UNIVERSITY OF GOTHENBURG

DEPARTMENT OF MARINE SCIENCES

OCEAN LITERACY IN THE SWEDISH CURRICULUM

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Thesis project for Master of Science (120 hp) with a major in Sea and Society
Degree Project for Master in Sea and Society MAR480 (30 credits)
Second Cycle

Semester/year:	Spring 2022
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Popular scientific summary

The prosperity of humanity has been highly interconnected with the well-being of the ocean. However, with human activity increasingly putting a lot of pressure on the ocean, it is necessary that we raise awareness and educate the society for a sustainable future. The Ocean Literacy movement set this as one of its main goals, in order to strengthen the inclusion of ocean-related topics in formal (i.e., school) and informal (i.e., museum) education. Within this movement a list of 7 essential principles and its 45 fundamental concepts have been established which address ocean-related topics that students should know until the end of high school, to become ocean literate.

The aim of this thesis was to show the salience of these concepts within the Swedish curriculum of the environmental subjects Biology, Physics, Chemistry and Geography. To analyze this, a summative content analysis method was used which allows the researcher to determine the underlying meaning of words and interpret the usage of them. It showed that the frequency of occurrence of the 7 essential principles was rather low. Only two (principles 6 and 7) were well represented which address the interconnectivity of humanity with the ocean and the unexplored nature of the ocean. The other principles showed a low occurrence and are likely to be poorly addressed in the classroom. Furthermore, opportunities for an improved inclusion of the ocean in the Swedish curriculum were identified and examples were given. Additionally, the extent to which the ocean is included in school lectures depends on the teachers´ beliefs and values. Therefore, well-educated and trained teachers are needed.

This research paper revealed that the presence of the ocean as a topic is still restricted in the Swedish curriculum. To increase the awareness about the ocean, it is necessary that ocean-related topics are more prominent in formal education in Sweden, to pave the way and contribute to a healthier ocean and a sustainable future.

Abstract

The health of the ocean is related to the health of humanity. Thus, it is important to raise society's awareness about the ocean. This thesis aims at identifying the presence of the Ocean Literacy essential principles and fundamental concepts in the Swedish curriculum, with a focus on the subjects of Biology, Physics, Chemistry and Geography in grades 1-9. The analysis revealed that all fundamental concepts are represented, even though many of them have a low occurrence. Principles 6 and 7, who address the interconnectivity of humanity with the ocean and the unexplored nature of the ocean, are the most represented ones in the curriculum. Whereas the other principles present a low occurrence. There are numerous opportunities to include the ocean in the Swedish curriculum and respective examples are provided. A clearer mentioning of the marine environment in the learning outcomes is suggested in order to contribute to a more sustainable future.

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1. Introduction

1.1. The importance of the ocean

The air we breathe, the water we drink and the food we consume are all connected to the ocean that covers more than 70% of the Earth. Not only does the ocean circulate the water around the world, it also is the life support system of Earth (Koutsopoulos & Stel, 2021). The ocean is the discrete regulator of the climate and weather as it takes up about 25% of the emitted carbon and more than 90% of heat energy (Turley et al., 2021). The ocean provides ecosystem services (i.e., pollution control, storm protection, carbon sequestration), goods and cultural benefits (i.e., religious significance, inheritance to future generations) (Barbier, 2017). Since the beginning of the industrial revolution, the ocean has been under tremendous pressure by many human-driven stressors, such as climate change, pollution, overfishing, ocean acidification as well as habitat and biodiversity loss (Aricò et al., n.d.; Kelly et al., 2021). Since the health of the ocean is related to the health and well-being of humanity (Sandifer & Sutton-Grier, 2014), it is essential for humans to understand their impact on the ocean and act accordingly to protect it.

1.2. Ocean Literacy

As Cava et al. (2005, p. 9) defined, an ocean literate person "understands the fundamental concepts about the functioning of the ocean, can communicate about the ocean in a meaningful way, and is able to make informed and responsible decisions regarding the ocean and its resources." The understanding of the ocean´s influence on humanity and our influence on the ocean is the overarching aspiration of Ocean Literacy (OL). Implementing ocean-related topics into the curriculum to understand this essential two-way connection is crucial for a sustainable ocean (Fauville et al., 2018). Therefore, raising awareness and behavioral change is needed (Costa & Caldeira, 2018). Environmental and science education in schools prepare students to make changes in forthcoming policies that will benefit the protection and conservation of the marine environment (Ferreira et al., 2021). Furthermore, OL has to be accessible to every student, regardless of their location, and to provide resources and different learning approaches (Santoro et al., 2022).

1.3. The history of Ocean Literacy

In the mid-1990s, scientists and educators realized that ocean-related topics were hardly mentioned in the National Science Education Standards for the grades K-12 (Schoedinger et al., 2010). As a result, in 2002, ocean educators and scientists in the United States came together to identify ocean content that needed to be implemented into formal and informal education (Cava et al., 2005). They identified seven Essential Principles (Figure 1) with its 45 Fundamental Concepts (see Appendix A) that constitute what students should know about the ocean by the end of high school (Schoedinger et al., 2010). Therefore, the Ocean Literacy Framework was developed including the following four documents (Payne et al, 2022):

- Ocean Literacy - The Essential Principles of Ocean Sciences K-12
- Ocean Literacy Scope and Sequence for Grades K-12
- Alignment of Ocean Literacy to the Next Generation Science Standards
- International Ocean Literacy Survey

The focus of this thesis is on the document "Ocean Literacy - The Essential Principles of Ocean Sciences K-12", in particular the revised version 3.1 from May 2021 (NOOA, 2020).

Figure 1

The seven principles of Ocean Literacy

Note: Figure taken from Santoro et al., 2022

Around 2004, this OL movement became global and other regions of the world (e.g., Europe, Asia) recognized OL and made it one of their objectives to implement (Fauville et al., 2019). Moreover, the United Nations (UN) recognized the OL concepts, which became one of the priorities for the Decade for Ocean Science for Sustainable Development (2021 - 2030) as

support for the Sustainable Development Goal (SDG) 14 (Mokos et al., 2020). [The SDGs consist of 17goals and are summarized in a plan by the UN to work for a better future (UN, n.d.).] In recent years, the effort and inclusion of the OL movement got support from all over the world. Many associations helped to create networks and promote the concept of OL in formal and informal education (Santoro et al., 2022).

1.4. Swedish education system

Schooling in Sweden is divided into three main stages. The first one is the Swedish preschool (förskoleklass) which is voluntary education. It prepares the children from the age one to five for elementary school, which starts when they turn six years old (Frogner et al., 2022). The Grundskola is the second stage and divided into the grades 1-3 (lågstadiet), 4-6 (mellanstadiet) and 7-9 (högstadiet) which constitute the compulsory school years (The Swedish education system, 2021). Finally, the pupils have the option to attend the upper secondary school for three more years (Gymnasium) in order to qualify to attend higher education (The Swedish education system, 2021).

In Sweden, the curriculum for formal education is determined by the state and has to be followed by public and private schools (Lundström & Parding, 2011). A curriculum is an official document providing an overview on the organization, the teaching and the assessment of the education system. The curriculum plays an important role in the way of implementing teaching and the planning process for Swedish teachers (Knekta et al., 2022).

The Swedish curriculum is structured in the following way. It begins with the "Fundamental values and tasks of the school" and "Overall goals and guidelines" which give an overview of the aim of the teaching. The curriculum states that the pupils should be able to discuss topics in a scientific and meaningful way, which relates to the definition of an ocean literate person by Cava et al. (2005). Further on, the aim and core content of the "Preschool class" and "School-age educare" are described. The main body is the Syllabus, which describes the learning outcomes (LOs) for each subject. This thesis is focusing on this section of the curriculum and it is further described in the Methodology (see section 2).

1.5. Previous research

This section discusses previous research comparing ocean-related topics to school curriculum. Guest et al. (2015) set up quizzes for students in Nova Scotia, Canada. The result showed that

the students' (age 12 - 18) marine knowledge was under 50%, which demonstrated the gap even in coastal communities. Additionally, a cross-cultural study was conducted with students from Italy, Greece and Croatia (Mogias et al., 2019). Surveys about general knowledge and a few region-specific questions were established to see the current state of the pupils' knowledge from grades 3-6. It revealed that their ocean-related knowledge was rather moderate.

