ANALYZING CAMBRIDGE LOWER SECONDARY SCIENCE LEARNING OBJECTIVES BY PISA 2018 SCIENCE FRAMEWORK

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ABSTRACT

ANALYZING CAMBRIDGE LOWER SECONDARY SCIENCE LEARNING OBJECTIVES BY PISA 2018 SCIENCE FRAMEWORK

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In this study, Cambridge Lower Secondary Science learning objectives were examined according to the Program for International Student Assessment (PISA) 2018 science literacy aspects - contexts, knowledge, and competency. In the research, the document analysis method, one of the qualitative research methods, was applied. In the analysis of the obtained data, descriptive analysis technique was used. Findings were obtained by making frequency and percentage calculations in line with descriptive analysis. These findings were categorized and supported by tables and graphs. In addition, expert analysis was also used to ensure internal validity. During the analysis, for each objective, first aspects and then subcategories of these aspects were determined. It was found that the ratios of objectives matching with the contexts aspect were lower than other two aspects, and there was less emphasis on the personal context subcategory. In the knowledge aspect, it was determined that the content knowledge has the highest weight while epistemic knowledge has the lowest weight. Considering the desired distribution tables specified by PISA 2018 science framework, the objectives matching with the competency aspects were distributed in a more balanced way than the other two aspects.

Keywords: Cambridge Lower Secondary Science Curriculum, Program for International Student Assessment (PISA), Science Literacy, Science Teaching, Student Achievement

ÖZ

CAMBRIDGE ORTAOKUL FEN BİLİMLERİ DERSİ KAZANIMLARININ PISA 2018 FEN BİLİMLERİ ÇERÇEVESİYLE İNCELENMESİ

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Bu çalışmada, Cambridge Ortaokul Fen Bilimleri kazanımları, Uluslararası Öğrenci Değerlendirme Programı (PISA) 2018 Fen Bilimleri Çerçevesinde bağlamlar, bilgi türleri ve yeterlikler boyutlarında analiz edilmiştir. Araştırmada, nitel araştırma yöntemlerinden doküman incelemesi yöntemi uygulanmıştır. Elde edilen verilerin analizinde ise betimsel analiz tekniği kullanılmıştır. Frekans ve yüzde hesaplamaları yapılarak veriler elde edilip, tablo ve grafikler oluşturulmuştur. Uzman incelemesiyle araştırmanın iç geçerliği sağlanmıştır. Her bir kazanım analiz edilirken, kazanımların aynı zamanda her bir boyutun hangi boyutları ile eşleştikleri tespit edilmiştir. Bağlamlar boyutu ile eşleşen kazanımların oranının düşük olduğu ve kazanımlarda özellikle kişisel bağlam vurgusunu az olduğu belirlenmiştir. Bilgi türleri boyutunda ise en çok vurgunun içerik bilgileri boyutuna yapıldığı, en az vurgunun ise epistemik bilgiler boyutuna yapıldığı görülmüştür. PISA tarafından belirtilen arzu edilen dağılım tabloları dikkate alındığında, kazanımların yeterlik boyutlarına göre dağılımlarının diğer boyutlara göre daha dengeli olduğu görülmüştür.

Anahtar Kelimeler: Cambridge Ortaokul Fen Bilimleri Müfredatı, Uluslararası Öğrenci Değerlendirme Programı (PISA), Fen Okuryazarlığı, Fen Öğretimi, Öğrenci Başarısı

To my dearest wife Işık

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LIST OF ABBREVIATIONS

MEB	Milli Eğitim Bakanlığı
NSTA	National Science Teaching Association
NRC	National Research Council
OECD	The Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
TIMMS	Trends in International Mathematics and Science Study
CIE	Cambridge Internal Examination

CHAPTER 1

INTRODUCTION

The race for supremacy between civilizations for thousands of years continues today, increasing its speed among states. The concept of power determined by the large number of people in ancient times and the presence of animals used in war, such as horses, is currently determined by how far ahead the countries are in science and technology. In this context, countries are trying to increase their scientific knowledge while trying to increase the scientific literacy of their citizens. Also, a large part of the workforce today relies on scientific and technological skills. The best place for the society to increase the scientific literacy is the schools. For this reason, countries are working on how to teach science to their citizens better via creating curricula. The earlier this education is given to people, the more beneficial it will be. Because, even at very young ages, kids have the capacity and tendency to observe and explore (NRC, 2012). Children in the age group addressed by the middle school science curriculum, which is the subject of this thesis, are in a very important time period due to their enthusiasm and understanding towards science and as well as, great physical, emotional and cognitive changes they have (NSTA, Position Statement).

The National Science Teachers Association (NSTA) recommends the following points about how the curriculum to be prepared for middle school students should be:

• There should be units that contain topics that are compatible with students' lives, interests and experiences.

• Students should be able to put into practice the content they learned in science courses and the skills they acquired in a way to explain events, create models and design solutions related to real-life problems.

• Engaging the classroom with the community, with place-based learning opportunities such as field trips, inspiring speakers and local partnerships
• Providing science-based career awareness by providing real-life experiences and enabling them to understand the relevance of science to their lives
• Providing critical thinking and decision-making activities so that students can be involved in community-based problems.
• Supporting societal goals for scientific, engineering and technological literacy.

1.1 Cambridge Lower Secondary Science Curriculum

Cambridge Lower Secondary Science Curriculum is created by the Cambridge Assessment International Education. As of September 2021, it started the new lower secondary science curriculum which is 3 years. The transition from the previous 1093 coded curriculum to this new curriculum coded 0893 will be completed in 2 years. Learning objectives of Cambridge Lower Secondary Science is provided in a document called "Cambridge Lower Secondary Science Curriculum Framework". There are more than 10,000 Cambridge schools in over 160 countries around the world. As of August 2022, 45 schools in Turkey implement the Cambridge curriculum at different levels. Below table depicts the names of 45 schools (Table 1.1).

Table 1.1 45 schools in Turkey that implement the Cambridge curriculum at different levels

School Name	School Name
Açı Schools	Özel Antalya Toplum Koleji Ilk Ve Ortaokulu
Adana Gundogdu College	Ozel Bahcesehir Koleji Etiler Ilkokulu
Al-Rafidain International Schools	Ozel Bahcesehir Koleji Gokturk Ilkokulu
Ankara University Development Foundation Schools	Ozel Buyuk Kolej
Baskent Universitesi Ozel Ayseabla Okullari	Ozel Istanbul Bilim Koleji
Baskent Üniversitesi Özel Baskent Okullari	Ozel Namik Altas Koleji
Bestepe College	Mef Schools Of Turkey
Bilkent Erzurum Laboratory School	Mev Koleji Özel Basinköy Ilkokulu Ve Ortaokulu
Bilkent Laboratory And International School (BLIS)	MEV Koleji Ozel Büyükçekmece Ilkokulu Ve Ortaokulu
Bjk-Kabatas Foundation Schools	Mev Koleji Özel Güzelbahçe Ilkokulu Ve Ortaokulu
Gazi University Foundation Private Schools	Mev Koleji Ozel Izmir Bornova Okullar
Gokkusagi Educational Institutions - Esenyurt Istanbul	Mev Koleji Ozel Ankara Ilkokulu Ve Ortaokulu
Gokkusagi Educational Institutions Bahcelievler Istanbul	Pakistan Embassy International Study Group
Gokkusagi Educational Institutions-Atasehir Istanbul	Private Antalya Konyaalti College
Gokkusagi Educational Institutions-Beylikduzu Istanbul	Private Antalya Manavgat College
Horizon International College	Private Antalya Muratpasa College
Horizon International Education Consultancy	Prof. Dr. Mümtaz Turhan Sosyal Bilimler Lisesi
International Gateway Academy	Tarabya British Schools
Istanbul Ataturk Fen Lisesi	Mef Schools Of Turkey
Istanbul B.C.	MEV Koleji Ozel Ankara Ilkokulu Ve Ortaokulu
Istanbul International School	Mef International School - Izmir
Kabatas Erkek Lisesi	Kazanim International School
Kartal Anadolu Imam Hatip Lisesi	

Cambridge International states that the "lower secondary science curriculum framework" is typically for 11- to 14-year-old students, although it may be appropriate to use it for slightly different ages to suit the context. Students at Cambridge Lower Secondary Science Curriculum develop their scientific knowledge through the strands namely, *Biology*, *Chemistry*, *Physics* and *Earth and Space*. They also develop scientific practices through the *Thinking and Working Scientifically* strand. Another feature of the Cambridge Lower Secondary Science curriculum is a strand called *Science in Context* which supports teachers in demonstrating the relevance of science to their students.

1. A skill strand – Thinking and Working Scientifically
2. Content strands – Biology, Chemistry, Physics, and Earth and Space
3. A context strand – Science in Context

"Cambridge Lower Secondary Science curriculum" consists of 3 stages: *stage 7*, *stage 8* and *stage 9*. In each stage, students are offered 90 hours of teaching time. In Cambridge lower secondary science, students meet foundational scientific concepts and they are encouraged to link science to real world contexts that are personal, local, national and global, identifying the relevance of science to the modern world. Cambridge Lower Secondary Science also leads students to develop their scientific skills so that students can become increasingly independent when questioning and investigating phenomena. It also motivates learners to become responsible, innovative, confident, engaged, and reflective.

Considering the strands, “Thinking and Working Scientifically” relates to the development of scientific skills and covers three core scientific approaches: Models and representations, Scientific enquiry, and Practical Work. The content strands are Biology, Chemistry, Physics, Earth and Space. Finally, “Science in Context” strand help learners study and understand the learning objectives within the other five science strands in a context relevant to them. In Cambridge Lower Secondary Science, learners are expected to begin to consider the role and impact of science at a local, national, and global level.

