 9</td>
</tr>
<tr>
<td>B</td>
<td>Earth Science</td>
<td>20+ years</td>
<td>Wrote science textbooks for 2009 curriculum</td>
<td>7, 8</td>
</tr>
<tr>
<td>C</td>
<td>Physics</td>
<td>20+ years</td>
<td>Wrote science textbooks for 2009 curriculum</td>
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<td>7, 9</td>
</tr>
</tbody>
</table>

Science inquiry and experiments in 60% to 80% of their classes, they recognized the importance of inquiry classes, and they had a strong will to practice inquiry with students in the classroom.

2.3  Data Collection and Analysis
Since the total number of inquiry topics introduced in the 2015 national science curriculum is large, data collection was conducted in two phases between March to May 2021. The first data collection phase was conducted as a written survey asking about the field suitability of each inquiry topic, and the second phase involved interviews focusing on inappropriate inquiry topics. In survey, teachers were presented with items of key inquiry topics in the 2015 national science curriculum (see Appendix), and their responses were collected using a 4-point Likert scale to assess the degree to which the key inquiry activity was deemed appropriate for the achievement of science education goals and competency development. The survey material consisted of items asking teachers to consider the suitability of the application of each individual inquiry in the classroom, the suitability of achieving competency goals, and suggestions for the future direction of science inquiry curriculum revision.
In phase two of this study, the survey data was analyzed by the researchers and based on teacher responses, follow-up one-on-one phone interviews were developed to ask the reason for choosing certain inquiry activities as inappropriate. For example, some teachers found an inquiry activity about methods for efficient heat insulation to be inappropriate. The researchers reviewed this inquiry activity in all four textbooks and to compare how the content was introduced in each. Open-ended questions were developed to interrogate what aspects specifically the teachers found to be inappropriate and teachers were asked to provide suggestions for improvement to get insights into the inherent problems of the inappropriate inquiry activity. Three open-ended questions were asked in the interview:

Q1: Which inquiry activities in the 2015 National Curriculum of Science aimed at fostering students’ scientific competencies did you have difficulties in carrying out?

Q2: When you selected this inquiry activity as inappropriate, what was the reason for your selection: not suitable for the students’ level, difficult for non-major teachers, tools and facilities are not properly equipped, incorrect procedure, safety concerns, and so on.

Q3: New instruction methods such as simulation experiments, AR/VR labs, utilization of real-life data, and so on, have been introduced recently. Indicate to which inquiry activity such methods can be applied to foster scientific competencies.

Interviews took between 20–30 minutes and were conducted via phone due to highly restricted social distancing policies related to the COVID-19 pandemic. Additional questions were asked when further information was needed. For example, when teachers mentioned that certain activities would be difficult to carry out, follow-up questions were asked to identify which specific parts would cause difficulty. Teachers noted students’ insufficient knowledge of the content or inappropriate cognitive development, lack of necessary science equipment in class, and safety concerns as issues that made certain activities challenging for classroom implementation.

All interviews were recorded, transcribed, and cross-analyzed between researchers. Researchers established positive inter-rater reliability while independently coding the interview data to identify common themes about what kinds of inquiry activities were unsuitable and why. The data from phases one and two were sorted and re-organized by school grade and degree of teachers’ difficulty. During analysis, researchers focused on understanding why teachers chose certain activities as being inappropriate for helping students achieve competency goals and why teachers considered certain activities to be
unsuitable for the classroom. Examples of what teachers found to be unsuitable included, little to no student involvement is required, very simple student activities are required, answers can be found without performing experiments, and/or answers cannot be found through experiments, and the knowledge necessary is not appropriate for the students’ school level, which reduces students’ interest and only confirmed key concepts through experiment but not by stimulating students’ scientific thinking.

Researchers generated keywords to group and sub-group activities and identified challenges by grade level. For example, activities that were difficult to carry out were categorized as: not appropriate for students’ grade level, difficult for non-major teachers to instruct, insufficient tools and environment, inaccurate methods, and unsafe. These categories inductively defined by the researchers and evidence for these categories were identified in participant responses in both phases of data collection. After the researchers completed their analysis, results were shared with teacher participants as part of a member-checking process. Finally, suggestions for science inquiry improvements were coded with similar keywords and then re-categorized by finding common elements and grouping them into higher categories. The results and discussion are organized around these categories and described in the next section.

3 Results

A total of sixty-four inquiry topics were listed in the 2015 revised national science curriculum of Korea for the middle school grades. Among them, nine topics for Grade 7 were addressed as inappropriate by the leading science teachers, 16 topics for Grade 8, and six topics for Grade 9. Inquiry activities at each grade level were categorized into one of the following five categories: inquiry is not suitable for students’ grade level, inquiry is difficult for non-major teachers, inquiry requires tools and facilities that not accessible, inquiry process methods are incorrect, and inquiry presents a safety concern. These findings have been further organized by grade level and provide context for challenges teachers that are inappropriate for the grade level, inappropriate for the classroom learning environment, and inappropriate for the classroom technology capabilities. Following the presentation of the findings, we report on teachers’ suggestions for improvement of the curriculum materials.

