Ocean Connections State-of-the-Art Review
National report Denmark

Project details

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Content

1. Introduction

The main objective of this Danish state-of-the-art National report is to document current and emerging educational trends, innovative/excellent practice and research in the field relating to the objectives of the OCEAN project – develop creative, digital approaches (AR/VR) to teaching/learning ocean literacy in schools and aquaria – in Denmark.

1.1 Research questions

RQ1 How and where is Ocean Literacy taught in Science and Geography in Denmark, United Kingdom and Spain (or just partner countries)?
RQ2 What innovative technologies and applications using AR/VR are used to support learning in Science?
RQ3 What innovative creative pedagogies are used to support learning in Science?
RQ4 How are these technologies/pedagogies used to support students' ocean literacy?
   i. What positive experiences exist in current practices in schools, aquariums and in cooperation between those?
   ii. What barriers exist?
RQ5 What pedagogical principals for teaching ocean literacy can be identified based on RQ1-RQ4?

[Limits: Science and Geography in primary and lower secondary (equivalent to) UK Key Stage 2 (ages 7-11) and Key Stage 3 (ages 11-14).]

2. Methodology

The Danish state of the art report has followed the methodology outlined in the "Handbook for State-of-the-Art review in Ocean Connection" using the agreed procedures and templates. In each subsection, we have elaborate on any aspect regarding methodology deviating or supplementing the handbook.

3. National Practices

3.1 Curriculum

3.1.1 Educational context in Denmark

The Danish Folkeskole is a comprehensive school covering both primary (grade 1 to 6) and lower secondary (grade 7-9/10) education. In other words, it caters for the 7-16/17-year-olds. The main laws concerning this is the Folkeskole Act, https://www.retsinformation.dk/Forms/R0710.aspx?id=196651. There are also quite a number of private schools. They are self-governing institutions required to measure up to the standards of the municipal schools. There are different types of private schools and some are based on a specific philosophy, a special pedagogical line or religious belief. There are also continuation schools (Efterskoler) that are private residential schools for pupils in grade 8-10.

Education in grades 1 – 9 is divided into 3 scholastic areas, where Natural science and technology, Geography, Biology and Physics/chemistry are the subjects most relevant for Ocean Connection:

HUMANITIES	PRACTICAL SUBJECTS AND MUSIC	NATURAL SCIENCES
Danish (all grades)	**Gym** (all grades)	**Mathematics** (all grades)
English (grades 3 – 9)	**Music** (grades 1 – 6)	**Natural sciences & Technology (grades 1 – 6)**
Christianity (all grades)	**Visual arts** (grades 1 – 5)	**Geography (grades 7 – 9)**
History (grades 3 – 9)	**Sewing, workshop and home economics** (grades 4 – 7)	**Biology (grades 7 – 9)**
Social studies (grades 8 and 9)		**Physics/chemistry (grades 7 – 9)**

At the completion of 9th grade, pupils must take the compulsory public school final examinations. For Geography, Biology and Physics/chemistry there is a shared practical, oral examination where students are to demonstrate science competences (investigative, modelling, perspectivation, communication) working problem based and experimental.

Please find more info on the Danish compulsory educational system here: http://eng.uvm.dk/Education/Primary-and-lower-secondary-education.

Initial teacher education (ITE) in Denmark is a 4-year professional bachelor program at a level corresponding to that of university bachelor programmes, but with a stronger focus on professional practice. Professional bachelor in teacher education combine theoretical studies with a practically oriented approach in form of mandatory work placement as a teacher. Natural science and technology, Geography, Biology and Physics/chemistry are offered as a minimum 30 ECTS course. Unlike the situation in most other countries, the university studies and the profession oriented ITE in Denmark are organized in two different sectors, under two different ministries and legislations. A corresponding university bachelor or master programme in science does not give accesses to teach science in primary or lower secondary school.

With respect to continues professional development (CPD), there are several diploma degrees (corresponding to the level of bachelor degrees) and master programmes within the pedagogical field of education. Danish teachers are also free to participate in in-service training. Most of the in-service training take place at the university colleges as courses or diploma degrees. Most municipalities will also have their own courses for teachers. Specialised state training institutions, resource and research centres, teachers' associations and the Ministry of Education also offer in-service training activities.

3.1.2 Resume of curriculum mapping in Denmark on Ocean Literacy (RQ1)

The Danish national curriculum for Natural science and technology (grad 1-6), Geography, Biology and Physics/chemistry (grade 7-9) is organized in terms of four competence-areas: investigation-, modelling-, perspectivation- and communication competences. The main emphasis on Ocean literacy can be found in Natural science and technology in primary school and Biology in lower secondary.

Ocean literacy in primary school – Natural science and technology (RQ1)

In Natural Science and technology (Annex 3.1.A Curriculum mapping Natural Science and technology) the science subject in primary school, the curriculum is formulated in general. There are the same competence goals as described for the science subjects in Lower Secondary school.

The overriding purpose with Natural science and Technology is: The pupil must in Natural sciences/technology develop competences of science and thereby understand how science contribute to our understanding of the world. The pupils must acquire skills and central knowledge about important phenomena's and connection, as well as they must improve their thoughts, language and terms about science, that has value in everyday life.
Central concepts in Natural Science and Technology connected to Ocean Literacy is:

- The pupil can study the adjustment of nature for animals and plants.
- The pupil has central knowledge of living conditions and habitats for plants and animals.
- The pupil can use models to explain the interaction of organisms in nature.
- The pupil has central knowledge of simple food chains and food webs.
- The pupil can produce models of the water cycle.
- The pupil has central knowledge of some atoms and molecules
- The pupil has central knowledge about the human influence on nature.

Evaluation in Natural Science and technology: There are no national exams or formal evaluation of science competences in the 4. To 6. Grade in Denmark. Instead, we make learning objectives to every lesson plan to each class and then evaluate the learning in the specific class. The teacher makes the evaluation and he/she decides the methods, content and the use of the evaluation.