1.2 Scientific literacy

The term, “scientific literacy” has been controversial over the years as the researchers has loaded different meanings on this concept. According to (Durant 1994), it implied what the general public ought to acknowledge about science. Jenkins presented broader understanding of science to its meaning; comprehension of the scientific ideas (Jenkins, 1994). Scientific literacy has gained significance during the second half of the 20th century. In 1970, the National Science Foundation (NSF) Advisory Committee on Science Education had the following recommendation: conventional methods in science education should be reconsidered with great extent even by those who do not to expect to become professional in an area of science and technology (Hurd 1998). The objective was to raise a socially responsible and competent citizen. Besides, National Research Council (NRC) stated a scientifically literate individual as the one who reads and understands popular science articles, make evaluations, and discusses socio-scientific problems and distinguish facts from fictions (NRC,1996). Since the advancements in science and technology changes so rapidly, the society is also expected to show adaptation. For this reason, individuals should be educated in a way that they meet current technological and scientific requirements (Cansiz, 2014).

Regarding OECD Programme for International Student Assessment (PISA), scientific literacy is defined as the "ability to engage with science-related issues, and with the ideas of science, as a reflective citizen". PISA makes a more comprehensive explanation; the individual can explain a phenomenon based on scientific facts, make assessments and interpretations scientifically. That way, they can apply scientific knowledge for any real-life cases (OECD, 2017)

1.3 Program for International Student Assessment (PISA)

The Organisation for Economic Co-operation and Development (OECD) is an international organization whose goal is to shape policies that foster prosperity, equality, opportunity and well-being for all (OECD). OECD was founded in 1960 and has got 38 member countries which are Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States in alphabetic order.

The OECD Programme for International Student Assessment (PISA) was started in 1997 and administrated in 2000. PISA has been currently embedding more than 80 countries. Every three years, PISA measures the 15 years olds' science, mathematics and reading performances and generates these as comparative data. In 2000, 2003, 2006, 2009, 2012, 2015 and 2018, reading literacy, mathematical literacy, scientific literacy, reading literacy, mathematical literacy, scientific literacy and reading literacy capabilities were respectively the major domains of the assessments (Figure 1.1). Besides, students' proficiencies are explored in an innovative domain in each cycle. For instance, "Global Competence" was the innovative domain of the year 2018. 2003 was the year in which Turkey joined the programme.

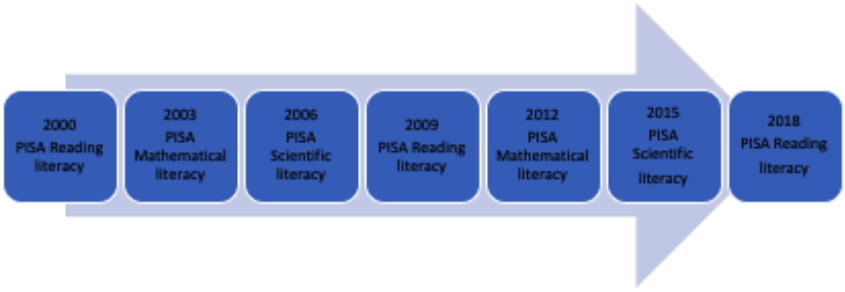


Figure 1.1 PISA's major domains by years (OECD).

PISA not only finds out whether the students produce knowledge or not but also explores how they produce knowledge in unfamiliar settings due to the modern economies rewarding the individuals based on their way of using of knowledge (OECD, 2019). In addition, PISA collects data on the learning environments of students and the related data on "approaches to learning" by using the questionnaires received from students, parents, teachers and school administrators.

PISA evaluates performance of students regarding science by the questions linked to:

- Contexts: include personal, local/national and global problems, both existing and historical, that requires some understanding of science and technology.
- Knowledge: indicates the major facts that generate the scientific knowledge which are classified as content knowledge, procedural knowledge and epistemic knowledge.
- Competencies: the ability to define phenomena scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically.

As mentioned before, Turkey has joined PISA six times so a far and the points received by Turkey quite fluctuated in years. The results were assessed from different perspectives and the country's scores showed improvements in

years. Figure 1.2 shows the points received by Turkey in the scientific literacy by years.

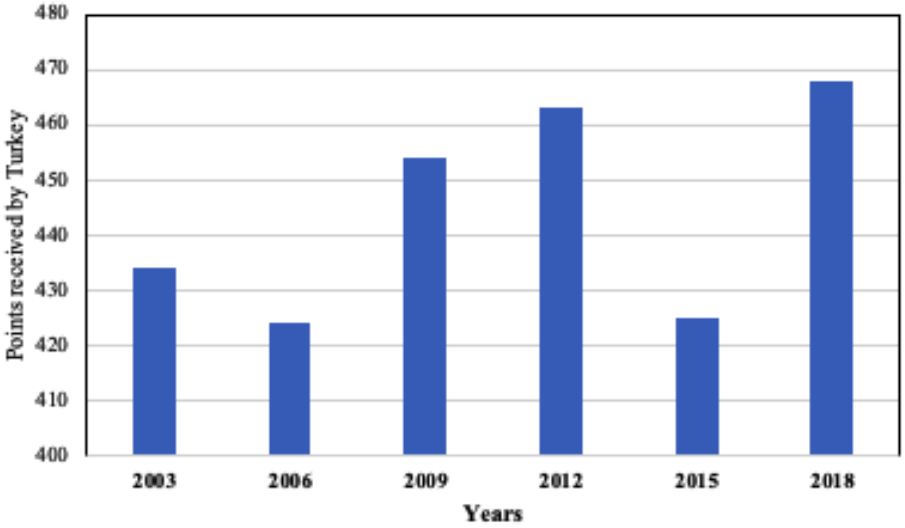


Figure 1.2 The points received by Turkey in the Scientific Literacy by years (OECD, 2019).

1.3.1 PISA 2003

PISA 2003 exam was applied to 4855 students which were chosen from 147 high schools and 12 primary schools located in the seven geographic areas. Following the exam, Turkey's scientific literacy point was calculated as 434. This exam was applied to 29 OECD countries and among, Turkey was 28th. Table 1.2 depicts the points earned by Turkey and OECD countries in PISA 2003.

Table 1.2 The points earned by Turkey and OECD countries in PISA 2003

	Average points	Percentage of students below 400 points	Percentage of students above 600 points
Turkey	434	38.6	5.7
Average of all OECD students	496	19.9	17.7
OECD average*	500	17.9	17.6

*Calculated assuming that all OECD countries possessing the identical number of 15-years-old students

1.3.2 PISA 2006

Turkey participated in PISA for the second time in 2006. This year, PISA's major focus was on science literacy. The number of schools participating in PISA from Turkey was 160 and the number of students was 4942. Turkey's average score in this assessment was 424. With this score, Turkey ranked 29th among 30 OECD countries participating in the assessment and 47th among all 57 countries.

Table 1.3 Percentage distributions of PISA 2006 based on scientific literacy

	Average points	Below 1st level (%)	1st level (%)	2nd level (%)	3rd level (%)	4th level (%)	5th level (%)	6th level (%)
Turkey	424	12.9	33.7	31.3	15.1	6.2	0.9	0.0
Average of all OECD students	491	6.9	16.3	24.2	25.1	18.7	7.4	1.4
OECD average *	500	5.2	14.1	24.0	27.4	20.3	7.7	1.3

*Calculated assuming that all OECD countries possessing the identical number of 15-years-old students

1.3.3 PISA 2009

Turkey's average score in this assessment was 454 and below the average score. Turkey ranked 31st among OECD countries and 42nd among 65 countries participating in assessment.

Table 1.4 Percentage distributions of PISA 2009 based on scientific literacy

	Average points	Below 1st level (%)	1st level (%)	2nd level (%)	3rd level (%)	4th level (%)	5th level (%)	6th level (%)
Turkey	454	6.9	23.0	34.5	25.2	9.1	1.1	0.0
Average of all OECD students	496	5.4	14.6	24.8	27.1	19.6	7.3	1.1
OECD average*	501	5.0	13.0	24.4	28.6	20.6	7.4	1.1

*Calculated assuming that all OECD countries possessing the identical number of 15-years-old students

1.3.4 PISA 2012

Turkey's average score in this assessment was 463 and below the average score. Turkey ranked 33rd among OECD countries and 43rd among 65 countries participating in assessment.

Table 1.5 Percentage distributions of PISA 2012 based on scientific literacy

	Average points	Below 1st level (%)	1st level (%)	2nd level (%)	3rd level (%)	4th level (%)	5th level (%)	6th level (%)
Turkey	463	4.4	21.9	35.4	25.1	11.3	1.8	0.0
Average of all OECD students	501	4.8	13.0	24.5	28.8	20.5	7.2	1.1
OECD average*	497	4.8	14.6	25.7	27.5	19.3	6.9	1.2

*Calculated assuming that all OECD countries possessing the identical number of 15-years-old students

1.3.5 PISA 2015

Second time, the major focus was on science literacy. A total of 72 countries, 35 of which are OECD members, participated in assessment. 5895 students from Turkey participated in the assessment which was digitally implemented. This was the first implementation of PISA as a computer-based assessment. The average science literacy score of Turkey in this assessment was 425, the average score of OECD countries was 493, and the overall average score of all countries was 465. (Table 1.6).