The National Marine Educators Association in collaboration with the ocean science community showed the importance of ocean components in the American curriculum from the grades K-12. Two OL documents ("Ocean Literacy: The Essential Principles of Ocean Sciences for Learners of All Ages" and "The Ocean Literacy Scope and Sequence for Grades K–12") were compared with the document Next Generation Science Standard (which identifies the K-12 science content standards). Therefore, a 4-point rating scale was used. It gives an overview of how the OL concepts should be mentioned or taught within a core idea (a core idea is comparable to a LO in the Swedish curriculum) depending on the grade. They were rated in the following manner:

- 1: The alignment should be obvious and does not need any explanation.
- 2: The OL principles and concepts are essential for the students to fully understand the core ideas.
- 3: Ocean-related examples fit here to help understand the core ideas.
- 4: The core idea helps students to understand the essential principles and concepts of OL.

Sometimes no alignment was found and therefore, no rating was given. It can be used as a guide for the teachers on how to implement the OL concepts in the classroom to achieve an ocean literate society (NMEA, 2010).

Mogias et al. (2021) conducted a content analysis on Greek primary school textbooks. The textual and visual elements were compared with the Ocean Literacy principles and concepts. Therefore, a deductive coding scheme was applied to identify the frequency of occurrence of the OL concepts. It showed that ocean science issues were limited in the textbooks. The Ocean Literacy Principle (OLP) 1 and OLP6 were well represented. The OLP4 and OLP7 had the weakest appearance.

Sá-Pinto et al. (2021) created a framework that teachers can use to implement ocean-related topics in their lessons. The main focus was on the subject biology and evolution in grades 1 to 9 in Greece, Italy, Portugal and Slovenia. The established framework can be used to analyze and compare school curricula with respect to evolution, which can support curricula development.

Pocze et al. (2020) analyzed the curricula of nine countries (Belgium, Croatia, Finland, France, Germany, Greece, Portugal, Romania and U.K.). Their goal was to find entry points for the ocean. First, keywords were established to be searched through the curricula in order to identify the sections where OL would fit in. In the second phase, entry points in the curricula were identified and examples for improvement were given. This study can serve as a guide for teachers to get an overview of the important ocean topics to teach in each country's natural science subjects in primary and secondary education.

Pazoto et al. (2022) compared the Brazilian curriculum on a regional and national level with the OL principles and concepts. The analysis revealed that the regional curricula aligned more with the OL concepts than the national curriculum. However, this study showed that 43 concepts were poorly covered in the Brazilian curriculum.

The purpose of this thesis is to show and examine the alignment between the OL principles and concepts and the Swedish curriculum. The research question is: To what extent are the OL principles and concepts salient in the Swedish curriculum in the subjects Biology, Physics, Chemistry and Geography?

2. Methodology

To analyze the current state of ocean-related topics in the Swedish curriculum, the OL principles and concepts will be used. These concepts will be compared with the "Curriculum for the compulsory school, preschool class and school-age educare" (Skolverket, 2018). The curriculum´s Syllabus includes all subjects taught. The LOs, within each subject, represent the compulsory topics that need to be reached by the end of each grade band. Therefore, LOs are the unit of analysis of this study.

A summative content analysis (Hsieh & Shannon, 2005) was conducted to identify the alignments between the LOs and the OL principles and concepts. This analysis focuses on "the contextual use of words or content" in order to interpret the content (Hsieh & Shannon, 2005, p. 1283). Through this method the underlying meaning of the analyzed words and content can be identified. Alternative terms can be recognized so that the context can be examined and not only the obvious elements will be found. The summative content analysis begins with identifying the occurrence of decided contents (Hsieh & Shannon, 2005), which were in the case of this study the 45 OL concepts. These were identified by two researchers independently.

The aligned concepts, of each individual work, were then compared, discussed and a final alignment was agreed upon.

Some LOs are verbatim identical in several subjects. For example, the LO “Simple systematic studies. Planning, execution and evaluation.” is present in both subjects Physics and Chemistry. This has been done to prevent repeatedly analyzing the same LOs. Further on, the alignment between OL concepts and the LOs were primarily descriptive and were visualized in a table.

3. Analysis

In Appendix B the core contents are listed with the associated LOs. Their occurrences within the curriculum are listed along with the concepts they align with. The following sections are the different core contents and their allocated LOs. Within these sections are the alignments between these LOs and the OL concepts described.

3.1. Seasons of the year in nature

This core content is present in Biology, Physics and Chemistry in the grades 1-3. **LO2** aligns with 3A, B, C, F, 5D and 6A. The ocean has the main influence on our climate and is therefore affecting the seasons (Turley et al., 2021). **LO3** aligns with the concepts 5A, B, C, D and E. **LO4** is aligning with the concepts 5B, 6D and 6B.

3.2. Body and health

This core content contains the functions and senses of our body. **LOs 5**, **8** and **9** focus on human well-being which could relate to the ocean, thus aligning with concept 6A. Fish as a food source as in 6B and 7C aligns with these LOs as well as the recreational interconnection of humanity with the ocean as mentioned in 6C. Furthermore, **LO14** states the evolutionary mechanisms which are represented in the concept 4B.

3.3. Materials and substances in our surroundings

This core content is stated in all three subjects of the grades 1-3. **LO18** addresses the interaction of humanity with natural resources which is stated in the concepts 6B, D, E, and G. Further on, **LO18** also aligns with the concept 1H, which describes the limitation of resources and 7C, concerning the increase of ocean resource usage.

The ocean covers almost 71% of the Earth's surface and 95% of water on Earth is stored in the ocean (Koutsopoulos & Stel, 2021) which means that the majority of the Earth's surface is covered with salt water and therefore essential to learn about it. Most of those transitions occur in the ocean which is represented in the concepts 1D, E, and F and 3D, that are aligning with **LO19**.

3.4. Narratives about nature and science

LOs 22 and **23** align with concept 6C, which addresses the connection between the ocean and cultures. Many myths in cultures were passed on through stories and had individual value and meaning for those cultures (Nunn, 2012). These mysteries, myths and oral traditions about science in other cultures can differ from our science standard. However, this wisdom does not have to be wiped out or standardized, much can be learned from it as well (Avery & Hains, 2017).

3.5. Methods and ways of working & exploring reality

LOs 24, **25**, **26** and **27** align with the concepts 7B and F. They describe that exploration, experimentation and collaboration among scientists is needed to get a better understanding of the complex systems of the ocean. **LOs 28**, **29** and **30** align with 7B, E and F. The **LOs 31**, **32** and **33** include mathematical models, technologies and interdisciplinary research, which aligns with 7B, D, E and F.

Questioning different sources and their credibility from concept 7F is represented in **LOs 36**, **37** and **38**. This applies also to **LO40**. In **LO41** are 7F and the models of 7E included. The use of new technologies from 7D aligns with the **LOs 34**, **42** and **43**.

LO35 states the identification and categorization of animals, plants and other organisms which aligns with the concepts 5A, B, C, D, and E. The evolution, identification, categorization and relationship of organisms from **LO44** is described in the concepts 4B, 5A, C and D.

Naming water basins from Sweden and Europe from the **LOs 45**, **46** and **51** aligns with 1A and G. **LO45** also states their features, which is described in 5I.

The different methods and processes of conducting research are stated in the **LOs 48** and **50**. Therefore, these two LOs align with 7D, E and F. In **LO53** this research is described in more detail and matches with 7A, B, D, E and F. Studying the impact of humanity on nature on a local scale is mentioned in the **LOs 49** and **54**. Understanding this interconnection and the impact we have align with 6A, B, C, D, E, F, G and 7B. In **LO55** are interdisciplinarity and new technologies represented from the concepts 7D and F.

3.6. Worldviews

LO59 aligns with the importance of the ocean for many cultures, as mentioned in 6C. The **LOs 60**, **61**, **62**, **63**, **64** and **65** address the history of discoveries and their importance for society as well as the worldview on the different subjects Biology, Physics and Chemistry. These statements are represented in all the concepts of principles 6 and 7, which are describing the interconnection of humanity with the ocean and that our ocean is largely unexplored. The **LOs 66**, **67** and **68** align with all the concepts of principle 7. The theories and models of the **LOs 69**, **70** and **71** match with the mathematical models and interdisciplinarity of the concepts 7E and F. The **LOs 76** and **77** state the development of life and biodiversity within the ocean. This aligns with 4A, B, C and 5C. In **LO77** is also the adaptation of organisms mentioned and therefore it aligns additionally with 5D.

In the **LO78** the focus is on the motion of the solar system, which seems in the first place not relevant for ocean-related topics. Nevertheless, the ocean is influenced by the solar system and influences the weather and therefore also the seasons of the year. If we take this into consideration, the concepts 1C, 3A, B and C as well as 6A are mentioning the ocean as the weather moderator.