Ocean literacy in upper secondary – Biology, Geography and Physics/chemistry (RQ1)

In lover secondary, Biology have the same four competences as the other science subject but organized in four different subjects areas: ecosystems, evolution, physiology/ health, and nature of science. The curriculum is described in very general terms, which no explicit reference to ocean literacy in the curriculum. Comparing with the ocean literacy framework it will be possible to find the seven principles about ocean literacy if the teacher "translates" the knowledge and skills so they can be used in teaching in ocean literacy. The students' studies can e.g. be on growth conditions of selected marine organisms and their reacting with their surroundings. The studies can include photosynthesis, substance absorption, respiration, excretion, growth and development.

Teaching in ocean literacy must include field biology studies and deal with abiotic factors like nutrients cycles, water, oxygen, light and temperature, e.g. including the students collecting data during data logging. The curriculum makes it possible to work with the metabolism of marine animal's e.g.

different respiration strategies and the relationship between different organisms in food chains and networks in different biotopes.

Concepts connected to Ocean literacy can also be found in both Geography and Physics/Chemistry. In geography the focus, in an Ocean literacy context, is working with concepts like the carbon cycle, global warming, the greenhouse effect, Milankovitch cycles, acid rain and the global water cycle, and to study living conditions for people, animals and plants in selected countries and regions.

In Physics/Chemistry, there are references in the curriculum to understanding the earth as a system, including the water cycle, weather and climate, ocean currents and how we as humans influence earths systems e.g. the carbon and nitrogen cycle. Technology and production is also an important subject in Physics/chemistry and students are expected to explore e.g. various examples of production technologies that would be relevant for how we as humans affects the ocean (e.g food production, farming, wastewater treatment) and whether it is sustainable.

Evaluating science competences in Denmark:

There are two different ways to evaluate the science competences of the students after 9.th grade. 60 % of the Danish students will by lottery go to an exam with a multiple-choice test made by the Danish Ministry of Education. The test can be in either biology, geography or physic/chemistry. 20 questions test the students' elementary knowledge of biology, geography or physic/chemistry.
The other exam is an oral exam for all students. It is a problem-based exam where the students have worked with a self-formulated transdisciplinary problem in science and made a project that is presented to the oral exam.

Students are tested to what extent they demonstrate competences in all the natural science areas including skills and knowledge to elucidate the self-chosen science problem. The student should be able to:

- organize, execute and draw conclusions from one or more science studies, including using models and with relevant perspectives
- explain and justify the choice of practical studies and models
- explain the connections between practical studies, models and science theory based on the self-chosen science problem
- argue for natural sciences and apply relevant subject terminology from both physics / chemistry, biology, and geography to the self-chosen science issue

3.1.3 Ocean Literacy in "designed" curriculum/teaching material (RQ1)

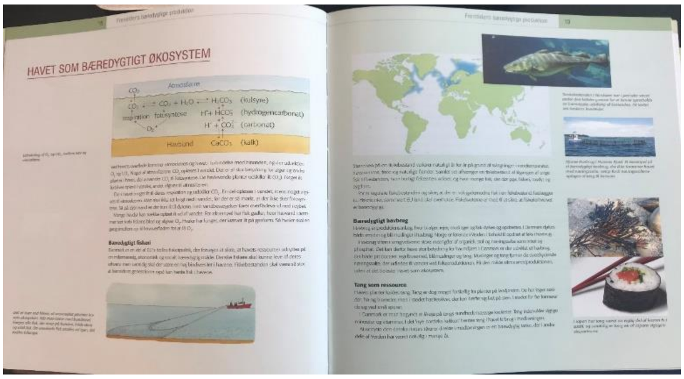
As part of the state-of-the art in Denmark, we have also mapped the occurrence of Ocean Literacy in the most extensively used textbooks biology (upper secondary) and Natural science and technology (primary).

Ocean Literacy in teaching material for biology (RQ1)

The teaching materials in Denmark used in biology all have a chapter concerning the Sea (Annex 3.1.B Curriculum mapping Biology). E.g the digital platform www.clioonline.dk has a course made to lower secondary school, where the main subject is the Ocean. Plenty of schools in Denmark use this platform. The course about the Sea has been estimated to a duration of 6 hours and the biology focus is that the students learn about the ocean ecosystem with the characteristics biotic and abiotic factors:
https://portals.clio.me/dk/biologi/forloeb/show-unitplan/?unit_plan=ff303ed9-d666-d7cb-6984-b3edcd196d9c&is_preview=1&cHash=a2fc29ab0837c37a35c6bcd88f172937
Field investigations and laboratory work are both included in this course.

Another teaching material used in the Danish school system is a digital platform or book from the Danish publisher “GO-forlaget”. Subjects in this material is e.g. the sea as an ecosystem with carbon and Nitrogen- cycles and the biology of seaweeds and phytoplankton. This material focuses on the visual part of learning and have therefore a lot of models and pictures in the chapter.

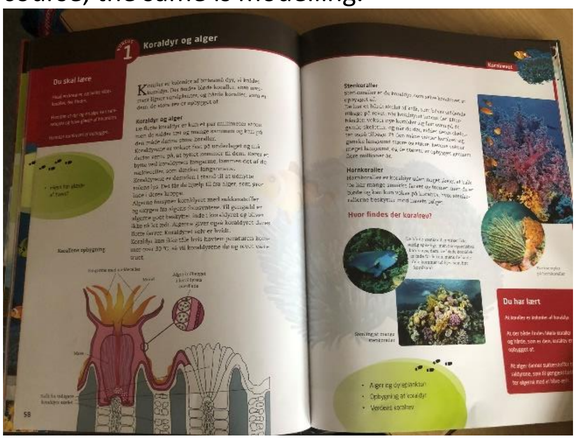
The same publisher has published a transdisciplinary teaching material “Xplore På tværs” where the focus is on the sea as a sustainable ecosystem. The material can be used in the period where the teaching is organized in a transdisciplinary way and where the students formulate and investigate scientific problems.