Table 1.6 Percentage distributions of PISA 2015 based on scientific literacy

	Average points	Below 1st level (%)	1st level (%)	2nd level (%)	3rd level (%)	4th level (%)	5th level (%)	6th level (%)
Turkey	425	1.1	43.3	31.3	19.1	4.8	0.3	0.0
Average of all OECD students	493	0.6	20.7	24.8	27.2	19.0	6.7	1.1
OECD average*	465	1.5	29.9	26.1	23.0	14.0	4.6	0.7

*Calculated assuming that all OECD countries possessing the identical number of 15-years-old students

1.3.6 PISA 2018

In PISA 2018, the major focus was on reading. Turkey was ranked 30th among 37 OECD countries participating in the assessment, and 39th among 79 countries in total. Turkey's score for science literacy was 468, the average score of OECD countries was 489, and the average score of all participating countries was 458

1.4 Statement of the Problem

Countries implement their own tests for different purposes and at different levels. In addition, exams such as PISA, International Mathematics and Science Trends Survey (TIMMS) are held to determine and rate success in the international arena. One of the international exams Turkey participates in is the PISA exams administered by the Organization for Economic Cooperation and Development (OECD), of which it is a founding member. PISA, first conducted in 2000, assesses 15-year-old students. Three different domains are evaluated in the PISA. These are mathematical literacy, reading literacy and science literacy domains. The major domain of the assessment

rotates in each cycle. Science literacy was assessed as the major domain in 2006 and 2015. Turkey participated in PISA for the first time in 2003.

Average scores and rankings obtained in international exams such as PISA allow countries to compare with each other in their scientific education and practices and show how much progress they have made.

Table 1.7 Average scores obtained in scientific literacy in years, 2006 and 2015.

	2015	2006
OECD average	493	498
Average of all countries	465	478
Average of Turkey	425	424
Number of participating countries	72	57

When the 2006 and 2015 PISA average scores are evaluated, various studies are carried out in order to improve the science literacy results of Turkey and to increase the quality of education in this context. Various reasons can be expressed regarding the reasons for low achievement. These may be insufficient parental support, scarcity of educational resources (OECD, 2013), inter-school disparity (OECD, 2016). On the other hand, an insufficiently qualified curriculum for science literacy may also be one of the reasons for this low success. In addition, many schools in Turkey apply international curricula along with national curricula. One of them is the International Cambridge curriculum, which is implemented in more than 160 countries. Considering that PISA is applied to 15-year-old students, examining the objectives of the Cambridge Lower Secondary Science Curriculum created for the 11-14 age group, can produce effective results that can be used to teach Cambridge Lower Secondary Science in a more effective

way. Therefore, a more effective Turkish science curricula can be created that would raise students with higher scientific literacy.

1.5 Purpose of the study

The purpose of this study is to examine the objectives of the Cambridge Lower Secondary Science Curriculum according to the aspects of the PISA 2018 science framework.

1.6 Significance of the study

According to the results from PISA, students in Turkey are found quite unsuccessful in scientific literacy. One of the international curricula applied in Turkey is the Cambridge Lower Secondary Science curriculum, and the number of schools that apply this curriculum in Turkey is increasing. In this study, the Cambridge curriculum were examined, and its strengths and weaknesses were determined according to the PISA 2018 science framework. It is expected that the results obtained will contribute to the creation of the next Turkish middle school science curricula, the more effective teaching of Cambridge curriculum by educators in Turkey, and the creation of the next Cambridge curriculum.

1.7 Limitations of the study

This study uses only the PISA 2018 science framework when examining the objectives in terms of scientific literacy. There is no specific data available on the PISA scores of schools that apply only the Cambridge curriculum or both the Turkish middle school curriculum and the Cambridge curriculum in Turkey.

CHAPTER 2

LITERATURE REVIEW

In the article published by Cansız and Cansız (2019), the 2017 Turkish Science curriculum for grades 3 to 8 was evaluated with the 2015 PISA scientific literacy framework. Unlike 2018, the 2015 PISA framework defined scientific literacy under four aspects. These are contexts, knowledge, competencies and attitudes. In other words, 2015 PISA science framework has an attitude aspect in addition to its successor, 2018 PISA science framework. According to the results of this study, the 2017 Turkish Science curriculum does not adequately reflect all aspects of science literacy. In addition, Turkish science curriculum objectives involves the context aspect of PISA's science literacy framework poorly. Another finding of this study is that while the content knowledge subcategory of the knowledge aspect is given a lot of space in the objectives, the epistemic knowledge subcategory is presented modest. Regarding the scientific competencies aspect while the Turkish science curriculum mostly includes *explain phenomena scientifically*, it rarely includes the other two aspects -*evaluating and designing scientific enquiry* and *interpreting data and evidence scientifically*.

In the master's thesis published by İlknur Zamir Khan (2017), the 11th grade biology curriculum of MEB and the 11th grade of Cambridge International Examinations (CIE) curriculum were compared in terms of laboratory practices. Laboratory practices in both curriculums were compared in terms of their objectives, scientific process skills, teaching materials, and assessment approaches. While there were similarities between laboratory activities, scientific process skills and materials, significant differences were found between the two curricula in terms of the content, assessment approaches and objectives of laboratory practices. It was emphasized that the laboratory practices were handled in a more planned and systematic way in the CIE program than in the MEB program. It was also determined that there was a complete harmony and overlap between the activity objectives and activities in the CIE curriculum, while the laboratory activity objectives in the MEB curriculum were not written specifically for the activities. In addition, it was determined that the laboratory applications in the MEB curriculum and the scientific research and process skills in the program did not fully overlap, while the laboratory applications in the CIE curriculum and the scientific research and process skills that were intended to be acquired by the students overlapped.

Another study carried out in Turkey on Cambridge Assessment International Education is the master's thesis conducted by Emir Ersoy (2021). In this study, the researcher analyzed the views of administrators and teachers regarding the implementation of the Cambridge General Certificate for Secondary Education (IGCSE) program in public high schools. The data were collected with a semi-structured interview form and analyzed with content analysis. It was determined that bureaucratic, legal, economic and academic problems were encountered during the acceptance and implementation of the program. In addition, it was argued that the level of English proficiency of both teachers and students were found insufficient from time to time. It was also emphasized that schools held weekend classes and opened summer schools in order to carry out both the MEB and Cambridge curricula.

In the master's thesis study by Merve Nur Genç (2020), assessment and evaluation activities in a MEB approved 8th grade science textbook were performed according to the PISA science framework. According to this study, end of chapter activities of the textbook were found to be quite inadequate in terms of context, knowledge and competency aspects. In order to develop high-level skills in the PISA science literacy proficiency scale, it is recommended that the content and activities of the textbooks be revised accordingly. It has been noted that content knowledge is given a lot of space to the activities in the textbook, and it has been determined that procedural knowledge and epistemic knowledge are given insufficient number of spaces.

In the master's study conducted by Fatma Yılmaz (2020), the characteristics of students with extreme high achievement in science literacy according to PISA 2015 Turkey data were examined. According to this study, it has been noted the variables of epistemological belief, scientific self-efficacy, enjoying science and enjoying cooperation have positive effects on student achievement. In the same study, the time allocated to weekly out-of-school study was determined as a variable that negatively affects student achievement.

In the master's study conducted by Azize Sultan Kömürcü (2021), the questions in between the 5th and the 8th grade science textbooks were examined according to the PISA science literacy levels. In the study in which a total of 1209 assessment and evaluation questions were examined according to science literacy, nearly 60% of the questions in the 5th, 6th, 7th grade textbooks and slightly more than 65% of the questions in the 8th grade textbook were determined at the 2nd level. It was also determined that the rate of questions at the upper performance level is quite low at all grade levels. In order to increase the success of PISA and to increase the level of science literacy, it was suggested to include a sufficient number of high-level questions in the textbooks and to update the textbooks by the researcher. The

researcher also suggested that studies should be conducted to examine the curriculum and nationwide exams within the scope of PISA science literacy.

PISA 2015 data was used in the master thesis study written by Burcu Orhan (2020). It was determined that the time spent for science learning, epistemological beliefs, environmental awareness and the professional status that students hope to have were found to affect all dimensions of science literacy positively. In the same study, it was found that the time spent studying science outside school, science activities and environmental optimism negatively affect all dimensions of science literacy.

In another graduate study by Alper Sadıç (2013), the correlation between 8th grade students' epistemological beliefs, their PISA achievement and science literacy was examined. As a result of the study, no significant relationship was found between students' scientific epistemological beliefs and conceptual understandings. In the addition, no statistically significant difference was found between the epistemological beliefs of the students and their gender.

In the master's study conducted by Hasan Gokdemir (2020), science literacy competencies of pre-service science teachers according to the PISA framework and the variations of these competencies according to grade levels were investigated. In this study, which included 244 pre-service teachers, there was no statistically significant difference between the mean achievement scores and grade levels in terms of science literacy competencies. The results of the study indicated that the participants did not demonstrate a significant improvement regarding PISA science literacy proficiency.

In the research conducted by Zeynep Candaş (2019), middle school 5th, 6th, 7th and 8th grade science textbooks were examined in terms of scientific literacy themes, and it was aimed to find out how much these themes took place in the textbooks. After the percentages of scientific literacy themes on

the basis of grade levels in the science textbooks were compared, it was found out *Science as a body of knowledge* theme took the most place in all grade levels and units with a share of 67.85%. Concerning other sub-themes of scientific literacy in the textbooks, it was found out that the *Science as a way of investigating* theme is 24.35%, the *Science, technology and society* theme is 4.96%, and the *Nature of science* theme is 2.84%. The data indicated that science literacy themes were not sufficiently involved in the textbooks.

In the study conducted by Sinem Demirci (2018), the scientific literacy of Turkish students was analyzed through the 2015 PISA results. According to the research, test anxiety, environmental awareness, interest in science subjects, playing computer games after school, mathematical literacy, reading skills and collaborative problem-solving skills were the most important variables in determining science literacy.

In the study conducted by Esengül Kantekin (2018), the 9^{th}, 10^{th}, 11^{th} and 12^{th} grade physics, chemistry and biology curricula were examined in terms of scientific literacy themes and it was investigated to what extent these themes were involved in the curricula. While the theme *Science as a body of knowledge* took more place in the curricula, the theme *Science as a way of investigating* and *Science-technology-society interaction* were not included sufficiently. Therefore, the distribution of the themes was not balanced.