3.7. Nature, society and everyday life

LO81 aligns with the concepts 4B, 5A, B and C, which are mentioning the life of organisms in the ocean. Furthermore, it aligns with the concepts 4A, C, 5D, E, F and G that cover the oxygen our ocean provides through photosynthesis and the ecological aspects. The knowledge and ecological relationship about agriculture and fishery in this LO represents the connection of water basins and resources we get from it, as mentioned in 1G, 5H, I, 6B, C, D, E, G and

7C. This is the first and only time an aquatic term is mentioned in the subjects Biology, Physics, Chemistry and Geography

LO82 aligns with many concepts as well. The energy flow of ecosystems is described in 1C, 2A, 3A, B, C, D, E, F, G and 5D. The recycling of materials matches with 2D, 6B, G and 7C. Photosynthesis is represented in 4A and C as well 5B, F and G, which are matching with the ecosystem services. The **LOs 88** and **89** are focusing on photosynthesis as well. Therefore, they align with 4A, C, 5B, F and G. Food as a source for our health is stated in the **LOs 90** and **91**. Ocean food is mentioned in the concepts 6B and 7C. That the ocean is beneficial for our health is mentioned in 6A.

The **LOs 92** and **93** state the energy flows and sources as well as their impact. For energy sources from the ocean 1C, 3A, B, C, D, F, G and 6B align with these LOs. The concepts 6D, G, 7B and C represent the sustainable use of resources and our responsibility. Energy sources are also mentioned in the **LOs 94** and **95**. Thus, they align with 6B, D, G and 7C. Additionally, **LO95** includes 7B. The concepts 3A, B, C, D, E, F, G, 6A and F are mentioning the importance of our ocean for our weather and the causes, which aligns with the **LOs 96** and **97**.

Within the **LOs 98**, **99**, **100** and **101** is our use of materials, their life-cycle and the recycling described. This aligns with the concepts 6B, D, G and 7C, which are mentioning the materials the ocean provides for us and our responsibility in using them in a sustainable way. A similar meaning has **LO102**, which matches with 6B, D, G, 7C and includes the recreational part from 6C. The concepts 3G, 6B, D, E, G, 7B, and C are represented in **LO103**. Ocean energy will provide clean energy globally in the future, but more research has to be done (Melikoglu, 2018).

LO104 aligns with the concepts 1C, E, F, 2C, 3E, F, G, 5F, 6D and E, which are describing the ocean as a carrier for substances and its distributing mechanism. Water is a precious resource and our use of it is stated in the concepts 4C, 6A, D and G, which aligns with **LO105**.

The **LO106** relates to sustainable development. Therefore, the 6th principle and all of its concepts are matching as well as the concepts 7B and C. Ecosystem services from the ocean are providing important goods and services for humanity (Barbier et al., 2011), which is represented in 3E, F, 4A, B, C, 5A, B, C, D, E, F and I.

The **LOs 107**, **108** and **123** are mentioning the particle models and their properties. Those properties of water and the ocean are represented in 1C, D, 2B, C, E, 3B, C, D, E, F, G, 5G and H. **LO109** is about the different ecosystems in the non-local and local environment, which aligns with all the concepts of principle 5. In **LO110** is the impact of people on nature

described, which aligns with all the concepts of the 6th principle and 7C. The **LO111** addresses many different concepts, which are 5C for the biodiversity, 3G, 6D, E, 7A, B for the threats, 5A, B, D, E, F, G, H, I for the favoring factors and 6G, 7C and F for the public discussions.

LO112 aligns with all the concepts of principle 5, which is about ecosystems. Furthermore, are the studies of ecological perspectives represented from 7A, B, D, E and natural resources in 6B and 7C. **LO113** is mentioning the interconnection of the ocean with humans and therefore aligns with all the concepts of principle 6. Additionally, it matches with the concepts about current research and the understanding of the ocean as in 3G, 7A, B, C and F. The greenhouse effect and climate change are mentioned in **LO115**, which aligns with 6A, D, E, F, G and all concepts of principle 3 as well as the mathematical models to describe those from 7E.

Noise pollution can have a strong impact on the organisms in the ocean (Peng et al., 2015). In **LO117** is the transmitted sound and the ways of recording it mentioned, which aligns with the concept 6D, that addresses sound pollution and 7D, where the new technologies in recording it can be discussed. **LO126** mentions the properties of water as in 1C, D, E, 3B, D and its circulation is represented in 1A, F and G. **LO124** states the properties and composition of air which aligns with the concept 4A since most of the oxygen comes from the ocean.

LO127 includes renewable energy sources as in 1C, H, 6B, 7C and the impact they can have from the concepts 1E, 6D, F, G, 7B, which we need to understand and can affect the climate. The ocean as a moderator for the climate is mentioned in all concepts of principle 3 and 6A. The **LO128** aligns with the circulation of the water as in 1C, F, G and the importance of the right pH as mentioned in 6E. Furthermore, the chemical processes of the carbon produced by the ocean from 2D and 5B. Additionally the effect on the climate from all concepts of principle 3 and 6A as well as the oxygen produced from 4A and C. Humanity's impact and responsibility are described in 6D and G. The properties of carbon and its circulation is described in **LO129**, which aligns with the concepts 1E, 2A, D, 3A, E, F and 5B.

3.8. Living together, in the neighborhood and in the world

The **LOs 134**, **140**, **144**, **147** and **149** are describing the history, narratives and activities in the local area, which sums up the cultural aspects as in 6C. This applies to **LO146** as well and it has added the use of natural resources from 6B. The causes and consequences of moving within a country from the **LOs 135**, **159** and **163** are mentioned in 3G, 6B and F. The rise of the sea

level from 1D can affect the distribution of population and therefore, is aligning with **LO159** as well. Our responsibility for the environment from 6G is represented in **LO137**.

The conditions in nature and the climate from **LO139** align with all concepts of the principles 1, 2, 3, 4 and 5. Additionally, the population and settlements are matching with all concepts of principle 6. Naming the continents and oceans as well as describing the way they were created in **LO145** align with 1A, B, C, G, 2B, C and E. In **LO148** are the traces of nature mentioned and align with the concepts 2A, B, C, E and 6C.

Environmental issues and our behavior in everyday life from **LO151** are described in 3F, G 6B, D, G and 7C. **LO155** is mentioning the current social questions, which aligns with 3G, 6A, B, D, E, F, G, 7A, B and C. The **LO156** describes the surface of the Earth that aligns with the concepts 1A, B, C, D, G, 2A, B, C and E. Furthermore, the consequences on people and nature align with 3G, 6A, B, C, D, E, F and G.

Natural landscapes and its features from **LO157** align with the concepts 1A, B, C, D, 1E, F, G, 2A, B, C, E. Natural resources and where they exist is described in **LO158** and aligns with 1C, E, F, G, H, 4A, C, 6A, B, D, G and 7C. The climate, its effect on people and vegetation zones from **LO160** are described in the concepts 1C, E, 3A, B, C, D, E, F, G, 5E, F, G, H, I, 6A and F. **LO161** is mentioning the climate change and its consequences, which aligns with 1C, 3A, B, C, D, E, F, G, 6A, B, D, E, F and G. Transportation of goods and resource management from **LO162** is described in the concepts 6B and D.

3.9. Environment, people and issues concerning sustainability

Humanity´s contribution to sustainable development from **LO164** aligns with the concepts 3G, 6D, E, G and 7C. The **LO165** describes the unequal access to education, healthcare and natural resources. Therefore, this LO is aligning with 3G, 6B, D and G. Vulnerable areas and their threats are mentioned in **LO166**, which aligns with 2B, C, 3D, G and 6F. The ways those vulnerable areas can be identified and the risks mitigated states the **LO167**. This LO aligns then with the concepts 6F, G, 7B, D, E and F.

The use and management of resources from **LO168** is represented in 6B and D. **LO169** describes different renewable energy sources, which aligns with 1C, 6B, D and 7C. The **LOs 170** and **171** are mentioning the cause of poverty and our health. The ocean can have an influence on this which is stated in 3G, 6A, B, D, F and aligns with both LOs.

4. Results

In total, the analysis identifies 892 alignments (Table 1) between the OL concepts and LOs in Biology, Physics, Chemistry and Geography.

Table 3

Alignment of the Ocean Literacy essential principles and fundamental concepts with the Swedish curriculum of the compulsory school years 1-9

*	LO	Principle 1								Principle 2					Principle 3							Principle 4			Principle 5								Principle 6							Principle 7						Σ
		A	B	C	D	E	F	G	H	A	B	C	D	E	A	B	C	D	E	F	G	A	B	C	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	A	B	C	D	E	F	
3	1																																														
3	2														3	3	3			3								3							3														18
3	3																								3	3	3	3	3																		15
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3	5																																	3	3	3							3						12
3	6																																															
3	7																																															
1	8																																	1	1	1							1						4
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*	LO	Principle 1								Principle 2					Principle 3							Principle 4			Principle 5									Principle 6							Principle 7						Σ
		A	B	C	D	E	F	G	H	A	B	C	D	E	A	B	C	D	E	F	G	A	B	C	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	A	B	C	D	E	F	
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*Occurrence of LO in the Swedish curriculum

The way they were distributed in percentage is displayed in Table 2 and Table 3. It shows that the OL concepts were equally distributed among the four analyzed subjects.
Separated by grade within each subject, the occurrence of the concepts shows that they were increasing through the advancing grades, except for Geography where the derived concepts were almost equally distributed throughout the grades of the subject.