3.1 Analysis of Grade 7 Inquiry Activities

3.1.1 Inquiry Is not Suitable for Students’ Grade Level

Inquiry activities that teachers found were not appropriate for the students’ grade level can be divided into two categories: inquiry activities that are
too simple to attract students’ interest or inquiry activities that are too difficult for students to perform and analyze. Some examples of activities that where too simple to attract students’ interest included those that explored the a) relationship between pressure and the volume of gases (Boyle’s law), b) relationship between temperature and the volume of gases (Charles’ law), and c) observing the phenomenon of when the state of matter changes.

These inquiries were also included in the 2009 curriculum and their instructional methods were little changed. Teachers felt that students’ interest would be greatly reduced because the inquiry process was presented as a cookbook-type experimental procedure. For example, all the textbooks introduced the Boyle’s law experiment by giving step-by-step procedures to simply follow, as shown in Figure 3.

Examples of inquiry activities which were too difficult for students to perform included an activity a) comparing the frictional force of an object on a slope and b) and activity observing the features of images using mirrors and lenses. In these cases, the gap between the actual phenomenon and the theory being described in the textbook, were deemed to be too difficult for students to understand and the non-major teachers to instruct. Other such examples taught at the middle school level included units examining motion that were taught with the assumption of no friction or air resistance. However, because these assumptions cannot be applied in inquiry practice in the classroom setting, results that students obtain from their experimentation is generally different from theoretical predictions, causing confusion for students. The inquiry activity in which students were asked to observe the features of images using mirrors and lenses inquiry was a simple observation, but teachers believed that students would have difficulty answering when asked about the image formation observed using the lenses and mirrors because the principle of image formation was beyond the curriculum of the middle school level.

**FIGURE 3** Inquiry activity on Boyle’s law as an example of cookbook-style procedures which reduce students’ interest
3.1.2 Inquiry Is Difficult for Non-Major Teachers
The teachers noted that science content covered in the grade 7 curriculum was not only challenging for students, but also for some teachers. In Korea, middle school science teachers major in one content area, such as, physics, chemistry, biology, or earth science while at university. However, once they are hired at middle schools, teachers are considered general science teachers and required to teach content in subjects outside of their majors. Teaching out of field was identified as a systemic problem that teachers face when carrying out science activities in the classroom. For example, exploring rock samples from national geoparks was identified as a challenging inquiry for non-earth science majors. In the unit on exploring rocks in national geoparks, the characteristics of rocks were not explained in clearly in the textbooks so teachers without a background in earth science had to access information from other sources.

3.1.3 Inquiry Process Methods Are Incorrect
Teachers found that the inquiry activities related to protecting biodiversity and exploring rocks in national geoparks were the most challenging. Some teachers mentioned that the activities for biodiversity conservation were not presented in a specific and systematic way in the textbooks. In an effort to foster competencies of scientific problem solving, communication, and life-long learning, the new textbooks dealt with the socio-cultural issues, such as biodiversity conservation, with the expectation that students would discuss this issue, express their suggested solutions, and participate in related practices. However, the guidance provided to students was so simple, such as “search information” and “make materials,” that the quality of instruction for the unit depended largely on individual teachers’ competencies. Due to this lack of information, teachers felt that non-major teachers would face difficulties in organizing this inquiry activity and would be unable to help students’ performance.

3.1.4 Inquiry Requires Tools and Facilities not Accessible
For the unit on rock exploration in national geoparks, textbooks introduced virtual reality (VR) activities as a new type of technology-based inquiry. Teachers felt this method could reduce non-major teachers’ burdens when observing rocks and would allow students to proactively investigate rocks. In addition, given the rich information geoparks have about rocks in different places, students could link the principles of rock generation to the geological features, which could improve their scientific thinking abilities. However, even by utilizing VR inquiry methods to explore national geoparks, teachers noted that because the internet infrastructure has not been fully established in most schools, students could not freely use VR content yet. As a result, it was
necessary for teachers to supply a guide for students, which presented a double challenge to non-major teachers who were not familiar with the content or the VR inquiry activities.

3.1.5 Inquiry Presents a Safety Concern
Examples of inquiry activities in grade 7 that were identified as unsafe included experiments using glassware and a heat source so that students could explore the relationship between changes in temperature and phase changes of matter. Teachers noted that seventh graders had little experience in using heat sources and glassware, so teachers needed to pay more attention needed to students, especially since this inquiry was scheduled at the beginning of the semester when teachers were still establishing classroom management norms. Table 2 summarizes the inquiry mentioned in Grade 7.