In the study of Özden Çolak (2014), the effect of inquiry-based science teaching method on science literacy and science literacy achievements of 6^{th} grade students, along with scientific process skills, scientific attitude and academic achievement of the Particulate Structure of Matter unit was examined. It was claimed that the inquiry-based science teaching method had a positive effect on the science literacy and the scientific process skills, scientific attitude and academic achievement.

CHAPTER 3

METHODOLOGY

In this study, document analysis from qualitative research methods was used. In document analysis, researchers interpret various resources such as curriculum materials and books (Bowen 2009). In the document analysis method, the researcher can access the data by analyzing the document without observation and interview (Yıldırım and Şimşek, 2008).

In the document analysis process, the following steps are followed: (1) reaching the documents suitable for the purpose of the research, (2) checking the originality of each resource by examining them, (3) understanding the examined documents and taking notes on the parts deemed necessary for the research, (4) analyzing the data using the notes taken, and some evaluation processes, (5) the use of data (Yıldırım and Şimşek, 2008). In this study, the purpose is to analyze the Cambridge Lower School Science curriculum in terms of three aspects expressed in the 2018 PISA science framework.

In the content analysis method, certain codes and themes are created from similar data. Then, the themes are arranged and interpreted in a meaningful way (Creswell, 2012). Content analysis is conducted in five steps. These steps are: (1) identifying the codes, (2) creating themes by bringing together similar codes, (3) organizing the codes and themes, (4) conducting validity and reliability studies, finding frequencies (5) describing and interpreting the findings (Denzin and Lincoln, 2005). These steps were fulfilled in the content analysis process of the current research.

Cambridge lower secondary science curriculum was started to conduct globally in September 2021. In the Cambridge curriculum, learning objectives are divided into main areas called strands and each strand is divided into sub strands. In science, there are three categories of strands, and they support learners in understanding and investigating natural phenomena. These strands also provide a foundation for developing future scientific skills, knowledge and attitudes:

1. A skill strand – Thinking and Working Scientifically
2. Content strands – Biology, Chemistry, Physics, and Earth and Space
3. A context strand – Science in Context

Cambridge lower secondary science curriculum is a 3-year curriculum and covers from stage 7 to stage 9. Strands and the number of objectives for each stage are given in the Table 3.1.

Table 3.1 Strands and the number of objectives for each stage of the Cambridge lower secondary science curriculum

		Stage 7	**Stage 8**	**Stage 9**
Skill strand		19	20	20
Content strands	Biology	11	12	14
	Chemistry	18	12	14
	Physics	11	14	12
	Earth and Space	8	7	7
Context strand		5		
Total		72	68	72

PISA 2018 science framework introduced the three aspects of science literacy as the contexts, the knowledge, and the competencies which are interrelated (Figure 3.1). In this study, Cambridge Lower School Science curriculum objectives (from stage 7 to stage 9) were categorized and analyzed according to PISA 2018 science framework.

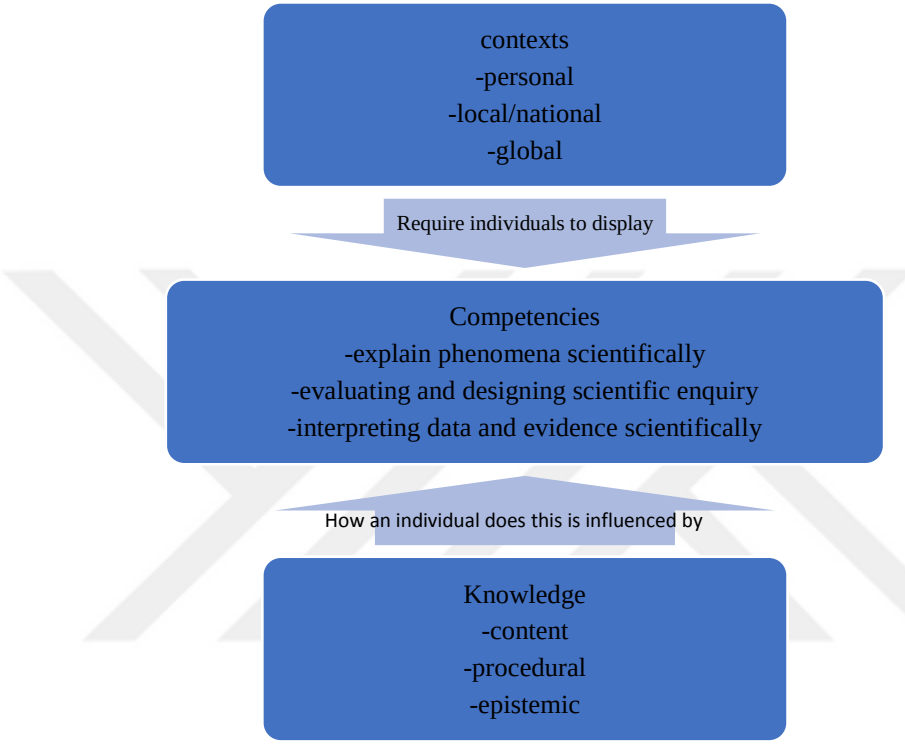


Figure 3.1 The link between the three aspects of PISA 2018 science framework (OECD, 2019).

The three aspects also have sub aspects, and these sub aspects have various practices.

3.1 Analysis

The objectives of Cambridge Lower Secondary Science Curriculum were analyzed according to PISA 2018 science framework by two experts. After analyzing the curriculum, both experts compared their findings. Objectives that were categorized differently were reanalyzed and finally a full consensus

was achieved. In the research, some objectives matched with more than one aspect, so the total frequencies and the total number of objectives in each grade may differ. While analyzing the objectives, each objective was first assigned to one of the three aspects. Then the decision was made for which subcategory of this aspect this objective belongs to. In the last step, it was determined which practice this subcategory is suitable for.

For example, let's consider how the objective, 8TWSa.04 in Cambridge Lower Secondary Science curriculum for stage 8 was analyzed.

8TWSa.04 Evaluate experiments and investigations, and suggest improvements, explaining any proposed changes.

In the first step, the researcher of this study and another expert decided that this objective belongs to the competency aspect.
In the second step, it was decided that this objective corresponds to the "evaluate and design scientific enquiry" subcategory of the competency aspect.
In the third step, this objective was found to comply with the task of "evaluate ways of exploring a given question scientifically".

CHAPTER 4

RESULTS

In this study, the weights of the Cambridge Lower Secondary Science Curriculum objectives were examined according to PISA 2018 science framework.

The analysis of the objectives of Cambridge Lower Secondary Science curriculum framework according to the PISA 2018 Science Framework find out that of the 210 objectives, 40 objectives are related to the contexts aspect, 236 objectives are related to the knowledge aspect, 126 objectives are related to the competencies aspect. Since some of the objectives are related to more than one aspect, the sum of the number of objectives related to each aspect is more than the total number of objectives. The following table demonstrates the weighed percentages of objectives related to the three aspects mentioned in the PISA 2018 Science Framework.

Table 4.1 Weighted percentages of three aspects in Cambridge lower secondary science objectives

	frequency	**%**
Contexts	40	10.0
Knowledge	236	58.7
Competencies	126	31.3

Table 4.2 Weighted average percentages of categories of contexts aspect

Contexts	Weighted average percentage (%)
Personal context	17.5
Local context	22.5
Global context	60.0

As a result of the analysis of Cambridge Lower Secondary Science curriculum objectives according to PISA 2018 science framework, it was seen that global contexts are the most, local contexts are less, and personal contexts are the least in terms of their weights. The ratio of objectives matching with global context is quite more than those matching with personal and local contexts.

Table 4.3 Weighed average percentages of categories of knowledge aspect

Knowledge	Weighted average percentage (%)	Desired distribution by PISA 2018 (%)
Content	53.8	54-66
Procedural	28.8	19-31
Epistemic	17.3	10-22

The analysis of the Cambridge curriculum shows that content knowledge related objectives have the highest ratios, procedural knowledge related objectives have less ratios and the ratios of objectives related to epistemic knowledge are the lowest.

Table 4.4 Weighed average percentages of subcategories of content knowledge category

System	Weighted average percentage (%)	Desired distribution by PISA 2018 (%)
Physical systems	52.8	36
Living systems	28.3	36
Earth and Space system	18.9	28

In Cambridge lower secondary science curriculum, objectives related to physical systems have the most, the objectives related to living systems have less, and the objectives related to Earth and Space systems have the least percentage. Compared to the "desired distribution of items, by content" of PISA (2018), objectives matching with physical systems contents have a higher ratio than PISA 2018 desired distribution, while objectives matching living system and earth and space system contents have a lower ratio than PISA 2018 desired distribution.

Table 4.5 Weighted average percentages of sub dimensions of competencies aspect

Competencies	Weighted average percentage (%)	Desired distribution by PISA 2018 (%)
Explain phenomena scientifically	32.5	40-50
Evaluate and design scientific enquiry	31.7	20-30
Interpret data and evidence scientifically	35.8	30-40

Objectives matching with "Interpret data and evidence scientifically" competency have the highest ratio, objectives matching with " Explain phenomena scientifically " competency have less ratio, and objectives matching with " Evaluate and design scientific enquiry" competency have the least ratio. Compared to PISA's (2018) "desired distribution of items, by competency", the objectives regarding the "Explain phenomena scientifically" competency are less than they should be, the objectives regarding the "Evaluate and design scientific enquiry" competency appear to be slightly more than they should be. The weight of the objectives for the "Interpret data and evidence scientifically" competency appear to be in the range they should be.