Table 2

Distribution of alignments of Ocean Literacy concepts among the subjects

	Biology		Physics		Chemistry		Geography	
Grades	Concepts	%	Concepts	%	Concepts	%	Concepts	%
1-3	38	4,26	38	4,26	38	4,26	80	8,97
4-6	89	9,98	48	5,38	77	8,63	72	8,07
7-9	113	12,67	102	11,43	117	13,12	80	8,97
Σ	240	26,91	188	21,08	232	26,01	232	26,01

Table 3

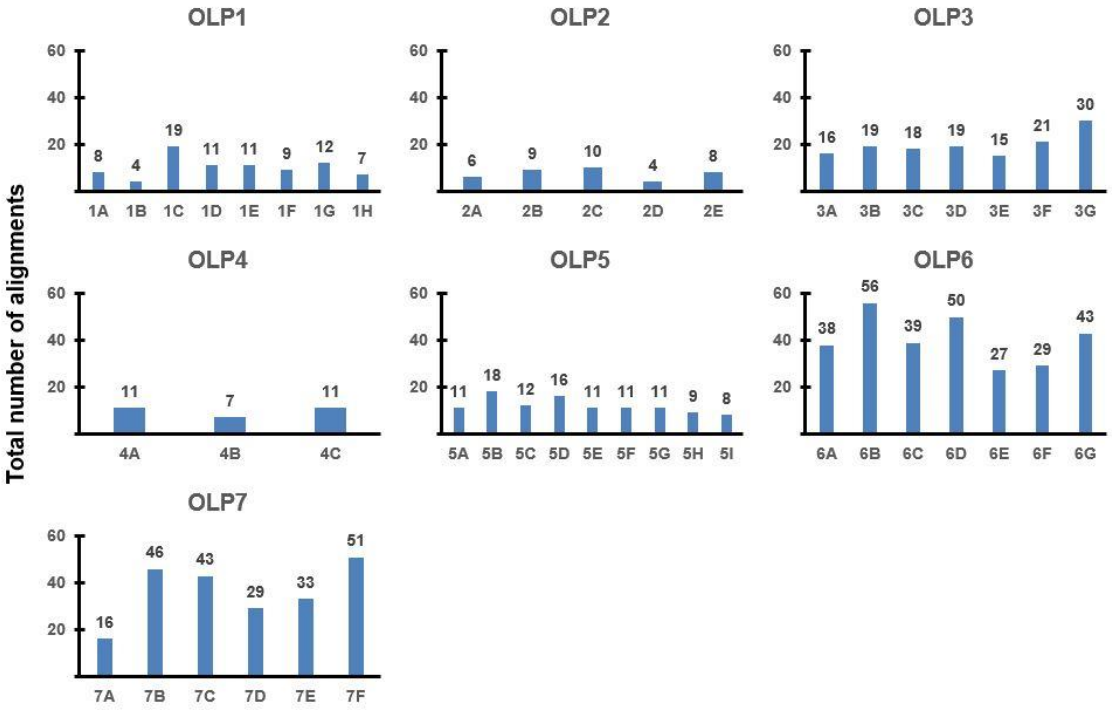
Distribution of alignments of Ocean Literacy concepts among the grades

Grades	Concepts	%
1-3	194	21,75
4-6	286	32,06
7-9	412	46,19

The total numbers of alignments per concept of the four analyzed subjects is represented in Figure 2. It shows that the concepts 1B and 2D align the least and are supposedly addressed poorly among these subjects. Furthermore, the concepts 1A, F, H, 2A, B, C, E, 4B, 5H and I align 10 times or less across the 222 analyzed LOs.

Figure 2

The total number of alignments per Ocean Literacy principle and concept among the four subjects Biology, Physics, Chemistry and Geography



By looking at the frequency of occurrence from the concepts of each principle summed up, it is evident that the principles 2 and 4 are poorly addressed and have the least occurrence among the subjects. Yet, to identify their occurrence, the principles have to be put in relation to the amount of concepts they cover. Principle 4 includes only three concepts and therefore it is likely that it will occur less than principle 5, which includes nine concepts. To eliminate this problem, the average of how often a concept of a principle occurs was calculated. In particular, the total number of the aligned concepts from a principle has been divided by the number of concepts this principle contains. The percentage of these averages was calculated from the total of the 222 LOs. This brought each principle to the same denominator so that they can be compared on an equal basis.

These results, which are represented in Figure 3, show that the OLPs 1, 2, 4 and 5 aligned around 5% or less among the four subjects and therefore are likely to be poorly addressed. On average an OLP occurs across Biology, Physics, Chemistry and Geography at a rate of 8.71%.

Figure 3

The average occurrence of an Ocean Literacy Principle per total number of learning outcomes in percentage

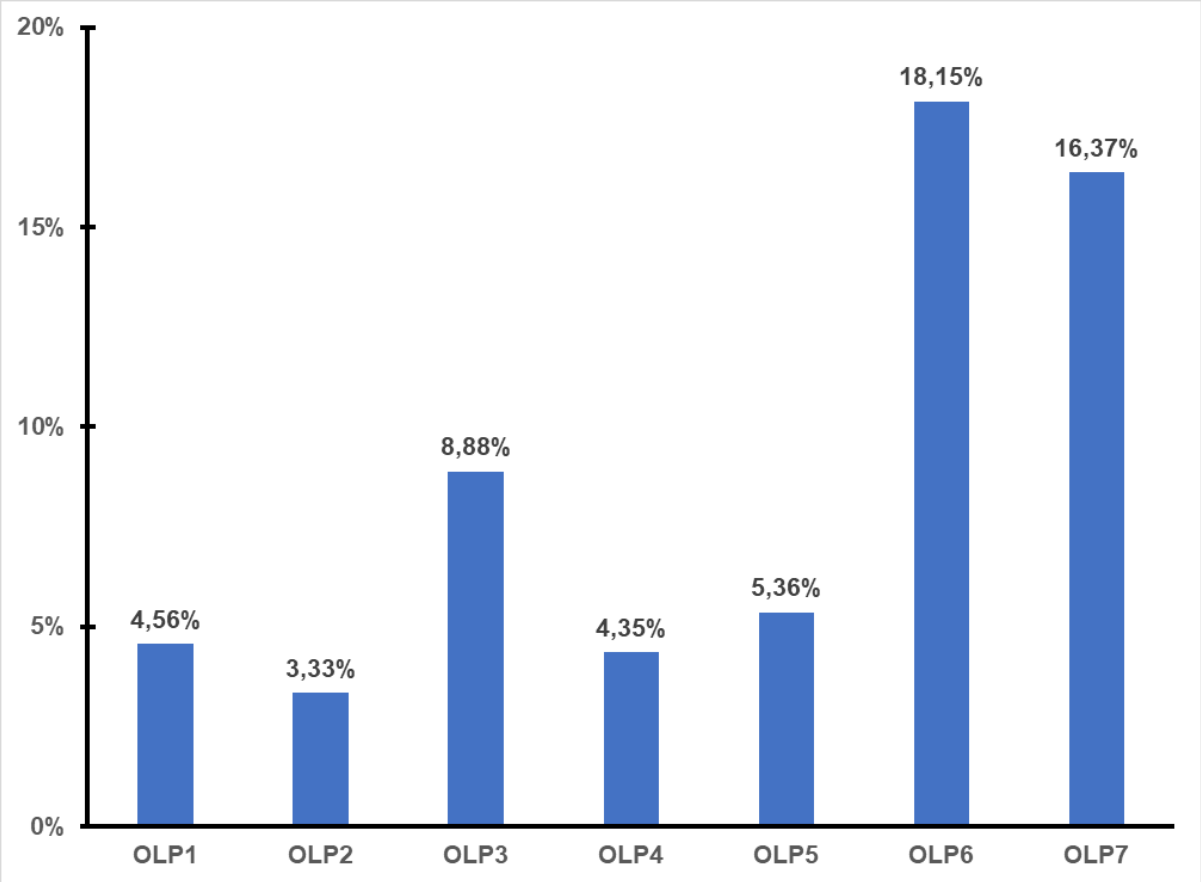
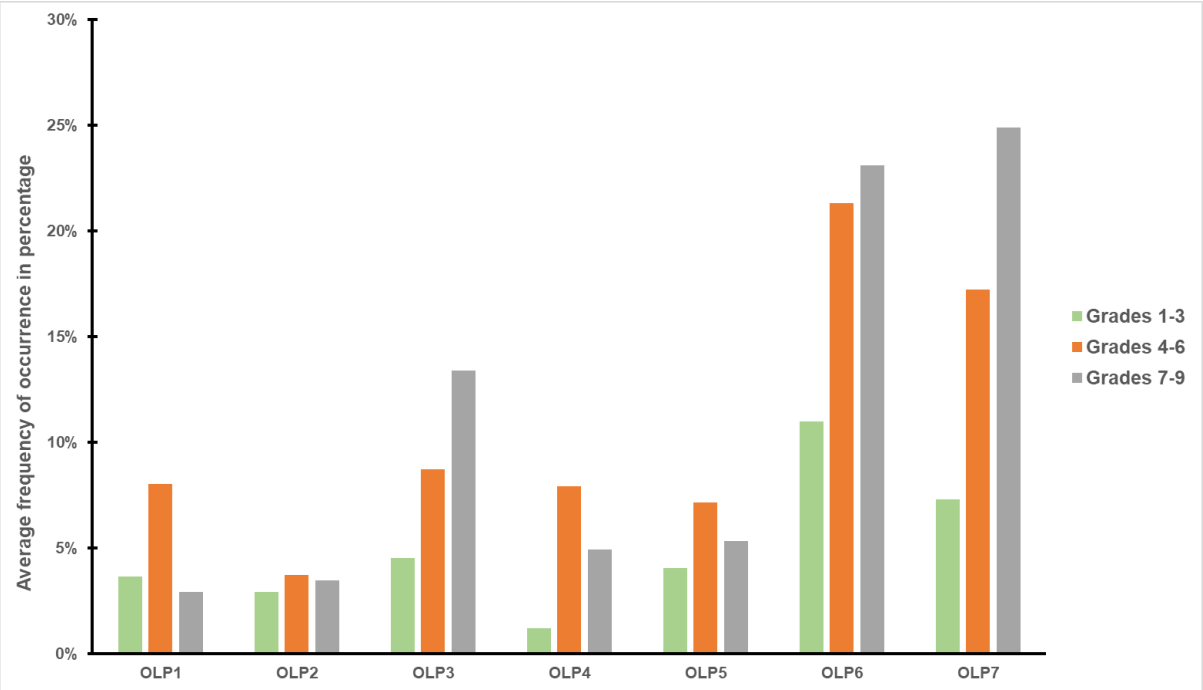