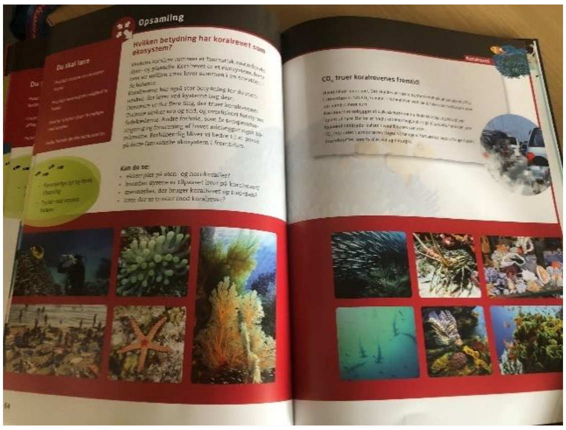


Ocean Literacy in teaching material for Natural science and technology (RQ1)

Most of the teaching materials in Natural science and technology have a chapter about the ocean. The Danish publisher “Alinea” develops one of these teaching materials with a chapter about the Coral Reef and the ocean surrounding it. The material is available online on www.naturteknologi.alinea.dk and in the teaching book “Signatur 6”. This chapter is developed for 6th grade. The estimated time of the course is about 8 hours. It is focusing on the corals, the animal life in and around it, and the impact from the coral reef on our life and human impact on the coral reef. The material is focusing on models and visual support.

Each lesson starts with a textbox with the focus and learning objective for this lesson, and ends with an evaluation of the same objective. Field investigations and laboratory work are both included in this course, the same is modelling.





OCEAN CONNECTIONS

3.1.4 Creative pedagogies in the Danish curriculum (RQ2)

There is no direct description in the Danish science curriculum about creative pedagogies and the need to teach using that. It is described in the curriculum that teaching in science must be based on varied forms of learning, which largely are based on the students own observations and studies e.g. in laboratory or fieldwork. The students' interest and curiosity towards nature, biology, geography and physics/chemistry, science and technology must be developed so that they want to learn more.

There is a long tradition in the Danish school system that the teacher has professional freedom of choosing the appropriate teaching and learning methods. Most teachers use a lot of variation in teaching approaches and value this free choice very high. However, in the teaching guide made by the Ministry of Education, it is explicated that teaching must be based on varied teaching method. The students shall most of the time work with an investigative approach e.g. using IBSE and the students must practice in using creative and different expressions when presenting their work.

The teaching material used in Danish Schools have varied suggestions to work with the science concepts. Looking in different teaching material it is obvious that there are very different ways to work with and develop science competences. There are examples of assignments where the student shall draw, write, modelling, make a screencast, do laboratory- and/or fieldwork, formulate a hypothesis, make role-playing games with science issues, present concepts to younger students and so on.

3.1.4 Digital technologies in the Danish curriculum (RQ3)

Digital technology is not a separate subject in primary or lower secondary school in Denmark, although the new school subject "Technology literacy" are tried and tested now in selected schools. In March 2019 the Danish Ministry of Education has started an investigation to examine how the best way is to implement technology literacy. The new attempt wants to integrate learning about technology in the teaching from primary to lower secondary school. The attempt is divided in two different ways trying to find the most meaningful way to integrate learning about technology.

The first part is trying to implement a new subject called "technology-literacy". The purposes to this subject are:

1. In the subject "technology literacy", students must develop professional competences and acquire skills and knowledge so that they can participate constructively and critically in the development of digital artefacts and understand their significance:
2. The students' mastery of the subject requires a mastery of digital design processes and of the languages and principles of digital technologies in order to iteratively and collaboratively analyze, design, construct, modify and evaluate digital artefacts for the recognition and resolution of complex problems.
3. In the field of technology understanding, students gain professional competencies to understand the potential of digital technologies and the impact of digital artefacts in order to enhance students' understanding of understanding, creating and acting meaningfully in a digitized society where digital technologies and digital artefacts are a catalyst for change.

The second part of the attempt is trying to integrate technology literacy in all subjects.

Technology and production is also an important subject in Physics/chemistry and students are expected to explore e.g. various examples of production technologies (food production, farming, wastewater treatment) and how digital technology affect our lives. Simple programming is specifically mention as one aspect of their digital literacy in Physics/chemistry.

3.2 Pedagogical Approaches in schools (excellent practice)

The following is a resume of excellent practice in Danish schools relating to ocean literacy, creative pedagogies and/or digital technologies (VR/AR). The detailed description of each excellent practice can be found in annexes 3.2 A-.

3.2.1 Ocean Literacy and excellent practice (RQ1)

Although Denmark is a country with easy access to the ocean with many schools located in close proximity to the coast line, the overall picture in that few primary and lower secondary schools use the ocean as a learning context (biotope) on a regular basis. The neighbouring forest or fresh water lake/river/stream are far more common when planning an excursion or field trip. There are several reasons for this. There are strict regulations on water activities with children (e.g. at least two trained lifesaver per 15 students swimming or wading in coastal areas.). Many science teachers will not feel qualitied to teach e.g marine life ecology or lack confidents that the relevant organisms will be present at the time for field trip. We have included three examples of excellent practises to show the variation of different approaches in Danish schools.

Syddjurs friskole

Syddjurs friskole, a combined primary and lower secondary private school (Annex 3.2.A Excellent practice Syddjurs Friskole) organised an interdisciplinary science week in fall 2018 where the ocean was the overall theme for the first 3 days. Some of the primary students visited Kattegatcenteret, while 7., 8. and 9. grade had a field trip to the local beach/coastline (Kaløvig) to investigate the costal ecosystem. The work was problem based, where students developed their own "investigations questions" based on their personal interest. As an example, 8. grade students collected sea weed the first day using a key to categorise and name the macro algae's. They studied the macro-algae as part of the coastal zone ecosystem. The biology teachers focused on algae's as primary producers. The second day, students had made two aquariums in the lab to model the eco system. As an example of students investigation, students worked in group to explore if and how macro algea can be used as biofuel to be used in transportation or energy sector. The alega collected the first day was dried and then determined the heat of combustion with a very simple calorimetric setup. The students also investigated how see weed could be used to produce alcohol by fermentation. Fermentation of the agelea collected was consider not suitable by the teachers, so sugar and yeast was used to model the process. The science week was well received by students, however the time of year (November) made the field trip less attractive to students.