<table>
<thead>
<tr>
<th>Category</th>
<th>Experiment</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry not suitable for students' level</td>
<td>Frictional force inquiry using the slope of a bevel</td>
<td>This activity assumes non-zero friction between objects on a slope and assumes zero friction for other interactions, such as air resistance, causing a mismatch between theory and observation</td>
</tr>
<tr>
<td></td>
<td>Observing the features of images using mirrors and lenses</td>
<td>Principle of image formation is beyond grade level content as the concept has not yet been taught</td>
</tr>
<tr>
<td></td>
<td>Observing phenomena when the state of matter changes</td>
<td>Observation was guided as “cookbook-like” inquiry with fixed steps, reducing students' interest</td>
</tr>
<tr>
<td></td>
<td>Exploring the relationship between the pressure and volume of gases</td>
<td>Simple cookbook-like activity does not stimulate students' interest</td>
</tr>
<tr>
<td></td>
<td>Exploring the relationship between the temperature and volume of gases</td>
<td>Simple cookbook-like activity does not stimulate students' interest</td>
</tr>
</tbody>
</table>
3.2 Analysis of Grade 8 Inquiry Activities

The curriculum of Grade 8 contained more inappropriate inquiries than the other grades, and teachers’ critiques were evenly distributed among inquiry activities from biology, chemistry, physics, and earth science. However, teachers found that inquiry activities in biology and earth science were particularly difficult to apply in the context of schools.

3.2.1 Inquiry Is not Suitable for Students’ Grade Level

Examples of inquiry activities that were not suitable for the students’ grade level included a) finding an efficient method for thermal insulation and b) making a simple electric motor. Teachers’ critiques about how to instruct students to find an efficient thermal insulation method varied depending on the textbook used. In some cases, the activities were presented such that students had to compare insulation efficiency using only preselected items, while in other cases, open-ended inquiries encouraged students to engage in simple experiments to identify properties of insulators (Figure 4). Teachers recognized that the activity supplying preset items limited students’ opportunities for improving their inquiry abilities, such as problem-solving and designing trials that could cultivate problem-solving ability. Instead, too many constraints
were imposed that prohibited students’ free thinking and consequently did not meet the goal of improving students’ competencies in this area. Instead, teachers considered inquiry activities to be helpful when students’ freedom of choice for experimenting was included. In the case of making a simple electric motor, teachers noted the learning content was not presented sequentially, such that the activity of making a motor was presented first, which required students to make the motors without understanding the relevant principles and procedures. In this case, scientific inquiry could cultivate students’ scientific thinking abilities, but without first providing the necessary science concepts and theories, teachers questioned whether the inquiry-related competencies could be improved.

There are ways to draw conclusions or list examples without explaining principles or theories or performing experiments, which sometimes causes difficulties when guiding inquiry activities. Especially in the absence of theory or introductory explanations about the force being exerted by the current flowing through a wire, [students] can build a simple motor without fully, fully understanding the relevant principles. The inquiry activity of simply making an electric motor serves only to make students interested.

Interview, Teacher E

3.2.2 Inquiry Is Difficult for Non-Major Teachers

Teachers identified several earth science content related inquiry activities, including using a telescope to observe sunspots, the moon, and the planets, as being difficult for non-earth science major teachers to instruct. They stated
that it was time-consuming to construct a telescope and conduct an exploration with a large group of students, and for the sunspots activity, teachers noted it was not actually possible to observe the sun with a regular telescope due of safety risks.

Honestly, I think it would be hard to handle a telescope unless [you] majored in earth science. Unlike the microscope, it’s sort of complicated. It’s hard to prepare because it’s big, in addition, the price is not cheap. Also I’m worried that students will touch it carelessly once I give it to them. And I’m hesitant because observations are influenced by the weather and hence, I may not be able to proceed with the class as planned. I’m worried that students might get hurt while observing the black spots of Sun. Therefore, I don’t usually do this part, and I tend to just show the pictures and move on.

Interview, Teacher F

3.2.3 Inquiry Requires Tools and Facilities not Accessible

Experienced teachers perceived that the tools and facilities for this inquiry were not appropriate. In general, teachers noted that schools did not have enough telescopes for students to use for explorations involving astronomical observations. Other problems identified, included that schools located in cities did not have rooftops and the many tall apartments nearby would obstruct the view. In addition, there was competition with physical education courses for scheduling use of the playground for conducting these observations. While teachers agreed that experiencing various types of inquiry is helpful for improving students’ inquiry abilities and scientific thinking competencies – they noted that if inquiry activities are created without considering the real school learning environment context, then implementation would not be possible. Instead, teachers would need to have students rely on memorization of the learning outcomes related to different inquiry activities so that students achieve the learning goals covered on the assessments.

Teachers found that inquiry activities involving analyzing and expressing data about natural phenomena can also cause difficulties in terms of tools and facilities. Investigation and presentation of data related to water resources, interpretation of real-time data on tidal phenomena, and investigation of disasters were all activities that required wireless internet and tablets, making it difficult for these inquiry activities to be performed.

I don't think it's easy to do research at school. There aren't many science rooms with Wi-Fi installed yet, and if you give a tablet to each group,
honestly there are students who play with it [the tablet]. However, if I download and give the data in advance while doing real-time data interpretation activities, this is not real-time data for students. It feels like the teacher processed it. School environment should be provided with that tablets are distributed individually and where access of Wi-Fi is more easily allowed.