Figure 4 displays the calculated average occurrence of each principle per amount of the LOs within the different grade bands. This shows the distribution of the different OLPs among the grades.

Figure 4

The average occurrence of an Ocean Literacy Principle per total number of learning outcomes of the grade bands in percentage



Five concepts (1A, 1B, 2B, 2C, 2E) were not present in Biology. OLP1 and OLP2 had a low presence in this subject. In Physics 10 concepts (1A, 1B, 1G, 2A, 2D, 4A, 4B, 4C, 5F, 5I) were absent and OLP4 was missing completely. In the subject Chemistry three concepts (1B, 4B, 5I) were not present. OLP2 and OLP4 were the least occurring principles here. All the concepts aligned at least once with the subject Geography. However, OLP4 and OLP5 had a low occurrence.

5. Discussion

The aim of this thesis was to show the salience of the OL principles and concepts in the subjects Biology, Physics, Chemistry and Geography from the Swedish curriculum. The results reveal that the Swedish curriculum addresses marine-related topics in a limited way. Moreover, the results show that all of the OL concepts are represented, but some have a low occurrence.

As depicted in Figure 2, OLP6 has the most frequent occurrence. It addresses the interconnectivity of humanity with the ocean. Human health (concept 6A) can be connected with the ocean in many ways (Costello et al., 2019). Swimming for example is one of the most

advantageous sports to support important body functions and stay healthy (Jennings, 1997). Another aspect to consider is to understand the impact of human activities on the ocean and its ecosystem services (concepts 6D and E). Threats caused by human activities will decrease the benefits the ocean provides (Barbier, 2017).

Similarly represented is the OLP7, which covers the unexplored nature of the ocean. The importance of interdisciplinary collaboration among scientists as in 7F is the most occurring concept from OLP7 and offers great potential to embed this in the student's work methods. Moreover, the OLP7 aligns with some LOs that refer to field studies (i.e., LOs 24, 25, and 29). As shown by Hole (2018) where a field excursion in the subject Biology helped the students to develop a better scientific understanding. Furthermore, it enhanced their hands-on working in science projects and supported their understanding of interpreting results. Such excursions are not only beneficial for the students, but they also help the teachers to assess their teaching methods by defining their beliefs and values during those field studies (Steenekamp et al., 2018). However, an excursion by itself cannot favor the LOs, it has to be well planned and carefully designed to ensure successful teaching (Hodson, 1996).

OLP3 aligns about half as often than each of the previous two principles. It covers the importance of the ocean regulating the climate. Many students begin school with misconceptions about the climate. If the lesson is poorly designed, it can lead to new misconceptions for the students and teachers (Henriques, 2002). Students need to understand the whole climate system, in which the ocean plays a key role. Multidisciplinary research is needed to establish a curriculum supporting climate education (Shepardson et al., 2012) and needs to be taught throughout the subjects (Leal Filho, 2010).

OLP5 represents the biodiversity and the uniqueness of the ecosystems in the ocean. Identifying species and understanding ecosystems increase the willingness of students to protect their environment, which contributes to sustainable development (Palmberg et al., 2015). The study by Palmberg et al. (2015) showed that only 3% of the students were able to identify the plants and animals in question. Nonetheless, over 60% showed a high interest in learning more about nature and its species. Furthermore, the students preferred to learn about biodiversity by doing outdoor activities, as in OLP7. The interest in biodiversity goes beyond the scientific community, as society's awareness is increasing due to the media. It is important to include biodiversity and ecosystems in the curriculum with suitable teaching methods (Heip et al., 2009).

OLP1 describes the size, interconnectivity and features of the ocean. The concept 1B occurs 4 times among the 222 LOs and was exclusively found in the subject Geography.

However, these emerging islands, tranches etc. should be included in the other environmental subjects as well. Subsequently, it seems reasonable that the concept is addressed in more subjects due to its complexity. There are three more concepts with a low occurrence among the subjects, which are 1A, F and H. Concept 1A discusses the size of the ocean and its various water basins, an essential topic that students need to be aware of. The water cycle, as in 1F, is our major freshwater flux and contributes to the variability of salinity in the ocean (Obianyo, 2019). The third poorly addressed concept is 1H which addresses the finity of resources of the ocean. The capacity and resources of the ocean are limited and necessary to be managed in a reasonable way for a sustainable future (Horton & Horton, 2019). These concepts should be obvious and be addressed appropriately in the curriculum.

Evolutionary theory is described in OLP4. It is important to start teaching about evolution in an early stage and in a suitable way, so that it becomes easier for the students in the future to understand those complex interactions (Prinou et al., 2011). As shown in Figure4 the OLP4 occurrence is very low in the grades 1-3. A change in the content of the curriculum and well-trained teachers result in a better understanding of evolution (Prinou et al., 2011). Furthermore, humanity depends on the oxygen the ocean provides. Yet, it has been the anthropogenic activity which led to a decreasing oxygen production in the ocean (Pitcher et al., 2021). Therefore, it is crucial to understand the importance of the ocean. It is where everything started and what makes it possible to live on the Earth.

The least represented principle is OLP2, which addresses the geological processes of the ocean. The concept 2D occurs 4 times across the subject studied in this thesis. The concepts 2A, B, C and E would give the pupils the chance to study and understand how the world was shaped historically, how it is formed today and how it will look like in the future. Assaraf & Orion (2005) revealed that students' understanding of the water cycle is either incomplete or has many misconceptions. However, students have the ability to identify these complex geochemical and biogeochemical systems. Studies have shown the difficulty for students to understand these complex systems (i.e., Hmelo et al., 2000; Kali et al., 2003). It is important for the students to break these complex processes down into subsystems to understand the entire system (Hmelo et al., 2000) and identify the relationships between these processes (Assaraf & Orion, 2005).

Regarding the overall distribution of the concepts, it can be assumed that the LOs related to the ocean will be discussed in an increased scope throughout the years. In grades 4-6 the concepts occur 10.31% more often than in grades 1-3, whereas in grades 7-9 they occur 14.13% more often than in grades 4-6. A similar pattern of increasing occurrence of concepts through

the grades can be seen within the subjects (Table 3). As previously mentioned, the exception is Geography where the appearance of the concepts is evenly distributed.