Nordagerskolen

Nordagerskolen, a primary and lower secondary school at Fyn, has a special "science class" in upper secondary with students actively choosing a special focus on science. Each year they are working interdisciplinary with the ocean as a theme. They are having an annual field trip to the coastline (both for recreational and scientific purposes) using resources from "Head in the sea" (se section 3.3.1), specially working with plastic in the ocean and seaweed (Tangtastic). Each year they do different projects. Last year the worked closely with "Fjord&Bælt", a combined research and experience centre which communicates knowledge about marine life in the waters of Denmark, focusing on their research on porpoise and seals at the week stay at the facilities. This include behavioural training of porpoise and seals in captivity and studies in the wild with e.g. hydrophones. After returning home from the stay at the research centre, they used hydrophones borrowed from Fjord&Bælt to investigate "noise pollution" at the local coastline and compared this with land based noise pollution e.g. from wind mills, and how they affected living conditions for humans and animals.

Vestre skole

At Vestre skole, a combined, public school, the biology teacher in x. grade organised a field trip to the local beach collecting blue mussels. An aquarium was set up to study the filtration potential of mussels using yeast as a substitution for micrp algea. [*Nete will elaborate on this*].

3.2.2 Creative pedagogies to support learning in science (RQ3)

As already stated, there are no specific reference to creativity or creative pedagogies in the Danish national curriculum. The tradition for “methodical freedom” in Danish schools, leaves us with a very diverse practice regarding teaching methods and pedagogical strategies. We have selected two excellent practices to try to capture this diversity.

Kattegatskolen

At Kattegatskolen they work with an innovative course where the students from lower secondary school learn about designing new methods for water treatment. The learning objectives in this course is to develop students understanding about cleaning water, the water cycle, evaporation, condensation and flooding. Through a challenge, the students explore different solutions to cleaning salty or dirty water. The course is planned in 5 steps inspired by the IBSE-learning cycle:

1. Understanding: what is the problem?
2. Examination: The students examine the water cycle, evaporation and condensation through practical activities. Afterwards they read and work with these concepts.
3. Getting ideas and clarification: The students are brainstorming in groups. They try to find their own solution to clean water, using what they learned in the previous sections. Afterwards they try to clarify why they would use their solution
4. Construction: The students start building their suggestion of a good solution to the problem. They are constructing a way to clean water from salt or from dirt.
5. Presenting: The students are presenting their solutions, and showing how their model is working. They are testing the water afterwards to see if they succeeded in cleaning it.

Efterskolen Ådalen

At Efterskolen Ådalen (continuation school), they have a long tradition for using creative pedagogies, also in science. Based on interview with one teacher (Annex 3.2.B Excellent practice Aadalen) a number of creative approached was given as examples. E.g. the school organised an architectural competition “Design a new student dormitory” amongst their students. The competition is initiated in Mathematics, but is truly interdisciplinary with focus on creative, “out of the box” design processes. The deign challenge (dormitory) is something the students have a personal interest in, so they are highly motivated, invest considerable time and effforts. The work process is characterised with students in “flow”. The students are among others asked to make different models (e.g mock-ups, floorplan, facade drawings to scale) to visualise different design principles. They are also using creative pedagogies when making models in science, eg. modelling the water, carbon and nitrogen cycle with drawings and animations, “dancing” the movement of objects (sun, planet, moon) in the solar system or making podcast portraying well know scientist to tell their story, both personal and their scientific contribution. The teacher feels confident in using creative pedagogies, however sees time consumption and “performance anxiety” among students as some of the major obstacles. The limit “performance anxiety” the creative process is emphasised rather than the product/presentation, witch at their school limits the use of performance art.

3.2.3 VR/AR and other digital technologies to support learning in science (RQ2)

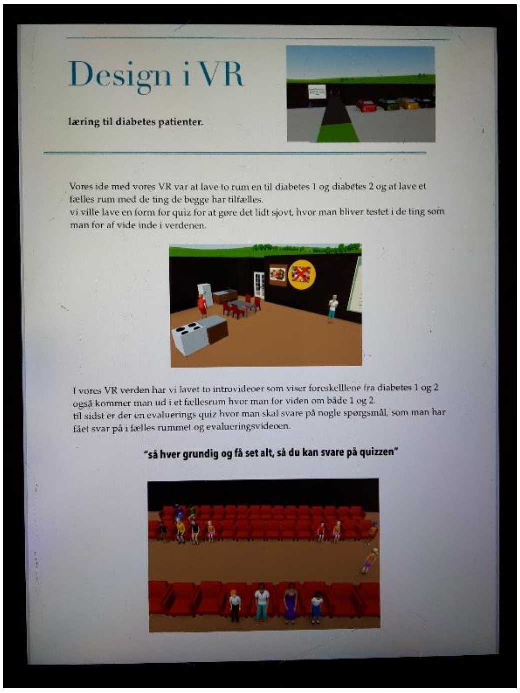
Digital technology is not a separate subject in primary or lower secondary school in Denmark, although the new school subject “Technology literacy” are tried and tested now in selected schools. It is mandatory to integrate digital technology in every school subject (including science). We have included two excellent practices. The first is from a lower secondary school (Marienhoff skole). The second is from upper secondary school. We have chosen to bring this because of the innovative and game-based approach not found elsewhere.

Marienhoff skole

The first excellent practice is from Marienhoff skole (Annex 3.2.C Excellent practice Marienhoff)where a resource teacher in technology works. The students are between 13-15 years old. The project objective is to use the VR technology and create a piece of information about the diabetes to patients that suffer of this disease. In the beginning of the project period, the student visit and talk with a doctor, physiotherapists and patients to get professional information's about the disease. After the input about the disease, they started to create a VR-solution. The students work in Co-spaces with Oculus Go.

Description of two solutions made by students:

1) The type of patient divides the information. One "room" for type 1 diabetics, one for type 2 and one room that describes common features of the diabetes types. The "rooms" includes videos that the students have recorded /put together, facts posters on walls, a doctor injecting insulin, etc. And the end of the walk in the VR-universe the patients got a quiz that tests if you have all the facts - if not, you get "a Donald Trump"☺



2)Murder mystery - who killed the diabetes patient? A corpse is on the street, and bunches of people are gathered around it. A patient was on her way to rehabilitation. The people around the body give you information about diabetes that you need to remember. Then you go into a number of "virtual rooms" where you meet some people who ask you questions. If you answer correctly, you get a clue to solve the murder. The clue is uploaded automatically to a board with pictures of five suspects. When you have enough, you go to another wall and press a button. If you guess right, a police car will move, and you will come to a new place and will probably have a deepening of the right answer.