4.1 The Contexts Aspect at Cambridge Lower Secondary Science Curriculum

Objectives in the Cambridge Lower Secondary Science curriculum may relate to personal (the self, family, and peer groups), to local (local and national) or to global (life across the world) contexts. In some situations, the context may include historical element or technology. These three contexts are classified into five applications. These applications are *health and disease, natural resources, environmental quality, hazards,* and *the frontiers of science and technology*. Table 4.6 shows how these five applications interact with the personal, local, and global contexts. The PISA science assessment doesn't assess contexts. Instead, it assesses knowledge and competencies in specific contexts.

Table 4.6 Contexts for the PISA 2018 scientific literacy assessment (OECD, 2019).

	Personal	Local/National	Global
Health and disease	Maintenance of health, accidents, nutrition	Control of disease, food choices, community health	Epidemics, spread of infectious diseases
Natural resources	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non-renewable natural systems, population growth, sustainable use of species
Environmental quality	Environmentally friendly actions, use and disposal of materials and devices	Population distribution, disposal of waste, environmental impact	Biodiversity, ecological sustainability, control of pollution, production and loss of soil/biomass
Hazards	Risk assessments of lifestyle choices	Rapid changes (e.g., earthquakes, severe weather), slow and progressive changes (e.g., coastal erosion, sedimentation), risk assessment	Climate change, impact of modern communication
Frontiers of science and technology	Scientific aspects of hobbies, personal technology, music and sporting activities	New materials, devices and processes, genetic modifications, health technology, transport	Extinction of species, exploration of space, origin and structure of the Universe

Table 4.7 Distribution percentages of the contexts of objectives from Stage 7 to Stage 9 in Cambridge Lower Secondary Science curriculum.

	Cambridge Lower Secondary Science Curriculum					
	Stage 7		**Stage 8**		**Stage 9**	
	f	**%**	**f**	**%**	**f**	**%**
Personal						
Health and Disease	-	-	-	-	-	-
Natural Resources	-	-	-	-	-	-
Environmental Quality	-	-	-	-	-	-
Hazards	2	2.8	1	1.4	1	1.4
Frontiers of Science and Technology	1	1.4	1	1.4	1	1.4
TOTAL	3	4.2	2	2.9	2	2.9
Local/National						
Health and Disease	-	-	-	-	-	-
Natural Resources	-	-	-		-	-
Environmental Quality	-	-	1	1.4	1	1.4
Hazards	-	-	1	1.4	-	-
Frontiers of Science and Technology	2	2.8	2	2.9	2	2.9
TOTAL	2	2.8	4	5.7	3	4.3
Global						
Health and Disease	-	-	2	2.9	-	-
Natural Resources	-		1	1.4	-	-
Environmental Quality	4	5.6	5	7.1	3	4.3
Hazards	-	-	1	1.4	-	-
Frontiers of Science and Technology	3	4.2	2	2.9	3	4.3
TOTAL	7	9.7	11	15.7	6	8.6

In stage 7, objectives related to local context has the least weight. Objectives related to the global context are more than objectives related to the personal context. In stage 7, application called "frontiers of science and technology" has the highest weight in general.

In stage 8, objectives matching with the personal context has the lowest weight. Of the other two contexts, global context is more involved to the objectives than local context. In the global context, the weight of the "environmental quality" application is more than the weights of other applications.

In stage 9, similar to stage 8, objectives matching with the personal context has the lowest weight while objectives matching with the global context has the highest weight. Considering the average of personal, local and global contexts, the "frontiers of science and technology" application has the highest weight.

Personal context's “health and disease”. "natural resources" and “environmental quality” applications do not exist in any stages of Cambridge Lower Secondary Science curriculum. Local context's "health and disease" and "natural resources" applications do not exist in any stages of Cambridge lower secondary science curriculum framework. Considering the global context, there is at least one objective in the Cambridge curriculum matching with any of the five applications.

Table 4.8 Examples to objectives of the context aspect of scientific literacy

CONTEXTS	APPLICATIONS	OBJECTIVES
Personal		
	Health and Disease	N/A
	Natural Resources	N/A
	Environmental Quality	N/A
	Hazards	7TWSp.05 Know the meaning of hazard symbols, and consider them when planning practical work.
	Frontiers of Science and Technology	9SIC.04 Describe how people develop and use scientific understanding as individuals and through collaboration, e.g. through peer-review.
Local		
	Health and Disease	N/A
	Natural Resources	N/A
	Environmental Quality	8Be.03 Describe how a new and/or invasive species can affect other organisms and an ecosystem.
	Hazards	8Be.03 Describe how a new and/or invasive species can affect other organisms and an ecosystem.
	Frontiers of Science and Technology	7SIC.02 Describe how science is applied across societies and industries, and in research.
Global		
	Health and Disease	8Bp.03 Discuss how human growth, development and health can be affected by lifestyle, including diet and smoking.
	Natural Resources	8ESp.02 Identify renewable resources (including wind, tidal and power, and bioplastics) and non-renewable resources (including fossil fuels), and describe how humans use them
	Environmental Quality	7SIC.05 Discuss how the uses of science can have a global environmental impact.
	Hazards	8TWSp.05 Make risk assessments for practical work to identify and control risks
	Frontiers of Science and Technology	7SIC.05 Discuss how the uses of science can have a global environmental impact.

4.2 The Knowledge Aspect at Cambridge Lower Secondary Science Curriculum

4.2.1 Content knowledge

PISA's assessment on the content knowledge is chosen from physics, chemistry, biology, and earth and space sciences. The assessment's questions which are suitable for 15-year-olds are related to real-life situations. Table 4.9 displays the categories of content knowledge.

Table 4.9 Content knowledge in the PISA 2018 science assessment (OECD, 2019)

Physical systems, including:
Structure of matter (e.g., particle model, bonds)
Properties of matter (e.g., changes of state, thermal and electrical conductivity)
Chemical changes of matter (e.g., chemical reactions, energy transfer, acids/bases)
Motion and forces (e.g., velocity, friction) and action at a distance (e.g., magnetic, gravitational and electrostatic forces)
Energy and its transformation (e.g., conservation, dissipation, chemical reactions)
Interactions between energy and matter (e.g., light and radio waves, sound and seismic waves)
Living systems, including:
Cells (e.g., structures and function, DNA, differences between plant and animal cells)
The concept of an organism (e.g., unicellular vs. multicellular)
Humans (e.g., health; nutrition; subsystems such as the digestive, the respiratory, the circulatory, the excretory and the reproductive and their relationship)
Populations (e.g., species, evolution, biodiversity, genetic variation)
Ecosystems (e.g., food chains, matter and energy flow)
Biosphere (e.g., ecosystem services, sustainability)
Earth and space systems, including:
Structures of the Earth (e.g., lithosphere, atmosphere, hydrosphere)
Energy in the Earth (e.g., sources, global climate)
Change in the Earth (e.g., plate tectonics, geochemical cycles, constructive and destructive forces)
Earth's history (e.g., fossils, origin and evolution)
Earth in space (e.g., gravity, solar systems, galaxies)
The history and scale of the Universe and its history (e.g., light year, Big Bang theory)

4.2.2 Procedural knowledge

Procedural knowledge which was also called "concepts of evidence" (Roberts, Gott, and Glaesser 2010; Millar et al. 1994) is the knowledge of the standard concepts and procedures vital for scientific enquiry that gives support to the collection, analysis, and interpretation of scientific data (OECD, 2019). Procedural knowledge is required to perform scientific

enquiry and to review evidence to support specific claims. Below table lists some examples of testable procedural knowledge.

Table 4.10 Procedural knowledge in the PISA 2018 science assessment (OECD, 2019)

Procedural knowledge
The concept of variables, including dependent, independent and control variables;
Concepts of measurement, e.g. quantitative measurements, qualitative observations, the use of a scale or other instruments, categorical and continuous variables;
Ways of assessing and minimising uncertainty such as repeating and averaging measurements;
Mechanisms to ensure the replicability (closeness of agreement between repeated measurements of the same quantity) and accuracy (the closeness of agreement between a measured quantity and its true value) of measurements;
Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use; The control of variables and its role in experimental design;
The use of randomised controlled trials to avoid confounded findings and to identify possible causal mechanisms; The nature of an appropriate design for a given scientific question, e.g., experimental, field-based or pattern-seeking.

4.2.3 Epistemic knowledge

(Duschl 2008) describes epistemic knowledge as the knowledge of the constructs and features crucial while building knowledge in science and their functions in confirming the knowledge created by science. Epistemic knowledge helps students to differentiate among facts, hypotheses, observations, theories and models. Epistemic knowledge explains why certain procedures, such as experiments, are central to establish scientific knowledge.

Table 4.11 Epistemic knowledge in the PISA 2018 assessment (OECD, 2019)

Epistemic knowledge
The constructs and defining features of science, that is: • The nature of scientific observations, facts, hypotheses, models and theories; • The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), what constitutes a scientific or technological question, and what constitutes appropriate data; • The values of science, such as a commitment to publication, objectivity and the elimination of bias; • The nature of reasoning used in science, such as deductive, inductive, inference to the best explanation (abductive), analogical and model-based; The role of these constructs and features in justifying the knowledge produced by science, that is: • How scientific claims are supported by data and reasoning in science; • The function of different forms of empirical enquiry in establishing knowledge, including both their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies); • How measurement error affects the degree of confidence in scientific knowledge; • The use and role of physical, system and abstract models and their limits; • The role of collaboration and critique and how peer review helps to establish confidence in scientific claims; • The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

The desired distribution, by percentage of items, among the three knowledge types is shown in the table below.

Table 4.12 Desired distribution of items for knowledge aspect

Knowledge types	**Systems**			
	Physical	Living	Earth and space	Total over systems
Content	20-24	20-24	14-18	54-66
Procedural	7-11	7-11	5-9	19-31
Epistemic	4-8	4-8	2-6	10-22
Total over knowledge types	36	36	28	100

Table 4.13 Distribution percentages of the objectives related to knowledge aspect in Cambridge lower secondary science curriculum framework.