The word "ocean" appears only twice in the LOs and only in Geography. This is another indication that more attention needs to be paid to the ocean. In the Swedish curriculum it is often included in and referred to as 'nature' or 'the environment'. However, when talking about nature or the environment, many people assumingly think about or refer to terrestrial surroundings. Similarly, this applies to animals and plants. Many people might think mainly about terrestrial flora and fauna with these terminologies. Since there is only one aquatic word (fishery in **LO81**) stated among the four subjects, the focus should be equally distributed on water organisms as well. For an equal inclusion of the ocean and aquatic terminologies in the curriculum it should be more obviously mentioned. Table 4 provides examples of re-wording of LOs in order to be more inclusive of the marine environment.

Table 4

Examples for increased inclusion of the ocean in some learning outcomes within the Swedish curriculum

#	LO in the curriculum	Possible suggestions
35	How animals, plants and other organisms can be identified, categorised and grouped.	How **(marine-)** animals, plants and other organisms can be identified, categorised and grouped.
89	Photosynthesis and combustion, and also energy conversion in these reactions.	Photosynthesis and combustion, and also energy conversion in these reactions. **(in water and on land)**
104	Water as a solvent and carrier of substances in the ground, plants and the human body. Solutions, deposits, acids, bases and pH values.	Water as a solvent and carrier of substances in **water basins**, the ground, plants and the human body. Solutions, deposits, acids, bases and pH values.
146	Man's origins, migration, hunting and gathering, and the introduction of agriculture.	Man's origins, migration, hunting**/fishing** and gathering, and the introduction of agriculture **and aquaculture**.

#	LO in the curriculum	Possible suggestions
162	Where different goods and services are produced and consumed, and also how goods are transported. How people support themselves and how trading patterns have changed over time.	Where different goods and services are produced and consumed, and also how goods are transported. **(on water, land and in the air)** How people support themselves and how trading patterns have changed over time.
169	Renewable sources of energy, such as solar and wind energy and alternative fuels.	Renewable sources of energy, such as solar and wind energy and alternative fuels **and ocean energy**.

Since the topics in the Swedish curriculum and its LOs are mentioned in a general form (Sá-Pinto et al., 2021; Billmayer & Day, 2021), it is difficult to evaluate to which extent the ocean will be addressed in the classroom. As mentioned earlier, the teachers decide on the teaching method and approach they use during their lectures (Billmayer & Day, 2021). Therefore, the curriculum should provide all the necessary information needed so that it is impossible for the teacher to omit mentioning the ocean in certain LOs. As shown in Table 5, these examples make it very clear for the teachers that they have to consider the ocean. The studies from Mogias et al. (2015) and McPherson (2018) have revealed that teachers do not include OL concepts due to lack of training and/or awareness. A change in the curriculum would be the first step to raise awareness so that the teachers recognize the ocean.

6. Limitations and future research

First, the restricted time frame of this thesis makes it difficult to provide more elaborate analyses. Secondly, analyzing the English version of the curriculum (originally written in Swedish) might have changed the context of some LOs.

With regard to future research, there are some opportunities to dive deeper into the topic and shed more light on the Swedish curriculum. Firstly, the results can be compared with the document Scope and Sequence of OL to see to what extent the certain principles should be included in the different grade bands. The alignment will show the state of OL in the curriculum from another perspective. Additionally, the timetable from Skolverket, which represents the

hours a subject will be taught per grade, can be another factor to include. This shows how much the concepts can be addressed within a subject throughout a school year.

Furthermore, a guide as in the alignment document of the Ocean Literacy Framework can be established. It can help teachers to identify and understand in which way certain concepts should be included into the LOs. Moreover, school textbooks are an important component in forming the content and teaching style. They include obvious and hidden messages, which are not represented in the curriculum (Caravita et al., 2008). Analyzing Swedish textbooks can offer a broader overview of ocean-related topics in the Swedish education system.

7. Conclusion

This thesis examined the presence of OL in the Swedish curriculum. The analysis revealed that all OL concepts are represented in the Swedish curriculum, however, five essential principles are likely to be poorly addressed. Thus, a stronger implementation of ocean-related topics in the Swedish curriculum is needed. By doing so, it can increase society's awareness and contribute to sustainable development in the future. Furthermore, several studies have shown that the topics teachers include in the classroom and during their lessons depend on their beliefs, values and skills (i.e., Billmayer & Day, 2021; McPherson, 2018; Mogias et al., 2015; Prinou et al., 2011; Sá-Pinto et al., 2021). Therefore, well organized training and continued education related to marine education needs to be available for teachers. Moreover, this thesis can be used as a baseline for the presence of the OL concepts and can be the first step to do further research on this topic. To conclude, the Swedish curriculum addresses the ocean in a limited manner that might jeopardize the level of OL of Swedish citizens and in turn negatively impact the health of the ocean and of the humans that depend on it.

Acknowledgement

Thank you to my supervisor, Géraldine Fauville, who has been the ideal mentor and offered me great advice and encouragement. I am grateful to have received her guidance and inspiration throughout this thesis.

I would also like to thank my mother and sister who made this opportunity possible for me.

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Appendices

Appendix A

The seven essential principles and 45 concepts of the Ocean Literacy Framework

Essential Principle	Concept
1. The Earth has one big ocean with many features	A. The ocean is the defining, physical feature on our planet Earth - covering approximately 70% of the planet´s surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.
	B. Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest plains are all in the ocean.
	C. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth´s rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This “global ocean conveyor belt” moves water throughout all of the ocean basins, transporting energy (heat), matter and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems.
	D. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools. E. Most of Earth´s water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.
	F. The ocean is an integral part of the water cycle and is connected to all of Earth's water reservoirs via evaporation and precipitation processes.
	G. The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the ocean.
	H. Although the ocean is large, it is finite, and resources are limited.

2. The ocean and life in the ocean shape the features of Earth.	A.	Many earth materials and biogeochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the fast volume of siliceous and carbonate rocks.
	B.	Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	C.	Erosion - the wearing away of rock, soil and other biotic and abiotic earth materials - occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sans is redistributed seasonally by waves and coastal currents.
	D.	The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.
	E.	Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather and climate	A.	The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth's energy, water, and carbon systems.
	B.	The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.
	C.	Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought. Significant examples include the El Nino Southern Oscillation and La Nina, which cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.
	D.	Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones. Most rain that falls on land originally evaporated from the tropical ocean.
	E.	The ocean dominates Earth's carbon cycle. Half o f the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.
	F.	The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean´s circulation have produced large abrupt changes in climate during the last 50,000 years.
	G.	Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.

4. The ocean made Earth habitable	A.	Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth´s atmosphere was necessary for life to develop and be sustained on land.
	B.	The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.
	C.	The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth (Essential Principles 1, 3, and 5).
5. The ocean supports a great diversity of life and ecosystems.	A.	Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.
	B.	Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.
	C.	Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.
	D.	Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.
	E.	The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.
	F.	Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.
	G.	There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.
	H.	Tides, waves, predation, substrate, and/or other factors cause vertical zonation patterns along the coast; density, pressure, and light levels cause vertical zonation patterns in the open ocean. Zonation patterns influence organisms´ distribution and diversity.
	I.	Estuaries provide important and productive nursery areas for many marine and aquatic species.

6. The ocean and humans are inextricably interconnected.	A.	The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.
	B.	The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.
	C.	The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.
	D.	Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
	E.	Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).
	F.	Much of the world's population lives in coastal areas. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).
	G.	Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.
7. The ocean is largely unexplored.	A.	The ocean is the largest unexplored place on Earth - less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.
	B.	Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.
	C.	Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.
	D.	New technologies, sensors and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.
	E.	Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.
	F.	Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists,

	meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Appendix B

Core contents and their learning outcomes from the Swedish curriculum and their occurrence among Biology, Physics, Chemistry and Geography

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
Seasons of the year in nature	1	Motion of the Earth, Sun and the Moon in relation to each other. Different phases of the Moon. Constellations and the appearance of the sky at night during different seasons of the year.	1			1			1					
	2	Seasonal changes in nature and how to recognize the seasons. The life cycles of animals and plants, and their adaptation to different seasons of the year.	1			1			1					
	3	Animals and plants in the local environment and how they can be categorised, grouped and their species determined, and also the names of some common species.	1			1			1					
	4	Simple food chains describing the relationship between organisms in ecosystems.	1			1			1					
Body & Health	5	Importance of food, sleep, hygiene, exercise and social relations in order to feel good.	1			1			1					
	6	Parts of the human body, their names and functions.	1			1			1					
	7	People's experiences of light, sound, temperature, taste and smell using all the different senses.	1			1			1					
	8	How mental and physical health are affected by sleep, diet, movement, social relationships and addictive substances. Some common diseases and how they can be prevented and treated.		1										
	9	How physical and mental health is affected by sleep, diet, exercise, social relationships and addictive substances. Common diseases and how they can be prevented and treated. Viruses, bacteria, infection and the spread of infections. Antibiotics and resistant bacteria.			1									
	10	Organ system of the human body. Names of organs, appearance, location, function and interaction.		1										