Game College (RQ2 & RQ3)

The second example of excellent practice combines technology with creative pedagogy. The provider is Game College and the participants are second year student at Game College, 16 - 20 years. The course duration is one month - 50 lessons of 45 minutes (Annex 3.2.D Excellent practice Game College)
Students construct "Escape rooms" in VR. Escape Rooms is a game where you are unlocked in a room in a group or alone. The mission is to get out of the room again.
You solve the mission by collaborating, thinking creatively, solving puzzles, and coping with the tasks and posed challenges by finding a number of clues that help players continue. The clues can e.g. be hidden, visible, locked in.
Often, the people participating in the game are solving puzzles or breaking codes along the way to gain access to new clues, which in turn can provide access to more clues.
https://thecodex.ca/13-rules-for-escape-room-puzzle-design/
The main pedagogical approach is working problem based in groups. The students are collaborating with many subjects using different brainstorming methods. They work with this template: Use-modify-create.

3.3 Pedagogical Approaches in out-of-school contexts (excellent practice)

There are a large number of external learning environments in Denmark. Among them, there are 8 aquariums including both fresh water and marine aquariums. Interestingly, although all the aquariums are strong advocates for ocean literacy, none of the aquariums portray them self as learning environments with particular emphasis on creativity or AR/VR. None of the aquariums is therefor included as excellent practice in this report. The following is a resume of seven of the most relevant excellent practice in a out-of-school context relating to ocean literacy, creative pedagogies and/or digital technologies (VR/AR). The detailed description of each excellent practice can be found in annexes 00-00.

3.3.1 Hoved i havet (RQ1)

Hoved i havet (”Head in the Sea”, Annex 3.3.A Excellent practice Hoved I havet), is an educational facility about the sea to schools made by the University of Aarhus. The school can book an interpreter for a period of 1 hour to 1 day. The interpreter visits the school and offers a workshop including a presentation about the newest research in Sea ecology, followed by experiments performed by the students. The main pedagogical approach is a mix of hands on and minds on activities, a mix of presentations, assignments and practical exercises. There is a wide variety of materials and links on the web pages, making it easy to the schoolteacher to plan several hours of teaching before and/or after the visit.
Homepage: http://projekter.au.dk/havet/forloeb/
There is a wide range of subjects/themes to choose from, ranging from drinking water over plastic in the oceans to sustainable fishing.

Example 1: “Tang-tastic” – a 1½-3 hour offer (specified to the needs of the particular school) on algae and their role in the ecosystem. Involves photosynthesis, respiration and carbon cycle, atoms, the cell, the role of algae in energy production and cultivation of algae.

Example 2: “Plastik på tværs” – typically a 1-1½ hour offer on plastic in the oceans. Involves the physical and chemical composition of plastic, extraction of raw materials, plastic in seas, effect on ecosystems and filtrating animals, recycling and other technologies, political issues.

The project is supported by Nordea fonden, and the offer lasts till April 2019. The interest has been overwhelming from schools all around Denmark and the interpreters have not been able to visit all the schools that applied for it. Furthermore, the web page has been widely used – one of the most frequently visited web pages on Bioscience’s homepages.

3.3.2 Maritime nyttehaver (RQ1)

Maritime nyttehaver (“Maritim Kitchen garden”, Annex 3.3.B Excellent practice Maritime Nyttehaver), i an out-of-school practice designed for students from 4.-9. Grade. Maritime Kitchen Garden is a kind of a “blue school service” that allows school classes to try the work as a sea farmer and with all senses gain insight into the harbour’s ecosystem and the eye for the connection with the large, global food systems. The kitchen gardens produces mussels, oysters and seaweed in the harbour of Copenhagen. The main pedagogical approach is the focusing on practical experiences and presentations. The pedagogical focus is to stimulate the students with many sense impressions to give the students an eye for the connection between the big global systems of foods. The pupils will learn about local and sustainable food production in the harbour, and focus is on students getting a bigger understanding of the ecosystems in the ocean. This excellent practice offer four courses to pupils in primary and lower secondary schools. The schools can book a course and a visit at the harbour, the course will last 2-4 hours. In the courses, the pupils will visit “gardens” under water, where the project is cultivating mussel, seaweed and oysters. After visiting and participating in the production of food under water, the pupils will make examination of the water conditions, dissect mussels or the oysters and at the end of the visit, they will make a meal out of the harvest. During the course, the pupils will learn more about ecosystems in the ocean, organisms in the ocean, sustainability and the environment in general.

3.3.3 WWF Denmark (RQ1, RQ4)

WWF (World Wide Fund for nature, Denmark, Annex 3.3.C Excellent practice WWF), practice combines ocean literacy with the technology part. WWF have different offers that use technology in their teaching.

One of the aims of WWF is to create and support awareness about the importance of the oceans and the challenges related to the oceans. The pedagogical focus is on scaffolding the students' knowledge with both hands on and minds on activities.

Example 1: it is difficult for students to really understand the idea of primary producers and their key role in the sea. However, when the students have caught plankton using a net and have observed the different species of plankton through a microscope they understand that water is not just water.

Example 2: dissection of e.g. fish or mussels, complemented by activities such as filtration experiments. Seeing and touching the organs creates an emotional learning as well as a deeper understanding of connection between biological concepts and ideas.

WWF – Denmark work with technology in different ways:

1) A WWF-produced 3D-film is in the making, and can be seen on this web site: https://undervisning.wwf.dk/opdag-havet
   It is meant to be used for teaching in high schools but might be used by students aged from 12 years. The idea is to show different oceanic biotopes using VR-goggles (or just the phone) to create a feeling of being there yourself. The students will use the film as a starting point for working with complex concepts such as biodiversity, ecologic adaptations etc. For instance, they might use the film to «hunt» species and discover how the diversity among biotopes differ. Or they could use the species of the film to create a food web

2) Podcasts about the sea. Students (high school) listen to the podcast while answering simple questions on a sheet (multiple choice). The podcast give the answers to the questions, which lasts for a maximum of 7 minutes.
3) Explainer videos explaining complex concepts in biology, e.g. limiting factors, climate, eutrophication etc. followed by specific activities such as drawing sketch/cartoon of the concept.
4) E-book for high school students, but might be used for students aged 13-16 too (https://undervisning.wwf.dk/opdag-havet).