Interview, Teacher A

3.2.4 Inquiry Process Methods Are Incorrect

The 2015 revised national science curriculum includes many inquiry activities that allow students to utilize real and authentic data and to analyze and present data in order to foster competencies related to scientific inquiry and communication skills. However, as expressed in Teacher A’s comments, real and authentic data are not generally organized well enough for students to deal with. As a result, data analysis can become the job of the teacher, which can be a burden as they need to complete the task and work to involve students in data analysis activities too. A teacher described an example challenge from an inquiry activity in which the experimental data students obtained from a biology experiment related to photosynthesis was different from the data provided in the textbook. The classroom activity related to the detection of nutrients during digestion had to be conducted in a short period of time, so the observed results were different from the expected. As a result, the students tended to believe that they were wrong or had had difficulties in their analysis. This undermined the students’ confidence for engaging in inquiry activities. Another example involved the use of small-scale exploratory experiments, such as measuring the vertical temperature distribution of seawater, which is intended to generate results that can be compared to data collected from research on large-scale phenomena, such as air and ocean currents.

Most inquiry activities in middle school give clear data, which are confirmed by the relevant theories and concepts. However, in the real-world scientists have unclear results and their research methods need to be modified through discussion so they can obtain better results in the future. In order to cultivate similar problem-solving abilities, textbook authors have attempted to develop activities that require problem solving using incomplete data with the aim of coming up with improved inquiry methods. However, in this example, students’ inaccurate results complicated the comparison and prevented students from forming the proper concepts. In this case, teachers noted that interpreting data that had actually been measured in the ocean would be more
scientifically accurate and pedagogically useful. It is important to note that the same kinds of activities were included in the 2009 curriculum and have been identified as problematic, but they continue to appear in the 2015 curriculum due to a lack of alternative solutions.

Another example teachers identified as having inaccurate experimental methods included a role-playing inquiry focused on the relationship between digestion, circulation, respiration, and excretion. While teachers agreed it was a valuable investigation for helping students confirm the connections between digestion, circulation, respiration, and excretion, it was difficult to proceed with the inquiry activity because no instructions were given on how to guide the students. In the case of role-play, even though it can be effective in helping students to understand subject knowledge, it was not easy to teach them how to find the difference between analogy and reality on their own. As a result, teachers found the educational impact of the activity was insignificant compared to the effort teachers had to put into managing the activity.

Teachers found that inquiry activities that required specialized equipment for collecting and organizing real-time data was difficult to implement and it was not easy to teach students to interpret real-time data. For example, teachers noted an activity that required students handle power supplies to explore the relationship between resistance, current, and voltage was especially challenging as the teacher and student textbooks provided no explanation about the parts and functions of a basic power-supply kit. As a result, it was difficult for teachers to help students to derive an accurate relationship between resistance, current, and voltage with this inquiry activity.

3.2.5 Inquiry Presents a Safety Concern
Teachers also identified activities that presented safety concerns. One example included an activity in which students were comparing the specific heat of two objects using oil as a reference object. Teachers were concerned about the potential for accidents, but they also reasoned that not all experiments can be replaced with virtual experiments or completely be avoided. Because teachers felt that handling tools was pedagogically important, they noted that simply finding an inquiry activity to be inappropriate did not mean the activity was not worthy of being done. Instead, teachers commented it was necessary to find safe alternatives and more proper methods for engaging in these inquiries. Table 3 summarizes the inquiries mentioned in Grade 8.
<table>
<thead>
<tr>
<th>Category</th>
<th>Experiment</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry not suitable for students' level</td>
<td>Finding efficient thermal insulation methods</td>
<td>Using the preselected items did not successfully improve the inquiry ability</td>
</tr>
<tr>
<td></td>
<td>Making simple electric motors</td>
<td>Performing the process before learning the relevant principles has a limited effect on inquiry ability improvement</td>
</tr>
<tr>
<td></td>
<td>Comparing the specific heat of two objects</td>
<td>Simply comparing the specific heats of two materials does not include scientific thinking</td>
</tr>
<tr>
<td>Difficult experiments for non-major teachers</td>
<td>Telescope observation of sunspots, the moon, and the planets</td>
<td>Handling a telescope is difficult for non-major teachers and also observation of sunspots is dangerous</td>
</tr>
<tr>
<td>Inquiries for which tools and facilities are not adequate</td>
<td>Investigating and presented data related to water resources</td>
<td>Not-enough training on searching and interpreting and presenting real data</td>
</tr>
<tr>
<td></td>
<td>Interpreting real-time data on tidal phenomena on Korean coasts</td>
<td>Not enough training on searching, interpreting, and presenting real data</td>
</tr>
<tr>
<td></td>
<td>Investigating disaster cases</td>
<td>Not enough training on searching, interpreting, and presenting real data</td>
</tr>
<tr>
<td></td>
<td>Telescope observation of sunspots, the moon, and the planets</td>
<td>Telescopes are not readily available enough at schools</td>
</tr>
<tr>
<td>Inquiries where processing methods are incorrect</td>
<td>Detecting nutrients</td>
<td>The results of an experiment do not clearly confirm a concept or theory</td>
</tr>
<tr>
<td></td>
<td>Digestion experiments</td>
<td>Obtained results are different from those supplied in textbooks</td>
</tr>
</tbody>
</table>
3.3 Analysis of Grade 9 Inquiry Activities

Inquiry activities developed for 2015 national science curriculum were first applied to Grade 9 classes in 2020 when the COVID-19 pandemic limited in-person activities for most of the school year. In Korea, the new school year begins each March, which is when the first social distancing measures first closed schools. As a result, teachers’ experiences with the inquiry activities for Grade 9 were conducted in an online format. Thus, for this grade level, it was necessary to interpret the results in terms of what activities could be implemented. As a result, this section only identified challenges in three of the five sections and does not include challenges related to non-majors and safety concerns.