	Cambridge Lower Secondary Science Curriculum					
	Stage 7		**Stage 8**		**Stage 9**	
	f	**%**	**f**	**%**	**f**	**%**
Knowledge of the Content of Science						
Physical systems	20	27.7	26	37.1	19	27.1
Living systems	11	15.3	12	17.1	17	24.3
Earth and space systems	8	11.1	7	10	7	10
TOTAL	39	54.2	45	64.3	43	61.4
Procedural Knowledge						
The concept of variables, including dependent, independent and control variables	1	1.4	1	1.4	2	2.9
Concepts of measurement, e.g. quantitative measurements, qualitative observations, the use of scale o other instruments, categorical and continuous variables	9	12.5	4	5.7	2	2.9
Ways of assessing and minimizing uncertainty such as repeating and averaging measurements	6	8.3	6	8.6	2	2.9
Mechanisms to ensure replicability and accuracy of measurements	5	6.9	5	7.1	7	10
Common ways of abstracting and representing data	3	4.2	2	2.9	2	2.9
The control of variables and its role in experimental design	1	1.4	2	2.9	1	1.4
The use of randomized controlled trials	2	2.8	2	2.9	1	1.4
The nature of an appropriate design for a given scientific question, e.g. experimental, field-based or pattern-seeking	1	1.4	1	1.4	1	1.4
TOTAL	28	38.9	23	32.9	18	25.7
Epistemic Knowledge						
The nature of scientific observations, facts, hypotheses, models and theories	4	5.6	4	5.7	4	57
The purpose and goals of science as distinguished from technology	-	-	-	-	-	-
The values of science, such as a commitment to publication, objectivity and the elimination of bias	1	1.4	2	2.9	2	2.9
The nature of reasoning used in science, such as deductive, inductive, inference to the best explanation, analogical and model-based	1	1.4	1	1.4	1	1.4
How scientific claims are supported by data and reasoning in science	-	-	-	-	-	-
The function of different forms of empirical enquiry in establishing knowledge, including both their goal and their design	1	1.4	1	1.4	1	1.4
How measurement error affects the degree of confidence in scientific knowledge	-	-	-	-	1	1.4
The use and role of physical, system and abstract models and their limits	1	1.4	-	-	3	4.3

	Cambridge Lower Secondary Science Curriculum					
	Stage 7		Stage 8		Stage 9	
	f	%	f	f	%	f
The role of collaboration and critique and how peer review helps to establish confidence in scientific claims	2	2.8	2	2.9	3	4.3
The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues	2	2.8	2	2.9	2	2.9
TOTAL	12	16.7	12	17.1	17	24.3

In stage 7, objectives related to content knowledge is 54.2% of all objectives. On the other hand, objectives related to procedural knowledge is 38.9% and objectives related to epistemic knowledge is 16.7% of all the objectives in stage 7. Within the content knowledge, the percentages of the objectives that match with the physical systems (27.7%) is greater than the percentages of the objectives that match with the living system (15.3%), and percentages of the objectives that match with the Earth and Space system (11.1%). In stage 7, there could not be found objectives matching with the epistemic knowledge's "The purpose and goals of science as distinguished from technology", "How scientific claims are supported by data and reasoning in science", and "How measurement error affects the degree of confidence in scientific knowledge" applications.

In stage 8, objectives related to content knowledge is 64.3% of all objectives. On the other hand, objectives related to procedural knowledge is 32.9% and objectives related to epistemic knowledge is 17.1% of all objectives in stage 8. Within the content knowledge, the percentages of the objectives that match with the physical systems (37.1%) is greater than the percentages of objectives that match with the living system (17.1%), and objectives that match with the Earth and Space system (10.0%). In stage 8, there could not be found objectives matching with the epistemic knowledge's "The purpose and goals of science as distinguished from technology", "How scientific claims are supported by data and reasoning in science", "How measurement error affects the degree of confidence in scientific knowledge", and "The use

and role of physical, system and abstract models and their limits" applications.

In stage 9, objectives related to content knowledge is 61.4% of all objectives. On the other hand, objectives related to procedural knowledge is 25.7% and objectives related to epistemic knowledge is 10.0% of all objectives in stage 9. Within the content knowledge, the percentages of the objectives that match with the physical systems (34.0%) is greater than the percentages of objectives that match with the living system (14.3%), and objectives that match with the Earth and Space system (24.3%). In stage 9, there could not be found objectives matching with the epistemic knowledge's "The purpose and goals of science as distinguished from technology" and "How scientific claims are supported by data and reasoning in science" applications.

Some applications do not match any objective on all stages. These are: "The purpose and goals of science as distinguished from technology" and "How scientific claims are supported by data and reasoning in science" applications which are under the epistemic knowledge category.

Table 4.14 Examples to the objectives of the knowledge aspect of scientific literacy

KNOWLEDGE	APPLICATIONS	OBJECTIVES
Knowledge of the content of science	Physical systems	7Cm.01 Understand that all matter is made of atoms, with each different type of atom being a different element.
	Living systems	7Bs.01 Understand that all organisms are made of cells and microorganisms are typically single celled.
	Earth and space system	7ESp.02 Describe how earthquakes, volcanoes and fold mountains occur near the boundaries of tectonic plates.
Procedural knowledge	The concept of variables, including dependent, independent and control variables	7TWSp.04 Plan a range of investigations of different types, while considering variables appropriately, and recognise that not all investigations can be fair tests.
	Concepts of measurements…	7TWSc.02 Decide what equipment is required to carry out an investigation or experiment and use it properly.
	Ways of assessing and minimizing uncertainty such as repeating and averaging measurements.	7TWSc.04 Take appropriately accurate and precise measurements, explaining why accuracy and precision are important.
	Mechanisms to ensure the replicability and accuracy of measurements	7TWSa.01 Describe the accuracy of predictions, based on results, and suggest why they were or were not accurate.
	Common ways of abstracting and representing data…	7TWSm.02 Use symbols and formulae to represent scientific ideas.
	The control of variables and its role in experimental design	8TWSp.04 Plan a range of investigations of different types, while considering variables appropriately, and recognise that not all investigations can be fair tests.
	The use of randomized controlled trials to avoid confounded findings…	9TWSa.02 Describe trends and patterns, identifying any anomalous results and suggesting why results are anomalous.
	The nature of appropriate design for a given scientific question…	9TWSp.04 Plan a range of investigations of different types to obtain appropriate evidence when testing hypotheses.
Epistemic knowledge	The nature of scientific observations, facts, hypotheses, models, and theories	9TWSm.01 Understand that models and analogies reflect current scientific evidence and understanding and can change.
	The purpose and goals of science as distinguished from technology…	N/A
	The values of science, such as commitment to publication, objectivity and the elimination of bias.	8TWSc.06 Evaluate a range of secondary information sources for their relevance and know that some sources may be biased.
	The nature of reasoning used in science…	9TWSp.02 Describe examples where scientist's unexpected results from enquiries have led to improved scientific understanding.
	How scientific claims are supported by data and reasoning in science	N/A
	The function of different forms of empirical enquiry in establishing knowledge…	7TWSa.02 Describe trends and patterns in results, including identifying any anomalous results.
	How measurement error affects the degree of confidence…	9TWSc.03 Decide when to increase the range of observations and measurements, and increase the extent of repetition, to give sufficiently reliable data.
	The use and role of physical, system and abstract models and their limits	7TWSm.01 Describe the strengths and limitations of a model.
	The role of collaboration and critique…	7SIC.01 Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.
	The role of scientific knowledge, along with other forms of knowledge,…	9SIC.03 Evaluate issues which involve and/or require scientific understanding.

4.3 The Competency Aspect at Cambridge Lower Secondary Science Curriculum

Table 4.15, Table 4.16, and Table 4.17 give a detailed description of the tasks that form three competencies.

Students who demonstrate the competency of *explaining phenomena scientifically* can generate explanatory hypotheses for an observed phenomenon and make predictions.

Table 4.15 PISA 2018 scientific competencies: Explaining phenomena scientifically (OECD, 2019)

Explaining phenomena scientifically
Recognising, offering and evaluating explanations for a range of natural and technological phenomena through: • Recalling and applying appropriate scientific knowledge; • Identifying, using and generating explanatory models and representations; • Making and justifying appropriate predictions; • Offering explanatory hypotheses; • Explaining the potential implications of scientific knowledge for society

Students who demonstrate the competency of *evaluating and designing scientific enquiry* can propose ways of addressing questions scientifically and critically evaluate scientific investigations.

Table 4.16 PISA 2018 scientific competencies: Evaluating and designing scientific enquiry (OECD, 2019)

Evaluating and designing scientific enquiry
Describing and appraising scientific investigations and proposing ways of addressing questions scientifically through: • Identifying the question explored in a given scientific study; • Distinguishing questions that are possible to investigate scientifically; • Proposing a way of exploring a given question scientifically; • Evaluating ways of exploring a given question scientifically; • Describing and evaluating a range of ways that scientists use to ensure the reliability of data and the objectivity and generalisability of explanations.

Students who demonstrate the competency of *interpreting data and evidence scientifically* use mathematical tools to analyze and transform data to various representations. The learners who can demonstrate this competency can create and assess arguments and conclusions on the basis of scientific evidence (Kuhn, 2010; Osborne, 2010).

Table 4.17 PISA 2018 scientific competencies: Interpreting data and evidence scientifically (OECD, 2019)

Interpreting data and evidence scientifically
Analysing and evaluating scientific data, claims and arguments in a variety of representations and drawing appropriate conclusions through: • Transforming data from one representation to another; • Analysing and interpreting data and drawing appropriate conclusions; • Identifying the assumptions, evidence and reasoning in science-related texts; • Distinguishing between arguments that are based on scientific evidence and theory and those based on other considerations; • Evaluating scientific arguments and evidence from different sources (e.g. newspaper, Internet, journals).