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	11	Human puberty, sexuality and reproduction and also questions about identity, gender equality, relationships, love and responsibility.		1										
	12	The body's cells, organs and organ systems and their structure, function and interaction. Comparisons from an evolutionary perspective between man and other organisms.			1									
	13	Human sexuality and reproduction, and also questions concerning identity, gender equality, relationships, love and responsibility. Methods for preventing sexually transferable diseases and unwanted pregnancy at individual and global levels, and from a historical perspective.			1									
	14	Evolutionary mechanisms and their outcomes, and also heredity and the relationship between heredity and the environment. Genetic engineering, opportunities, risks and ethical questions arising from its application.			1									
Force and motion	15	Gravity and friction that can be observed during play and movement, such as on swings and slides.	1			1			1					
	16	Balance, centre of gravity and equilibrium which can be observed in play and movement, such as when balancing and on seesaws.	1			1			1					
Materials & substances in our surroundings	17	Properties of materials and how materials and objects can be categorised on the basis of such properties as appearance, magnetism, conductivity and whether they float or sink in water.	1			1			1					
	18	Man's use and development of different materials during the course of history. The different materials used to manufacture daily objects and how they can be recycled.	1			1			1					
	19	Various forms of water: solids, liquids and gases. Transition between the forms: evaporation, boiling, condensation, melting and solidification.	1			1			1					
	20	Basic properties of air and how they can be observed.	1			1			1					
	21	Simple solutions and mixtures and how these can be divided into their different components, such as through evaporation and filtering.	1			1			1					
Narratives about nature and science	22	Fiction, myths and art dealing with nature and people.	1			1			1					
	23	Narratives about science from earlier times, and the attempts of different cultures to understand and explain phenomena in nature.	1			1			1					
	24	Simple field studies and observations in the local environment.	1			1			1					

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
Methods and ways of working & Exploring reality	25	Simple field studies and experiments. Planning, execution and evaluation.		1										
	26	Simple scientific studies.	1			1			1					
	27	Simple systematic studies. Planning, execution and evaluation.					1			1				
	28	Systematic studies. Formulating simple questions, planning, execution and evaluation.									1			
	29	Field studies, experiments and how simulations can be used as support in modelling. Formulating simple questions, planning, execution and evaluation.			1									
	30	Systematic studies and how simulations can be used as support in modelling. Formulating simple questions, planning, execution and evaluation.						1						
	31	Documentation of science studies using text, pictures and other forms of expression, both with and without digital tools.	1			1			1					
	32	Documentation of simple studies using tables, pictures and simple written reports, both with and without digital tools.		1			1			1				
	33	Documentation of studies using tables, diagrams, pictures and written reports, both with and without digital tools.			1			1			1			
	34	Measurements and measuring instruments and how they can be combined to measure magnitudes, such as speed, pressure and output. Electrical sensors for measuring and registering properties in the environment.						1						
	35	How animals, plants and other organisms can be identified, categorised and grouped.		1										
	36	Interpretation and examination of information with links to biology, such as articles in newspapers and films in digital media.		1										
	37	Interpretation and examination of information with links to physics, such as articles in newspapers and films in digital media.					1							
	38	Interpretation and examination of information with links to chemistry, such as articles in newspapers and films in digital media.								1				
	39	Some methods for dissolving solutions and mixtures into their various components.								1				
	40	Critical examination of sources of information and arguments encountered by pupils in different sources and social discussions related to biology, in both digital and other media.			1			1			1			

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	41	The relationship between biological/physics studies and the development of concepts, models and theories.			1			1						
	42	Measurements and measuring instruments, such as clocks, tape measures and scales, and how they are used in studies.					1							
	43	Models for separation and analysis, such as distillation and identification of substances.									1			
	44	How organisms are identified, categorised and grouped, based on relationships between species and their evolution.			1									
	45	Names and locations of places, mountains, oceans and watercourses in Sweden, and also the main features of other parts of the Nordic area.											1	
	46	Names and location of different countries in Europe, and also more important islands, water, mountains, regions and places.											1	
	47	Maps, how they are constructed using colours, symbols and scale. Topographical and thematic maps.											1	
	48	Collection and measurement of geographical data from the local area, such as age distribution, flow of traffic and consumption of water.											1	
	49	Field studies to examine the natural and cultural landscapes, such as how land is used in the local environment.											1	
	50	Keywords and concepts needed to be able to read, write and discuss geography.											1	1
	51	Names and location of more important countries in different continents, water, islands, mountains, deserts, regions and places.												1
	52	Maps and their construction using graticule, colours, symbols and different scales. Topographical and different thematic maps.												1
	53	Methods for collecting, processing, assessing and presenting geographical data, covering climate, health and trade, using maps, Geographical Information Systems (GIS) and geographical tools available on the internet, such as satellite images.												1
	54	Field studies of the natural and cultural landscape, such as community planning in local communities.												1

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	55	Methods of searching for information from different sources: interviews, observations and measurements. How sources and information can be assessed and processed, both with and without digital tools.										1		
	56	Spatial understanding, using mental and physical maps of e.g. the neighbouring area and routes to school, both with and without digital tools. Size relations and points of the compass, spatial concepts such as place, location and boundary.										1		
	57	Timelines and time concepts – the past, present and future.										1		
Worldviews	58	Descriptions from the past of the structure of matter. The transition of chemistry from magic and mystery into a modern science.								1				
	59	Different cultures – their descriptions and explanations of nature in fiction, myths and art, and in earlier science.		1			1			1				
	60	Some historical and contemporary discoveries in the area of biology and their importance for people's living conditions and views on nature.		1										
	61	Historical and contemporary discoveries in the area of biology and their importance for society, people's living conditions, and also views of nature and the natural sciences.			1									
	62	Some historical and contemporary discoveries in physics and their importance for people's living conditions and views on the world.					1							
	63	Historical and contemporary discoveries in the area of physics and how these have been shaped and formed by world views. The importance of discoveries for technology, the environment, society and people's living conditions.						1						
	64	Some historical and contemporary discoveries in chemistry and their importance for people's living conditions and views on the world.								1				
	65	Historical and contemporary discoveries in the area of chemistry and their importance for a world view, technology, the environment, society and people's living conditions.									1			
	66	Current research areas in biology, such as biotechnology.			1									
	67	Current research areas in physics, such as elementary particle physics and nanotechnology.						1						
	68	Current research areas in chemistry, such as development of materials and nanotechnology.									1			

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			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	69	Usefulness of the theories and models of biology, their limitations, validity and variability.			1									
	70	Usefulness of the theories and models of physics, their limitations, validity and variability.						1						
	71	Usefulness of the theories and models of chemistry, their limitations, validity and variability.									1			
	72	Grouping of different types of atoms from a historical perspective.									1			
	73	Scientific theories about the origins of the universe in comparison with other descriptions.						1						
	74	Development of the universe, the occurrence of atoms, development of the stars.						1						
	75	Structure of the universe with planets, solar systems and galaxies, and also their movements and distances between them.						1						
	76	Scientific theories about the origins of life. The development of life and diversity from evolutionary theory perspectives.			1									
	77	Development of life and adaptation of organisms to different habitats.		1										
	78	The planets of the solar system and their motion in relation to each other. How day, night, months, years and seasons can be explained.					1							
	79	Man in space and the use of satellites.					1							
	80	Measuring time in different ways, from sundials to atomic clocks.					1							
Nature, society and everyday life	81	Life of animals, plants and other organisms. Photosynthesis, combustion and ecological relationships, and the importance of knowledge with regard to agriculture and fishery.		1										
	82	Energy flow of ecosystems and recycling of materials. Photosynthesis, combustion and other ecosystem services.			1									
	83	Electrical circuits with batteries and how they can be linked, and also how they can be used in daily electrical equipment such as torches.					1							
	84	Properties of magnets and their use in the home and society.					1							
	85	Forces and motion in everyday situations, how they are experienced and can be described, such as when cycling.					1							