3.3.1 Inquiry Is not Suitable for Students’ Grade Level

Teachers identified activities like a) creating a simple cooling device using chemical reactions; b) testing the expansion of the universe with sticker-attached
balloons, and c) interpreting family tree data using only one or two phenotypes as being too simple and not suitable for the students. These experiments require simple observations or a simulation of events, and the teachers anticipated that experiments for Grade 9 students should demand higher level skills and content knowledge. Creating a simple cooling device using chemical reactions was not suitable because it did not involve students in manipulating variables, but rather simply observing phenomena. Even though teachers felt the meaning of the activity was important, having students simulate the expansion of the universe with sticker-attached balloons was too simple. An activity that asked students to interpret family tree data by simply analyzing one or two gene phenotypes rather than collecting their own data was too simple and simply replicated other standard problems in the textbooks. Teachers felt the level of inquiry needed to match the level of science concepts being studied. But there were all too simple. Interesting, unlike at the other grade levels, teachers did not identify any activities that were above the cognitive level of the Grade 9 students.

3.3.2 Inquiry Requires too much Preparation
Teachers identified a new challenge in the Grade 9 textbook as there was an inquiry activity that required a lot of time to prepare. Teachers were frustrated by the lack of information about the time required for the inquiry activity to be completed. As most science classes take place in a 45-minute period, teachers felt that inquiry activities should be designed with this in mind. Teachers identified an activity that asked students to explore the relationship between the surface area and volume of a cell by having students consider how much time it would take for a cell with a large surface area to absorb pigments. This activity had no set end-time but suggested 2–3 days was needed, so teachers felt these kinds of activities were inappropriate due to time constraints.

3.3.3 Inquiry Requires Tools and Facilities not Accessible
As mentioned, in Grades 7 and 8 teachers identified not having the appropriate experimental tools or facilities as being a serious challenge to inquiry activities. Teachers noted that activities that require wireless internet and mobile devices such as tablets in the science labs and classrooms are challenging. Teachers identified an activity in which students were asked to search for cases of science and technology contributing to society (see Figure 5), however students they had difficulties in accessing searching tools in the classrooms due to lack of resources.

Another example included an activity in which students were asked to make a comparison of the relationship between time and velocity changes
of various objects with different masses in free-fall movement using a smartphone application. However, the application was not free for students to access and it should not be assumed that all students have smartphones or access to wi-fi for downloading the application. Teachers noted that even if devices were available to all students, it was not easy to install all the applications and to explain how to use the applications as part of the lesson. The teacher needed to learn how to use the application in advance to be able to show students, so this was also a challenge. Table 4 summarizes the inquiries mentioned in Grade 9 science.

![Figure 5: A case of inquiry activity on science and technology contributing to society](image)

**TABLE 4**  Inquiry with difficulties in field implementation (Grade 9)

<table>
<thead>
<tr>
<th>Category</th>
<th>Experiment</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry not suitable for students' level</td>
<td>Creating a simple cooling device using chemical reactions</td>
<td>Students’ activity should be at a higher cognitive level than simple observation</td>
</tr>
<tr>
<td></td>
<td>Testing the expansion of the universe with sticker-attached balloons</td>
<td>Students’ activity should be at a higher cognitive level than simple observation</td>
</tr>
<tr>
<td></td>
<td>Interpreting family tree data</td>
<td>Determining the gene type of a blood type is too simple for Grade 9</td>
</tr>
<tr>
<td>Experiment preparation takes too much time</td>
<td>Performing an experiment on the relationship between the surface area and volume of cells</td>
<td>Dye absorption into cells takes too much time (2–3 days)</td>
</tr>
</tbody>
</table>
4 Suggestions for Directions for Improvement

In this section, we share teachers’ suggestions for improvement that were gleamed from our analysis of teachers’ perceptions of the challenges associated with implementing inquiry activities from the grades 7, 8 and 9 science curriculum textbooks.

4.1 Suggestions for Making Inquiry Suitable for Students’ Grade Level

Teachers perceived that there was a gap between the cognitive level of students and the level of inquiry presented in textbooks and so teachers suggested the need to measure and better align the cognitive levels and science inquiry abilities of students by grade. Presently, some experiments were found to be too simple for middle school students to perform and some inquiries were not suitable for fostering inquiry skills because they presented the entire inquiry process using a cookbook-like process. One suggestion was to develop more self-directed inquiry activities that can strengthen the inquiry ability of students. Teachers also mentioned students need more opportunities to generate real data through their own inquiry and to compare and discuss the reasons for experimental differences. Teachers believed it would be more effective to avoid simple cookbook-like data confirming investigations and to instead conduct inquiries using actual deductive and inductive inquiry processes.