Table 4.18 Distribution percentages of the competencies aspect of objectives from Stage 7 to Stage 9 in Cambridge lower secondary science curriculum.

	Cambridge Lower Secondary Science Curriculum					
	Stage 7		**Stage 8**		**Stage 9**	
	f	**%**	**f**	**%**	**f**	**%**
Explaining phenomena scientifically						
Recalling and applying appropriate scientific knowledge	7	9.7	-	-	2	2.9
Identifying, using and generating explanatory models and representations	5	6.9	-	-	2	2.9
Making and justifying appropriate predictions	2	2.8	3	4.3	5	7.1
Offering explanatory hypotheses	2	2.8	1	1.4	4	5.7
Explaining the potential implications of scientific knowledge for society	3	4.2	2	2.9	2	2.9
TOTAL	19	26.4	6	8.6	15	21.4
Evaluating and designing scientific enquiry						
Identifying the question explored in a given study	-	-	-	-	1	1.4
Distinguishing questions that are possible to investigate scientifically	1	1.4	2	2.9	3	4.3
Proposing a way of exploring a given question scientifically	3	4.2	4	5.7	5	7.1
Evaluating ways of exploring a given question scientifically	3	4.2	3	4.3	3	4.3
Describing and evaluating a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations	4	5.6	5	7.1	2	2.9
TOTAL	11	15.3	14	20	14	20
Interpreting data and evidence scientifically						
Transforming data from one representation to another	1	1.4	2	2.9	4	5.7
Analysing and interpreting data and drawing appropriate conclusions.	4	5.6	6	8.6	7	10
Identifying the assumptions, evidence and reasoning in science-related texts	2	2.8	2	2.9	3	4.3
Distinguishing between arguments that are based on scientific evidence and theory and those based on other considerations	1	1.4	1	1.4	1	1.4
Evaluating scientific arguments and evidence from different sources (e.g. newspaper, internet, journals)	1	1.4	3	4.3	6	8.6
TOTAL	9	12.5	14	20.0	21	30.0

In stage 7, the percentage of competencies in all objectives are; “Explaining phenomena scientifically” 26.4%, “Evaluate and design scientific enquiry", 15.3%, “Interpreting data and evidence scientifically” 12.5%. Under “Explaining phenomena scientifically” competency “recalling and applying appropriate scientific knowledge”, under “Evaluating and designing scientific enquiry” “describing and evaluating a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations”, under “Interpreting data and evidence scientifically” competency” “analysing and interpreting data and drawing appropriate conclusions” have the highest percentage. Other than “identifying the question explored in a given study”, there is at least one objective matching with the PISA 2018 Science Framework competencies.

In stage 8, the percentage of competencies in all objectives are; “Explaining phenomena scientifically” 8.6%, “Evaluate and design scientific enquiry", 20.0%, “Interpreting data and evidence scientifically” 20.0%. Under “Explaining phenomena scientifically” competency “making and justifying appropriate predictions”, under “Evaluating and designing scientific enquiry” “describing and evaluating a range of ways that scientists use to ensure the reliability of data and the objectivity and generalizability of explanations”, under “Interpreting data and evidence scientifically” competency “analysing and interpreting data and drawing appropriate conclusions” have the highest percentage. There is no objective that could be identified matching with the “recalling and applying appropriate scientific knowledge”, “Identifying, using and generating explanatory models and representations” competencies which are under the “Explaining phenomena scientifically” and ““identifying the question explored in a given study” competency which is under the “Evaluating and designing scientific enquiry”.

In Stage 9, the percentage of competencies in all objectives are; “Explaining phenomena scientifically” 21.4%, “Evaluate and design scientific enquiry", 20.0%, “Interpreting data and evidence scientifically” 30.0%. Under “Explaining phenomena scientifically” competency “making and justifying

appropriate predictions", under "Evaluating and designing scientific enquiry" "proposing a way of exploring a given question scientifically", under "Interpreting data and evidence scientifically" competency" "analysing and interpreting data and drawing appropriate conclusions" have the highest percentage. There is at least one objective matching with the PISA 2018 Science Framework competencies.

Considering all three stages of Cambridge Lower Secondary Science curriculum, there is at least one objective matching with the competencies of PISA 2018 Science Framework.

Table 4.19 Examples to objectives of the competencies aspect of scientific literacy

COMPETENCIES		OBJECTIVES
Explain phenomena scientifically	Recalling and applying appropriate scientific knowledge.	7Bp.04 Use and construct dichotomous keys to classify species and groups of related organisms.
	Identifying, using and generating explanatory models and representations	7Cc.03 Use the particle model to describe chemical reactions
	Making and justifying appropriate predictions	7TWSp.03 Make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding.
	Offering explanatory hypotheses	9TWSp.01 Suggest a testable hypothesis based on scientific understanding.
	Explaining the potential implications of scientific knowledge for society	7SIC.05 Discuss how the uses of science can have a global environmental impact.
Evaluate and design scientific enquiry	Identifying the question explored in a given scientific study.	9TWSa.04 Evaluate experiments and investigations, including those by others, and suggest improvements, explaining any proposed changes.
	Distinguishing questions that could be investigated scientifically	7TWSp.01 Identify whether a given hypothesis is testable.
	Proposing a way of exploring a given question scientifically	9TWSp.04 Plan a range of investigations of different types to obtain appropriate evidence when testing hypotheses.
	Evaluating ways of exploring a given question scientifically	9TWSa.04 Evaluate experiments and investigations, including those by others, and suggest improvements, explaining any proposed changes.
	Describing and evaluating how scientists ensure the reliability of data and the objectivity and generalizability of explanations	7TWSc.03 Evaluate whether measurements and observations have been repeated sufficiently to be reliable.
Interpret data and evidence scientifically	Transforming data from one representation to another	9Cc.01 Use word equations and symbol equations to describe reactions (balancing symbol equations is not required).
	Analyzing and interpreting data and draw appropriate conclusions	7TWSa.01 Describe the accuracy of predictions, based on results, and suggest why they were or were not accurate.
	Identifying the assumptions, evidence, and reasoning in science-related texts.	9TWSc.01 Sort, group and classify phenomena, objects, materials and organisms through testing, observation, using secondary information, and making and using keys.
	Distinguishing between arguments that are based on scientific evidence and theory and those based on other considerations.	7TWSc.06 Evaluate a range of secondary information sources for their relevance and know that some sources may be biased.
	Evaluating scientific arguments and evidence from different sources	9TWSc.06 Make an informed decision whether to use evidence from first-hand experience or secondary sources.

CHAPTER 5

DISCUSSION, CONCLUSION, AND RECOMMENDATION FOR FURTHER RESEARCH

5.1 Discussion of the Results

This research was conducted to find out how well the Cambridge lower secondary science curriculum's objectives matched the PISA 2018 Science Framework. In this context, the Stage 7, Stage 8 and Stage 9 objectives of the Cambridge lower secondary science curriculum were examined. Considering that the curricula are decisive in the content to be taught, in the preparation of textbooks, designing activities and creating different teaching materials, it is expected that the findings of this study will contribute both to curriculum creators and science teachers. In addition, the strengths of the Cambridge Lower Secondary Science curriculum may be functional in the creation of the next Turkish middle school science curriculum.

The analysis of objectives according to three main aspects indicates that the aspect with the least percentage is context aspect with 10.0%. It is understandable for the contexts aspect to have a lower percentage than the other two aspects, however increasing the percentage of the contexts aspect can make the curriculum more effective because personal experiences (contexts) are components of the nature of science (NOS) and should be more explicitly integrated into students' scientific learning (“Chemistry Imagined: Reflections on Science” 1993; Weinburgh 2003).

While the weight of the competencies aspect is significantly more than the contexts aspect, its weight is less than the knowledge aspect. Globally competent students can use and merge disciplinary knowledge and modes of thinking acquired in school for asking questions, analyzing data and arguments, explaining scientific phenomena, and developing a position regarding a local and global issue (Boix and Jackson, 2013). Thus, increasing the weight of the competencies aspect may lead to a more effective future curriculum as well. Moreover, OECD recognizes the need to raise students' global competence as a very important component of the UN's call for quality education for all (Schleicher 2017).

Unlike knowledge and competencies aspects, no numerical data were encountered in PISA 2018 Science Framework regarding the desired distribution of items, possibly because contexts is not an aspect to be assessed. However, when the percentages related to analysis of contexts aspect are considered, it is seen that objectives matching with the global context has the highest weight. Since the Cambridge curriculum is an international curriculum, this result is predictable. The weight of objectives matching with local context is over the personal context. This is because some of the objectives matching with the global context is somehow related with local (national) context. Integrating local context to the objectives make activities and investigations more authentic and meaningful for students. To integrate personal and local contexts more teachers can choose place-based education (PBE) because PBE can provide experiences relevant to students' lives and local contexts. PBE also offers students the opportunity to gain and apply knowledge through first-hand experiences and collaboration with others in the community (NSTA, 2018). Regarding the local context, research indicates that when teens join scientific investigations of complex issues in their home communities, they gain confidence and ability to effectively address environmental issues (Ballard, Dixon, and Harris 2017).

There are five applications related to contexts aspect in PISA science framework. Among, the percentages of *health and disease* and *natural resources* applications are lower than those of the three applications. Increasing the contexts related to health and disease may increase the positive approach to biotechnology in the society as well. Based on the findings of a recent study, scientific literacy is positively associated with attitudes toward COVID-19 vaccines (Motoki, Saito, and Takano 2021).

Considering *natural resources* application, as educators, we have to teach students the significance and the conservation of natural resources since continuous population increase and rising consumption cause large-scale land conversion with deforestation and urbanization which result in the loss of biodiversity (EEA, 2010).