3.3.4 The student academy (RQ2, RQ3)

The private company "Elevakademiet" ("The student academy", https://elevakademiet.dk/hvad-er-elev-akademiet/, Annex 3.3.D Excellent practice The student academy), teach students from 7-16 years old. They make one-week summer camps called "maker- and tech camps". They teach in technology modules in schools, doing e.g. teaching plans/materials for some publishers and are consultants in different technology projects.

The firm is specialized in facilitating innovative processes where technology is a part of the solution. The teachers in the firm work a lot with creative pedagogies when teaching in technology. They use different methods to facilitate good ideas and their specific focus is on how students combine ideas from already existing knowledge in a new way to create something. A concreate example is that they teach in different technology-modules making small packages of knowledge about e.g. how cars works or how you make an electrical circuit and afterwards the knowledge is used in a new way that can create something.

According to the teachers in “Elevakademiet” it is important that their students get knowledge and skills in technology before the beginning of the creative part of the teaching plan.
Working with VR/AR the pointe according to the teachers is that the student are active producers in a way and not only inactive users consuming a VR-film.

3.3.5 LEGO-House (RQ2, RQ3)

The aim of the LEGO foundation is to re-define play and re-imagine learning. From LEGO’s point of view, playful experiences support children in developing the skills to serve them, their communities and society through a lifetime. The LEGO house(Annex 3.3.E Excellent practice LEGO house) offers students from 7-12 years to visit the house trying to cope with the creative part of learning. The LEGO-foundation believes that promoting children’s drive and motivation to learn, their ability to come up with ideas and imagine alternatives, as well as to connect with others and their surroundings in positive ways, is essential in a 21st-century reality. The activities in LEGO-house is developed towards five characteristics of playful experiences. According to LEGO, a playful experience is joyful, socially interactive, actively engaging, iterative and meaningful.

Two activities examples from LEGO house:

1) The students create a fish with LEGO bricks. They are free to design whatever they want and after the design process, they give their fish a personality. The fish joins the big aquarium (see photo) and swim together with other self-made fishes and the student can watch how their fish interact with other organisms in the aquarium. This activity stimulates the students’ creativity and their emotional skills.

2) Create a sustainable town. This activity challenged the students’ cognitive skills. They shall explore what the different squares on the table symbolise and how you, by manipulating the squares, can influence the infrastructure of the town.

3.3.6 Vadehavscenteret (RQ4)

Vadehavscenteret ("The Centre of the Wadden Sea") is an excellent practice combining AR-technology with Ocean Literacy (Annex 3.3.F Excellent practice Vadehavscenteret). It is part of the exhibition of the Center of the Wadden Sea, hence entrance has to be paid. The Centre has around 300 school classes visiting each year, and many of them visit the exhibitions on a guided tour in addition to the outdoor teaching they receive from the interpreters.

The visitor stands in an exhibition room with 3 telescopes and 10 wooden poles, each with a carved wooden bird on top of it. The visitor looks through a telescope, and suddenly the birds come alive as the telescope is pointed towards them. The plumage is coloured and they move in a way characteristic for the specific species. At the same time, a little sign with the species name appears in three languages. When the telescope is moved to another bird, this bird comes alive and the first one fades. Watch the video: https://www.youtube.com/watch?time_continue=133&v=8FyrXc9ucpw

The exhibition is meant to provide the visitor with an aesthetic experience of the birds of the Wadden Sea. It relates to the other parts of the exhibitions that all circle around the main topic "Birds of the Wadden Sea" and the purpose is to communicate the importance of the Wadden Sea area for the thousands of migrating birds that visit each year.

The AR technology allows the visitors to communicate while occupied by the experience. Augmented Reality, simple technology developed by "No Parking" (https://noparking.dk/).
It has been important for the Center of the Wadden Sea that the story they wanted to tell dictated the technology used – not vice versa. It is not their intention to compete with computer games and top-notch VR goggles.

3.3.7 Universe Science Park (RQ2)

Universe Science Park (Annex 3.3.G Excellent practice Universe Science Park) is an adventure park with a lot of possibilities with hands on science activities. It is one of Europe's largest exhibitions using VR/AR. Their knowledge and experience using these technologies made them offer two types of tuition. Business College Syd showed an interest, since they could offer their students new opportunities while the requirements for digitization were met.
Start-up spring 2018 – still in a state of learning and developing the offers.

<u>Example 1:</u> One full day spent at Universe Science Park using VR. Involving 8-30 students. Aim: Students get to know and understand VR and its use in commercial contexts. They are provided with a basic understanding of the potentials and how to implement the technology.

1. Tour in the exhibition to see examples of how VR has been used to promote a mercantile agenda e.g. Ikea Kitchen. The students are encouraged to relate the examples and principles to their own line of education.
2. Theory lesson on VR and the uses of VR in companies (VR is widely implemented for internal use in companies, e.g. for training). Introduction to exercise
3. Exercise: Production of 360° film. It is emphasized that the film must contribute in a way that a "normal" film cannot.
   The exercise is performed in small groups, and students must decide on a topic, create a storyboard, shoot the film and edit it. They can make use of the exhibitions at USP as well as discuss with the interpreter throughout the day.
4. Presentation of the film – feedback and new perspectives from interpreters and fellow students.

Challenges: Students tend to use the 360° camera like a smartphone camera. Furthermore, Universe Science Park developed some of the programs used – however, this launces to challenges: the upkeep is difficult and expensive, so they recommend using apps etc. that are already available and which can be used outside science park as well.

Another challenge is the level of abstraction – some students find it difficult to grasp the principles and relate it to their own line of work. Hence, the exercise does not seem relevant to them.
However, in general, students and teachers are happy with the teaching.

Example 2: One full day spent in the science park using AR to create a product. Focus on technology and engineering. The aim is to inspire students to use technology in professional and personal life.

The scaffold is similar to example 1 with a tour, a theoretic lesson, an exercise and a presentation. The exercise is to create a business card using AR. The business card must present something from their company – a product, an event or an offer. They must create the physical aspect as well as the VR layer.