Most of the experiments presented in middle school only make qualitative comparisons. Students’ feel easy to learn Charles’s and Boyle’s laws experiments because they are asked to observe phenomena qualitatively.
I think that science is basically about expressing a phenomena numerically and understanding its principles through it [numerically], but when conducting an experiment phenomenologically in middle school, there are problems. So maybe that’s why students find science more difficult when they go to high school? Measuring numbers does not make the experiment difficult.

Interview, Teacher H

4.2 Suggestions for Supporting Inquiry that Is Difficult for Non-Major Teachers

An in-depth study focused identifying the cognitive level of middle school students and the appropriate science content to be emphasized in the curriculum that makes connections between elementary, middle, and high school should be the most fundamental base for determining the content to be learned by students and to be taught by teachers. Teacher education programs for middle years teachers need to provide more appropriate content knowledge for middle years school science. In addition, teachers need more training about how to instruct students to engage in grade-level appropriate inquiry and more teacher resources are needed. Teachers noted that even if appropriate hardware was available, students’ successful acceptance of these new activities would depend on the way the teachers conducted their classes. Most teachers have not had experience learning using inquiry and they do not feel comfortable implementing these activities in their classroom. Teachers noted that the inquiry guidance presented in textbooks or teachers’ guides is very simple, and the 2015 national science curriculum did not emphasize training for middle school teachers for science inquiry.

A study by Joo et al. (2020) found that middle school teachers’ agreement about the amount of time that should be spent using inquiry in the classroom varied greatly. While the majority of teachers thought the amount was appropriate, considerable opinions were that it was insufficient or excessive. These responses indicate that not all teachers are sufficiently reflecting the intent of the curriculum in their classes (Lee et al., 2020; Kim & Na, 2017). This was also pointed out by teachers who felt that for all students to have access to a similar quality of inquiry activities, teachers needed support to faithfully guide students. They advocated that more teacher feedback be solicited to understand what was needed for improvement.

The teacher’s feedback is important in the process of inducing in-depth understanding in a simple inquiry, but in the process of doing this, there
are many difficulties due to the teacher’s lack of experience and the large number of students.

Interview, Teacher E

In addition to various types of detailed instructional materials, teachers noted that institutional measures such as expanding teacher training about inquiry instruction for non-major teachers, reducing the number of students in classrooms, and supporting teachers to be able to teach using inquiry by instructing them in teacher education courses using inquiry would all be beneficial.

4.3 Suggestions for Making Inquiry Requires Tools and Facilities more Accessible

Teachers need more instruction about how to engage students in inquiry that uses real-time data collection, use of AR-based inquiries, and inquiries focused on data searching. Currently school facilities and teaching and learning methods have not yet been properly prepared to support these kinds of activities. In order to minimize such difficulties, basic instruction should be given to students to perform inquiry activities using new advanced tools, and teachers should be required to set a proper time plan to guide such inquiry activities (Davies et al., 2020). Teachers need support to know how to instruct students to engage in inquiry activities using real-time data collected from various research institutes, for instance, the Korea Meteorological Administration, and that emphasize data searching with the internet. While new inquiry methods are increasingly possible due to the development of AR-based science inquiry tools (Son et al., 2018; Jeong & Son, 2020), the expansion of the school-based internet networks, and the supply of portable devices such as tablets. However, many teachers were of the opinion that schools still lacked appropriate environments to facilitate such inquiries. Teachers noted that middle schools did not receive sufficient budget support from the government compared to high schools, so science inquiry in the middle schools has not really changed. Improving the facilities of schools so teachers and students can properly new tools is required.

4.4 Inquiry Process Methods Are Incorrect

Teachers found that many inquiry activities are still described in a way that emphasizes the outcome rather than the process of inquiry. For example, students are encouraged in activities to conduct observations in order to draw conclusions about what is happening, but at the end of the activity, if students’ observations differ from the results presented in the textbook, students are just instructed to go by the results in the book. For example, if the observed color
of a digestive enzyme reaction or the flame color of metal elements does not match with the photo materials presented in textbooks, students might believe that their inquiry results were incorrectly performed (Jeong et al., 2016). Scientists go through iterative processes of revised and repeated experiments if different results are obtained than expected. However, when the results of the inquiry are already presented in the textbook and the results are different, there is not enough time to think about the reason or try again.

In addition, when an inquiry activity such as plant respiration experiments or observing the moon or sunspots take a long time and cannot be completed within 45 minutes, teachers conduct the inquiry in advance and share the results of the inquiry with students to discuss as a whole class. School inquiry activities that only confirm the correct answers do not contribute significantly to cultivating scientific thinking, problem-solving, and inquiry abilities (Germann et al., 1996; Bell et al., 2003). Thus, it is necessary to emphasize the inquiry process in textbook descriptions and to reform these descriptions so that experimental results are not presented as the “answers” in textbooks. Teachers proposed that as the existing inquiry activities tended to be carried out as a process of finding an answer in a short time, the inquiry process should be emphasized rather than the inquiry results. In addition, teachers argued that students need to experience inquiry processes by using methods that promote autonomous inquiry and project-based inquiry.