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			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	86	How sound occurs, is transmitted and understood by the ear.					1							
	87	Distribution of light from common sources of light and how this can explain areas of light and shadows and size, as well as how light is perceived by the eye.					1							
	88	Photosynthesis, combustion and some other basic chemical reactions.								1				
	89	Photosynthesis and combustion, and also energy conversion in these reactions.									1			
	90	Contents of food and the importance of nutrients for health. Historical and contemporary methods for extending the life length of food.								1				
	91	Content of food and beverages and their importance for health. Chemical processes in the human body, such as the digestive process.									1			
	92	Indestructibility of energy and flows, different types of energy sources and their impact on the environment, as well as the use of energy in society.					1							
	93	Energy flows from the sun through nature and society. Some ways of storing energy. Different types of energy quality, and their advantages and disadvantages in relation to the environment.						1						
	94	Electricity production, distribution and use in society.						1						
	95	Supply and use of energy historically and currently, as well as possibilities and limitations in the future.						1						
	96	Simple metrological phenomena and their causes, such as how wind occurs. How weather can be observed by means of measurements over time.					1							
	97	Weather phenomena and their causes. How the concepts of physics are used in meteorology and communicated in weather forecasts.						1						
	98	Conversion of materials through cultivation of raw materials to products, how they become waste which is handled and returned to nature.								1				
	99	Common chemicals in the home and society. Their use and impact on health and the environment, and also how they are labelled and should be handled.								1				
	100	Common chemicals in the home and in society, such as cleaning products, cosmetics, paints and fuels, and how they affect health and the environment.									1			
	101	Chemical processes in the manufacture and recycling of metals, paper and plastics. Life-cycle analysis of some common products.									1			

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
Nature, society and everyday life	102	Nature as a resource for recreation and experiences and what responsibilities we have when using it.		1										
	103	People's use of energy and natural resources, locally and globally, as well as what this means in terms of sustainable development.									1			
	104	Water as a solvent and carrier of substances in the ground, plants and the human body. Solutions, deposits, acids, bases and pH values.									1			
	105	Processes for purifying drinking water and waste water, locally and globally.									1			
	106	People's dependence on and the impact on nature and what this means for sustainable development. Ecosystem services, such as decomposition, pollination, and purification of water and air.		1										
	107	Particle models for describing and explaining the properties and phase transitions, pressure, volume, density and temperature. How the motion of particles can explain the distribution of matter in nature.						1						
	108	Particle models to describe and explain the properties of phases, phase transitions and distribution processes for matter in air, water and the ground.									1			
	109	Ecosystems in the local environment, relationships between different organisms and the names of common species. Relationships between organisms and the non-living environment.		1										
	110	Impact of people on nature, locally and globally. Opportunities for consumers and citizens of society to contribute to sustainable development.			1									
	111	Biological diversity, and factors threatening and favouring this. Public discussions on biological diversity, such as in the relationship between forestry and hunting.			1									
	112	Local ecosystems and how they can be studied from an ecological perspective. Relationships between populations and resources available in ecosystems. The local ecosystems in comparison with regional or global ecosystems.			1									
	113	Current societal issues involving biology/physics/chemistry.			1			1			1			
	114	Energy flows between objects with different temperatures. How the flow of energy can be affected by such means as clothes, thermos and house insulation.					1							
	115	Models in physics to describe and explain the earth's radiation balance, the greenhouse effect and climate change.						1						

Core content	#	Learning outcomes	Biology			Physics			Chemistry			Geography		
			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	116	Models of physics to describe and explain the occurrence of particle radiation and electromagnetic radiation, and also the impact of radiation on living organisms. How different types of radiation can be used in modern technology, such as in healthcare and information technology.						1						
	117	How sound occurs, is transmitted and can be recorded in different ways. The properties of sound and the impact of sound on health.						1						
	118	Forces, motion and changes in motion in daily situations and how knowledge of this can be used, such as in questions concerning traffic safety.						1						
	119	Levers and gearing in tools and devices, such as scissors, levers, blocks and pulleys.						1						
	120	Propagation of light, reflection and refraction in everyday contexts. Explanatory models of how the eye perceives colours.						1						
	121	The relationship between voltage, current, resistance and output in electrical circuits and how they are used in everyday contexts.						1						
	122	The relationship between electricity and magnetism and how this can be used in common electrical equipment.						1						
	123	Simple particle model to describe and explain the structure, recycling and indestructibility of matter. Movements of particles as an explanation for transitions between solids, liquids and gases.								1				
	124	Properties and composition of air.								1				
	125	Classification of substances and material based on properties' appearance, conductivity solubility, combustibility, and acidity.								1				
	126	Water, its properties and circulation.								1				
	127	Fossil and renewable fuels. Their importance in energy use and impact on climate.								1				
	128	Some chemical processes in the ground, air and water from environmental and health perspectives.									1			
	129	Properties of carbon atoms, and their function as the building blocks of all living organisms. The circulation of carbon atoms.									1			

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			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	130	Particle model to describe and explain the structure, recycling and indestructibility of matter. Atoms, electrons and nuclear particles.									1			
	131	Chemical compounds and how atoms are formed into molecular and ionic compounds through chemical reactions.									1			
	132	Various factors that enable materials such as iron and plastic to be broken down and how this can be prevented.									1			
	133	How chemicals and inflammable substances can be handled in a safe way.									1			
Living together, in the neighbourhood, in the world and environments	134	Depictions of life before and now in children's literature, songs and films, such as those depicting family life and school. Narratives of the past by people currently living.												1
	135	Moving within a country and between countries. What the causes and consequences of this may be.												1
	136	Life issues of importance for pupils, such as good and evil, right and wrong, friendship, gender roles, gender equality and relationships.												1
	137	Norms and rules in pupils' living environments, such as in school, in digital environments and in sports contexts.												1
	138	Traffic rules and how to act safely in traffic.												1
	139	Conditions in nature and the environment for population and settlements, covering land, water and climate.												1
	140	History of the local area. What places in the neighbourhood, buildings and daily objects can tell us about children's, women's and men's living conditions during different periods.												1
	141	The role of Christianity in the school and in the local area in the past.												1
	142	Religions and places of worship in the local area.												1
	143	Key functions of society, such as healthcare, emergency services and schools.												1
	144	Occupations and activities in the local area.												1
	145	The globe. The location of continents and oceans on the globe. Names and location of continents, and also countries and places of importance for pupils.												1
	146	Man's origins, migration, hunting and gathering, and the introduction of agriculture.												1

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			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	147	Different ages, the Stone Age, Bronze Age, and Iron Age.										1		
	148	How the past can be observed in our own time through traces in nature and language expressions.										1		
	149	Narratives about gods and heroes in ancient and Nordic mythology and how these can be looked at from a contemporary perspective.										1		
	150	Some ceremonies, symbols and narratives in Christianity, Islam and Judaism. Some narratives from the Bible and their meaning, and also some of the most common psalms.										1		
	151	Environmental issues in relation to pupils' everyday life, such as those involving traffic, energy and food.										1		
	152	Basic human rights such as the equality of all people and also the rights of the child as laid down in the Convention on the Rights of the Child.										1		
	153	How meetings, such as class councils, are organised and carried out.										1		
	154	Money, its use and value. Examples of different types of payment and what ordinary goods and services can cost.										1		
	155	Current social questions in different media.										1		
	156	The surface of the earth and the way in which it is formed and changed by people's use of land and nature's own processes, such as plate tectonics and erosion. The consequences of this on people and nature.											1	
	157	The Swedish, Nordic and other European natural and cultural landscapes. Underlying processes and their characteristic features and extent.											1	
	158	The Earth's natural resources, such as water, land available for cultivation, forests and fossil fuels. Where different resources exist and what they are used for. The importance of water, its distribution and recycling.											1	
	159	The distribution of population in Sweden, the Nordic area and other parts of Europe, as well as the causes and consequences of this distribution.											1	
	160	The Earth's climatic and vegetation zones and also the ways in which climate affects people's living conditions.												1

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			1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9	1-3	4-6	7-9
	161	Climate change, different explanations for this, and the consequences of changes on people, society and the environment in different parts of the world.												1
	162	Where different goods and services are produced and consumed, and also how goods are transported. How people support themselves and how trading patterns have changed over time.												1
	163	How the Earth's population is distributed over the globe, and also the causes of and consequences of the unequal distribution of population. Migration and urbanisation, and the causes and consequences of this.												1
Environment, people and issues concerning sustainability	164	How choices and priorities in everyday life can impact the environment and contribute to sustainable development.											1	
	165	Unequal living conditions in the world, such as varying access to education, healthcare and natural resources, and also some of the underlying causes of this. Work of individual people and organisations to improve people's living conditions.											1	
	166	Vulnerable areas and risks and threats posed by nature, such as flooding, drought and earthquakes, and the consequences of this on the natural and cultural landscape.												1
	167	Ways in which vulnerable places can be identified, and how individuals, groups and society can reduce risk.												1
	168	Conflicts of interest over natural resources, such as access to water and land.												1
	169	Renewable sources of energy, such as solar and wind energy and alternative fuels.												1
	170	The incidence of and causes of poverty and ill health in different parts of the world.												1
	171	Relationships between poverty, ill-health and factors such as population density, climate and natural resources.												1