Challenges: The Universe Science Park tried to introduce a «bring your own device» for this exercise – however, it turned out to be difficult to ensure that every student had an up-to-date device. Furthermore, it proved difficult and time consuming for the interpreter to provide every student with right and sufficient help. Now, the Science Park uses entirely commercial programs during the exercise due to the challenges faced during the VR teaching, (see example 1). They use different apps developed for mercantile purposes, and apps and programs are preloaded on devices – or run entirely online.

The teachers in the Universe Science Park experienced a higher level of motivation among students and a perception that students had less difficulties relating AR to their daily and professional life compared to VR. It was easier for the students to see the potentials in AR.

4. National literature review/perspectives

In Denmark, the research emphasis and public discourse regarding ocean literacy and creative pedagogies in science are sparse and not commonly reported in the public domain. On the other hand, digital technology and technology literacy in education has received quite a lot of political and media attention. A lot of new research and development initiatives has recently been launched, but few have yet to report own findings.

4.1 Danish (and Scandinavian) peer reviewed literature

The following is based on searches in the national peer reviewed literature in Denmark, but also in the other Scandinavian countries (Norway and Sweden). The systematic searches for Danish peer-reviewed research was conducted in March and May 2019 in the two database: bibliotek.dk and The Danish National Research Database. Bibliotek.dk is a portal for all Danish libraries (public libraries, specialized libraries and academic libraries) and gives broad access to what is published in Denmark. The Danish National Research Database (forskningsdabasen.dk) is primarily based on data collected from the local research databases of Danish universities and other Danish research institutions and covers published literature (e.g. journal articles, PhD theses and conference presentations). A search was also conducted in the Norwegian Oria-database (Oria.no) and the Swedish Swepub (http://swepub.kb.se/).

The identified literature was manually rated based on the inclusion criteria and relevance for the specific research questions (section 1.1 Research questions). The criteria for inclusion/exclusion was discussed both internally in the Danish research team and with international research partners. The selected literature was then summarised using the review template (Annex 4.1.A-C). In the next step of analysis themes relating to the focus of identifying pedagogical principles for research questions across studies. In the following findings will be presented under headlines of VR/AR, ocean literacy and creativity and with some key-points summing up synthesis from the search.

Virtual and augmented reality and other digital technologies

The literature from the search for virtual or augmented reality include 8 Danish studies (Annex 4.1.A Danish Literature Review DigitalTechnology PRrev) and two from Sweden. Results from the Danish part of the Erasmus+-project AR-sci (B. Nielsen, Brandt, Radner, Surland, & Swensen, 2017; B. L. Nielsen, Brandt, & Swensen, 2016, 2018) focus on how students' inquiries and exploratory talk are scaffolded, both the pre-planned sequencing of the lessons (macro scaffolding) and the micro scaffolding in the form of teacher-student dialogue. Another study (Majgaard, 2016) describes examples of the use of AR to support 6th graders understanding of the solar system. The study developed and tested an app where students could explore the proportions and movement patterns of
planets in the solar system. Both Natural science and technology students and teacher contributed actively in the design process. The observed experienced-based learning potentials was decribed in two themes: (1) to see the unseen – the use of technology as a lens to a distant reality and (2) to understand spatial objects and movements in three dimensions. Another interesting study (Majgaard, 2015) explored the learning potentials that arise by combining spatial modelling in physical and virtual media in a 5th grade art class. The study report that students obtained a better understanding of technology and creative design processes by acting as informants and design partners in the design process. There are also one reported Danish study (Buhl & Rahn, 2015) focusing on the use of VR-technology in nursing education. The design tests show that AR and wearables promote visual learning in a positive way, however that even small technical adjustments shifted the students' focus from learning about respiration to focus on the technology itself. They also report that VR and IBSE facilitate visual learning and support a holistic approach to learning anatomy.

Ocean Literacy

The literature research for ocean literacy in Danish studies is very sparse. The literature review (Annex 4.1.B Danish Literature Review Ocean Literacy PRrev) has been concentrated in the Danish scientific journal with peer-reviewed articles, MONA. In this journal, there have been no articles about research studies where ocean literacy has been the focus in the period 2010-2019.
Despite of that there is studies that the ocean connection-project could be inspired by. A study reported by Wistoft & Stovgaard (2012) describes a research-based evaluation of a project called "Gardens to Guts". Garden to Guts is an organic school garden and it has been a centre for children's nature experiences. The general intention was to expand children´s competences and their knowledge of nature, farming and cooking. The evaluation shows very positive learning outcomes linked to experience and desire to learn and provide the possibility of interdisciplinary and enjoyment based learning.

Creative pedagogies

The literature from the search for creative pedagogies (Annex 4.1.C Danish Literature Review Creativity PRrev) include different project from an informal learning context. A study reported in MONA (Murmann, 2011) describes the theoretical considerations regarding the design of a narrative school material made at the Danish science centre "Experimentarium". It is based on a case material called "The Emperor who only believed his own eyes", and it describes how this kind of narrative can be a useful tool for students when they have to navigate in an exhibition. The article describe how various narrative forms from books and virtual reality may inspire a design.
Another interesting study (Quistgaard, 2010) made on the natural history museum in Copenhagen describes a research project that investigated the impact on upper secondary school students of a visit design for a museum visit, consisting of worksheets with authentic questions in combination with a dialogical approach by a museum educator. The research shows that authentic questions had great potential, especially the questions that stimulated wonder, curiosity, and had high cognitive levels and centred on the students prior interests. The investigation also showed that the museum educators

approach was most successful in fostering dialogue and substantial engagement when being pronouncedly dialogical and student centred.

A study (Rask Petersen, Elkjær, Kragelund, & Poulsen, 2014) describes how informal learning settings can include games and game-like elements in a school visit at the science center "Oekolariet". The study discuss the conflict between the curriculum and free-choice learning that informal learnings setting stimulate. The evaluation show that the students report that the games help to imprint the science concepts in their minds but they also reflect on that the competition in the games came to fill too much so the focus was shifted from the academic content to the competition.