I would like to include experimental inquiry processes that allow [students] to attempt project-type inquiries. The process of establishing a hypothesis and completing an inquiry to confirm the hypothesis can only be done in science, but most activities in the 2015 curriculum are similar to the inquiry process of social studies.

Interview, Teacher A

Expanding the practical inquiry experiences to focus on the process through which the accuracy and validity of science activities is established can help students to understand the value and nature of science. Finally, institutional support that provides block time scheduling of science classes, that increase the number of class hours for science, and that develop student-centered inquiry textbooks for middle school science are necessary.

4.5 Inquiry Process Methods that Consider Safety

Teachers noted that while only some inquiry activities were deemed inappropriate due to safety concerns, the overall science inquiry experience of middle school students would be improved with more resources to source better
laboratory facilities with more safety features. In addition, teachers could be better prepared to address lab safety concerns by having more opportunities to experience laboratory activities as students at university and having more focused training and professional development about how to guide students to safely engage in their own inquiry activities.

5 Conclusions and Implications

This study explored teachers’ analysis of and perceptions about all the inquiry activities presented in the textbooks developed for the 2015 revised national science curriculum for Korean middle school grades 7, 8, and 9 and drew improvement plans based on teachers’ responses. Problems experienced by teachers during inquiry instruction were analyzed by dividing them into several categories, such as inquiry level, methods, tools, inquiry results, difficulty in guidance, and safety. This study found it is necessary to consider how to improve inquiry activities so that activities suitable for the middle school level can be achieved, beyond the basic activities that elementary school students often do. In this section, we offer some content specific conclusions drawn from analysis of activities across each grade level.

5.1 Content Specific Planning for Inquiry Activities Is Needed

When examining each content area across all grade levels, researchers found that chemistry inquiry activities focused almost solely on observing reactions. Students had limited opportunities to conduct other chemistry related activities. Researchers found that teachers felt many physics related topics were not suitable for inquiry activities at the middle school level because many factors made it difficult for students to effectively obtain and interpret experimental results. For this reason, simulation experiments or virtual experiments were preferred. In addition, since scientific knowledge related to electromagnetics or optics was not presented hierarchically in the curriculum, students could not properly answer the questions related to the inquiry and could not interpret the experimental results. So teachers recommended that content be spiraled within the curriculum and mapped to make sure students have the background knowledge necessary to successfully participate in the inquiry activities.

In the field of earth science, the most prominent opinion of teachers was that experimental tools, such as the telescope, and content related to teaching about the environment were insufficient. Despite the emphasis on inquiry activities using real data, it was still difficult to apply in the classroom because teachers did not have access to required items, such as tablets and wireless...
internet service. Finally, teachers found it was difficult to guide inquiry activities related to biology content due to the inaccuracy of the experimental methods and results presented in the textbooks. Experimental results often did not match the textbook content. In addition, the teachers’ guides and textbooks do not provide sufficient guidance information to support teachers to engage students in activities like role-playing, which were often used in biology related activities.

5.2 Implications for Improving Inquiry Activities in the Middle School

Teachers found there was a gap between the cognitive level of students and the level of inquiry presented in textbooks. Therefore, research is required so that the cognitive level of students is reflected in textbooks or curriculum. Second, newly introduced forms of inquiry, such as real-time data exploration, AR-based inquiry, and data research inquiry were challenging to implement in real classrooms because the school facilities and teaching and learning methods were not properly provided. Therefore, facilities that support teachers to use these inquiry methods should be provided, and various support measures for guiding students to use certain methods, like AR-based inquiries, are required. Third, there were many inquiry activities that emphasized the outcomes rather than the process of inquiry. It is therefore necessary to conduct block classes or reinforce project classes to emphasize the process, going beyond evaluation and teaching that emphasizes the results of inquiry, and to provide students enough time to conduct research. To support this type of inquiry, training programs for teachers and specific inquiry guidance materials for teachers and inquiry materials for students need to be developed.

5.3 Implications for Improving Science Teacher Preparation and Research

It is necessary to study different instructional methods for competency-oriented inquiry activities than the one that are traditionally used. Inquiry elements or tools such as searching data, arrangement of data, expression, presentation, simulation, AR/VR experiments were newly introduced and emphasized in the 2015 revised national science curriculum. However, because teachers were not familiar with and had not trained to use these tools, they might not be able to effectively implement these tools as part of their inquiry instruction. The types of science inquiry that students have performed in the past have changed. In the past, hypothesis and deductive inquiry activities prevailed; however, new types of inquiry activities that utilize authentic data sourced from various environment sensors, such as temperature, humidity, pressure, and so forth, can help students to perform problem-solving processes without starting from
making a hypothesis. Also, inquiry activities utilizing technologies such as simulation experiments and AR/VR-based experiments inherently set hypotheses and control experiments during program development; therefore, students’ involvement starts from data analysis.