The analysis of the Cambridge objectives based on the knowledge aspect shows that the distribution is well balanced because all three knowledge categories weights are in the range of PISA's desired distribution of items. Procedural knowledge refers to "knowing how to" (Gagne, 1985) and is required for making observations, inferring, designing experiments, controlling variables, collecting and analyzing data, drawing conclusions, and presenting findings (Odom and Bell, 2019). Considering the importance of procedural and epistemic knowledge, existing teaching learning processes should pay attention to both the conceptual understanding of science and the components similar to those identified as 'doing science' and 'knowing about science' (Hodson, 1991).

Concerning epistemic knowledge, science is a social enterprise that progresses through the evaluation of evidence, systematic argumentation from evidence, and the collaborative debate of ideas (Bell and Linn, 2002). The expression "nature of science" commonly refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992 and 2007). Nature of science involves understanding many different elements of science (Ryder,

Leach, and Driver 1999) like science-society interactions, peer review, historical and economic dimensions (AAAS, 2009). A curriculum should encourage teachers to integrate epistemology of science more since an important number of teachers think that they often concentrate on the content and focus little on the processes when they are teaching the nature of science (Abd-El-Khalick, Bell, and Lederman 1998).

Knowledge of the methods and concepts used by scientists are often components of science teaching, but they are hardly used as an integrated process by which scientific knowledge is improved, used, and modified (NSTA, 2000). Thus, students have epistemic understandings which do not show the underlying nature of scientific knowledge (Abd-El-Khalick, 2004).

In terms of content knowledge subcategory of knowledge aspect, compared to PISA's desired distribution of items table, physical systems subcategory's weight is quite high, while living systems and earth and space systems weights are lower. Earth and space science helps students to understand the world around them in a better way. While learning the Earth and space science, students do daily observations which encourage them to discover patterns, construct models, and engage in scientific thinking. (NSTA, 2020). Considering the distribution of objectives in the current Cambridge lower secondary science curriculum, the weight of the living systems and especially, Earth and space system objectives in the upcoming curriculum can be raised.

Regarding the desired distribution of items table related to competency of PISA 2018, the distribution of objectives in Cambridge lower secondary science curriculum is close to each other. The weight of the objectives related to the "explain phenomena scientifically" competency in the Cambridge curriculum is relatively lower compared to the PISA's desired distribution. In the upcoming curriculum this weight can be increased since encouragement of student engagement in science to explain science phenomena is crucial in science teaching and learning (NSTA, Position Statement).

In the PISA framework, there is at least one objective matching with the knowledge aspect's procedural knowledge subcategory. However, some objectives about the variables, especially on controlling of variables, were given implicitly. If objectives on variables is expressed explicitly textbook writers and educators may integrate them more in teaching because control of variables is a key process skill that is crucial for scientific investigations and development of interpretable results (Klahr, 2000).). Studies found out that students come across challenges with procedural knowledge as well as conceptual knowledge when engaged with control of variables in activities (Chen and Klahr 1999; Park and Pak 1997).

One of the strengths of the Cambridge curriculum about procedural knowledge is that there are several objectives matching with "mechanisms to ensure the replicability and accuracy of measurements" since replication of scientific results is a foundation of scientific inquiry and progress. Independently carried out scientific investigations obtain similar results that are consistent throughout a research. The decisions we make every day are based on the analysis of scientific and statistical reasoning. For this reason, understanding replication of scientific results is very important, whether students aim science related careers or not (Wagler and Wagler, 2014) although it is challenging for many students to conceptually grasp replicability (Peng 2015).

In the PISA science framework, no objectives were able to be found related to "the purpose and goals of science as distinguished from technology, what constitutes a scientific or technological question, and what constitutes appropriate data". There is a need for science teachers to differentiate the matches and differences between science and technology as disciplines and successively, the practices that characterize these disciplines (Bybee, 2011). Even adults have such needs, it is obvious that middle school students already need them. Therefore, strengthening the objectives with respect to this point may increase the effectiveness of the following curricula.

In the Cambridge curriculum just one objective (stage 9) is matching with the "Evaluate and design scientific enquiry" sub competency's "Identifying the question explored in a given scientific study" task. Questions are essential components for science and science learning. Scientific questions arise in various ways, but not all questions in science classrooms are "scientific questions" (NGSS Lead States, 2013). Since inquiry is the process of asking questions and carrying out experiments to figure out the natural world (NSTA, 2004), inquiry-based instruction, in other words asking questions, improves students' science content knowledge in addition to their competencies (Lee et al. 2010).

In the upcoming curricula, including objectives that are related to identifying assumptions, reasoning and evidence may make the curriculum more effective. Since an essential component of encouraging scientific literacy is to develop disciplinary literacy practices, such as obtaining information from text and sharing investigation results through talk and writing. (NSTA 2022; Fitzgerald 2012).

Especially with the growing social media, claims or information which were not formed in a scientific way, in other words pseudoscience, are getting more popular. There is no doubt that middle schoolers also use social media often. Thus, it is crucial that students can distinguish science from pseudoscience. In a study conducted by Afonso and Gilbert (2010), it was found out that students were unaware of the demarcation criteria between science and pseudoscience. Considering that the lack of scientific literacy usually pushes people to turn to pseudoscience, it is imperative to foster scientific literacy in order to reduce the effects of pseudoscience. In the upcoming curriculum, thus integrating "distinguish between arguments that are based on scientific evidence and theory and those based on other considerations" task into more objectives may create a more effective curriculum.

5.2 Conclusions

In this study, Cambridge Lower Secondary Science curriculum objectives were examined according to aspects of PISA 2018 science literacy - contexts, knowledge, and competency.

The weight of the objectives that match with the contexts aspect is less, increasing the number and weight of objectives related to the contexts aspect in upcoming curriculum studies can make the curriculum more effective.

Considering the knowledge aspect, the weight of the content knowledge is dominant compared to the other two categories of knowledge aspect. In future curriculum studies, the weight of objectives related to procedural knowledge and epistemic knowledge are recommended to be raised. It is believed that if the educators currently teaching this course take more time on objectives that match with procedural and epistemic knowledge, the learning will be more meaningful, and students' general and PISA achievement scores will significantly increase.

In terms of competencies aspect, the distribution of the objectives of the Cambridge Lower Secondary Science curriculum is similar to the desired distribution of items of PISA. Only the application "explain phenomena scientifically" falls slightly below the PISA desired distribution. The weight of this application can be increased in future curriculum studies with a few changes.

In addition to what was stated above, it was determined that the objectives of the Lower Secondary Science Curriculum do not include some applications at all, for example, *the purpose and goals of science as distinguished from technology*. It is believed that the integration of these applications will lead to a more effective future curriculum.

Finally, the strong sides of the Cambridge Lower Secondary Science Curriculum can be used in the creation of the next Turkish Middle School Curriculum.

5.3 Recommendations for Further Research

- Similar studies can be conducted for reading literacy and mathematics literacy.
- Similar studies can be conducted for elementary school and secondary school Cambridge curricula.
- Similarities and differences between levels can be examined in more detail.

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APPENDICES

A. TURKISH SUMMARY / TÜRKÇE ÖZET

Bu çalışmada Cambridge Ortaokul Fen Bilimleri kazanımları, Uluslararası Öğrenci Değerlendirme Programı (PISA) 2018 Fen Okuryazarlığı Değerlendirme Çerçevesi'nde bağlamlar, bilgi türleri ve yeterlikler kriterlerinde analiz edilmiştir. Bu araştırma, Uluslararası Cambridge Ortaokul Fen Bilimleri Müfredatı kazanımlarının PISA 2018 Bilim okuryazarlığı boyutlarıyla ne oranda eşleştiğini bulmak için yapılmıştır. Bu kapsamda Cambridge müfredatının 7., 8. ve 9. seviye kazanımları incelenmiştir. Derslerde öğretilmekte olan içeriklerin, ders kitaplarının, öğretim etkinliklerinin ve farklı öğretim materyallerinin hazırlanmasında müfredatın belirleyici olduğu göz önüne alındığında, bu çalışmanın hem müfredat oluşturucularına hem de fen bilgisi eğitimcilerine katkı sağlaması beklenmektedir.

Bilgi türleri ve yetkinlikler boyutlarından farklı olarak PISA 2018 Fen Okuryazarlığı Değerlendirme Çerçevesi'nde bağlamlar boyutunda arzu edilen dağılıma ilişkin sayısal verilerle karşılaşılmamıştır. Bununla birlikte, bağlamlar boyutu ilgili yüzdeler analiz edildiğinde, kişisel bağlamları vurgulayan kazanımların ağırlığının arttırılmasının daha dengeli bir dağılım oluşturacağı söylenebilir.

PISA'nın arzu edilen madde dağılımı tablosuna kıyasla, fiziksel sistemlerle ilgili kazanımların ağırlığı oldukça yüksekken, canlı sistemleri ve Dünya ve uzay sistemleriyle ilgili kazanımların ağırlıkları düşüktür. Bu durum göz önünde bulundurulduğunda, bir sonraki müfredat oluşturulurken, fiziksel sistemler kazanımlarının ağırlığı azaltılırken, canlı sistemleri ve Dünya ve uzay sistemleri kazanımlarının ağırlıkları arttırılabilir.

Kazanımlar, bilgi türleri boyutuna göre analiz edildiğinde, içerik bilgilerinin dağılımı arzu edilen dağılımın çok üzerindedir. Öte yandan, epistemik bilgilerin ağırlığı, PISA'nın istenen madde dağılımı tablosuna kıyasla düşüktür. Gelecekteki müfredat çalışmalarında, epistemik bilgiler ile ilgili kazanımların sayısı artırılabilir ve şu anda bu dersi veren öğretmenler epistemik bilgiler ile ilgili kazanımlara daha fazla odaklanabilir.