Considering such changes in inquiry types, further studies to increase field applicability and to not lose the essence of inquiry are necessary to foster students’ competencies in science. Additionally, there is a demand for research on the specification of inquiry skills that match the cognitive level of students. Even though the levels of inquiry skills are presented at each school level in some countries, in the current science curriculum of Korea, the level of inquiry skills is not specified and only types of skills are listed from Grades 3 to 10. Levels of concepts that are on students’ cognitive levels have been rather well specified by many studies, but levels of inquiry have not been specified. Therefore, levels of inquiry differ from textbook to textbook, do not fit students’ cognitive levels, and do not match with levels of concepts, all of which cause difficulties when learning through inquiry.

In particular, inquiry skills based on students’ age need to be standardized with consideration of the goals of the education system and the qualifications of the teachers. Otherwise, changes in the national standards may not be welcomed by teachers and will also fail to effectively foster inquiry-based instruction. Furthermore, the targeted goal for being proficient at a specific scientific skill (like classifying or observing) can be different depending on the age of the student and even for the scientific concept to which the skill is being applied. Students can experience different difficulties for the same skill depending on the concept being explored. For example, when modeling skills are applied to science classes in middle school, students may feel that models in earth science are easier than models in chemistry since the former can be found in real life and are observable.

5.4 Limitations of Study

In conclusion, this study analyzed the field applicability of individual key inquiry activities in the 2015 revised national science curriculum by collecting the perspectives of leading science teachers. The applicability of detailed individual inquiries to the field was identified from their perspectives rather than from a survey on the perceptions of a general population of teachers, and the features of inquiries and improvement measures were derived based on this. However, due to the generalization issue of the opinions of a small number of leading science teachers and due to the COVID-19 pandemic situation, there is a limitation that only a part of the inquiry activities of Grade 9 could be included. While examining all science inquiry in the 2015 revised national
science curriculum as a whole, it is meaningful that problems that have arisen in conducting inquiry classes in the real world were identified from teachers’ perspectives and that improvement plans were derived from teachers’ recommendations. Based on this study, it is necessary to identify the points to be considered when developing materials for science inquiry included in the curriculum and to conduct further research on practical inquiry experiments that can cultivate the science inquiry ability of students.

**Abbreviations**

AR  Augmented Reality  
VR  Virtual Reality

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**Ethical Considerations**

The data collected from this project were obtained with the necessary clearance from the participants involved in the study. The names of the participants are not used in this study.

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References


## Appendix

### The Items of Key Inquiry Topics for Middle School in the 2015 Science Curriculum

<table>
<thead>
<tr>
<th>Grade 7</th>
<th>Grade 8</th>
<th>Grade 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td><strong>Topic</strong></td>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>Change in Earth</td>
<td>Making a model of Earth's internal structure</td>
<td>Composition of matter</td>
</tr>
<tr>
<td></td>
<td>Observing properties of minerals and classifying rocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investigating rocks in the national geological parks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Understanding volcanic and seismic zones</td>
<td></td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td>Various forces</td>
<td>Weighing objects with a spring</td>
<td>Electricity and magnetism</td>
</tr>
<tr>
<td></td>
<td>Frictional force of an object using an inclined plane with different slopes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measuring buoyancy of an object in liquid</td>
<td></td>
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</tr>
<tr>
<td>Grade 7</td>
<td>Grade 8</td>
<td>Grade 9</td>
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<tr>
<td>--------</td>
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</tr>
<tr>
<td><strong>Unit</strong></td>
<td><strong>Topic</strong></td>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td><strong>Bio-diversity</strong></td>
<td>Classifying organisms at the system level</td>
<td>Solar system</td>
</tr>
<tr>
<td></td>
<td>Finding activities to conserve biodiversity</td>
<td></td>
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<tr>
<td><strong>Properties of gases</strong></td>
<td>Relationship between gas pressure and volume of gases</td>
<td></td>
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<tr>
<td></td>
<td>Relationship between temperature and volume of gases</td>
<td></td>
</tr>
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<td></td>
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<tr>
<td><strong>State changes of matter</strong></td>
<td>Observing phenomena when the state of matter changes</td>
<td>Animals and energy</td>
</tr>
<tr>
<td></td>
<td>Measuring temperature when the state of matter changes</td>
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<tr>
<td>Grade 7 Unit</td>
<td>Topic</td>
<td>Grade 8 Unit</td>
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</tr>
<tr>
<td>Light and wave</td>
<td>Exploring the synthesis of light</td>
<td>Characteristics of matter</td>
</tr>
<tr>
<td></td>
<td>Observing the features of images by mirrors and lenses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exploring amplitude, frequency and waveforms of sound</td>
<td></td>
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<tr>
<td>Science and my future</td>
<td>Searching science-related occupations</td>
<td>Circulation of hydrosphere and seawater</td>
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### (cont.)

<table>
<thead>
<tr>
<th>Grade 7</th>
<th>Grade 8</th>
<th>Grade 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Topic</td>
<td>Unit</td>
</tr>
<tr>
<td>Heat and our lives</td>
<td>Finding an efficient way of thermal isolation</td>
<td>Science, technology and human civilization</td>
</tr>
<tr>
<td>Disaster and Safety</td>
<td>Comparing the specific heat of two objects</td>
<td>Investigating the cases of disasters</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>