4.2 Subject Associations and its journals (not peer reviewed)

In Denmark primary and lower secondary science teachers are organised in national associations for biology (Biologforbundet, https://www.biologforbundet.dk/), physics/chemistry (Danmarks Fysik- og kemilærerforening, https://fysik-kemi.dk/) and/or geography (Geografforbundet, http://www.geografforbundet.dk/). Each association has its own journal. These journals are not peer reviewed, and will not normally meet academic standards regarding research question, methodology and reporting of finding. We have reviewed the content of the last 5 years in these journals:

- Kaskelot, the journal of the National association for biology teachers (Biologforbundet).
- Fysik/Kemi, the journal of the National association for physics/chemistry teachers (Danmarks Fysik- og kemilærerforening).

Ocean Literacy

In Kaskelot (journal of the National association for biology teachers), several articles addresses projects or activities to do with elements of ocean literacy (Annex 4.2.A Danish Literature Review OceanLiteracy non-PRev). The theme of Kaskelot journal number 208 (2015) was citizen science and how to integrate citizen science in school. There are several examples connecting to ocean literacy e.g. registering whales and report it to a homepage www.hvaler.dk. Another example is to use an app from WWF called "explore the sea" and report the marine organisms found on a field trip.
The journal number 212 from 2016 has a theme about plastic and the oceans. In this journal there is an article about a cooperation between the natural history museum Aarhus, the art museum AROS and the history museum Moesgaard in a project called "The Sea and the human" (https://www.naturhistoriskmuseum.dk/Files/Billeder/Undervisning/Havet%20og%20mennesket%20rapport.pdf). The project tried to integrate science, art and history, they made an event with the opportunity to explore the smallest organisms in the sea in the microscope, examine mussels and crabs, make seaweed salt and oysters over bonfires like the Stone Age people, and the Vikings did. All the participants were involved in making a large work of art with the sea as a theme.

The Kaskelot numer 211 (2016) describe and inspire to involve hands on activities like dissections in the teaching. There is detailed descriptions of fish dissections and what learning potentials the dissections can develop.

VR, AR and other digital technologies

There are few relevant articles in the two teacher journals of the Danish associations for science teachers (Kaskelot and Fysik-kemi), se Annex 4.2.B Danish Literature Review Digital technologies non-PRev. One article by Karunahara & Azoulay (2017) in Kaskelot reports on a Danish developed VR-material focusing on UNs 17 sustainability goals and globalisation. Students travel virtual to Sri Lanka and joins "Sajani" in different parts of the country to explore the effects of e.g. climate change, deforestation and waste. The article emphasize that immersiveness affect students emotions with students quotes like "it just easier to relate to how they feel, and how they are coping" when working with the VR-resource. The articles in Fysik/kemi relating to digital technology are focused on either use of digital resources like online learning material, digital test or technologies like tablets, Mico-bits or apps in an educational context. There are a few examples of the use of AR/VR-technologies, but they are presenting the potential possibilities of the technology rather than reporting testing or actual use with students.

Creativity

There are very few references directly to creative pedagogies or arts in either of the journals of the Danish associations for science teachers (Annex 4.2.C Danish Literature Review Creativity non-PRev). E.g. in Fysik-kemi there are a few article reporting on practice where creativity are mention alongside innovation (Dahl, 2014; Hjortlund, 2018; Ottar Jensen & Artmann, 2016), but without any specific description on how the practice is creative or innovative. It is worth noticing that creativity seems to mentioned alongside programming and use of digital technologies like Arduino, Micro-bit, 3D-printers etc.

4.3 National and regional conferences (not peer reviewed)

There are a number of national and regional science teacher conferences in Denmark, with the Big Bang Conference definitely being the larges one. It is difficult to make a systematic search in the conference contributions, as they are not accessible in a public database. However, many of the contributions with academic standards would be registered in the National Danish research database (forskningsdatabasen.dk). A search her reveal nothing. A google search at the bigbangkonferencen.dk website revealed only 3 presentation, all within the last 3 years on augmented reality and only one presentation of virtual reality.

5. International research literature on Ocean Literacy in Science Education including perspectives on ICT & Learning and socio-scientific issues

5.1 Abstract

This part of the literature review leads to suggesting pedagogical principles, in headlines summed up as: 1) technology-supported, 2) inquiry-based, and 3) data-driven science teaching, using 4) real-time data if possible, 5) supported by virtual and/or augmented reality to e.g. illustrate the invisible phenomena and processes, and with 6) communication between school students and external stakeholders (the public and/or scientists), 7) a systems approach to critical concepts and processes, such as the water and carbon cycles, and a focus on 8) model-based inquiry, where students design their own models, and use them to test out their ideas.

5.2 Methodology

The following is based on 3 searches from the international literature plus some snowballing from these references (see all references in annexes DK1 A, B and C). The first search (DK1A) was with the search string [ocean literacy] in Eric and Teacher Reference Centre. The next search (DK1B) was broader across research publications and with the search string [(ocean literacy) AND ict AND (science education)]. Finally, the search DK1C was with the search string [(ocean literacy) AND science AND socio-scientific]. The snowballing procedure lead to including literature reviews from research in science education in relation to scientific literacy, socio-scientific issues, learning technologies, digital technologies & representations (see figure 1 and the last section below).

The systematic searches for international peer-reviewed research was conducted in February and March 2019. The identified literature was manually sorted after the inclusion criteria of relevance for the specific research questions (above). Criteria for inclusion/exclusion was discussed in the group of researchers. Research applying a wide range of quantitative and qualitative methods was included in the narrative synthesis (Gough, Sandy, & Thomas, 2017; Popay et al., 2006). The procedure was, that first a summary of each study, from the final pool of articles, was made using the review template (see Annex 5.1-4). In the next step of analysis themes relating to the focus of identifying pedagogical principles for teaching about Ocean Literacy were identified across studies. This was beside the literature on narrative synthesis informed by the analytical approach thematic analysis widely used in qualitative and mixed methods research (Braun & Clarke, 2006).

5.3 Findings

The findings will be presented under headlines of each of the searches and with some key-points summing up after the synthesis from the search. In this way, the discussions in the groups of researchers during the process of reviewing the literature are presented as they actually occurred in time.
After these 3 sections there will be a final discussion across the full pool of literature identified in the 3 searches plus the snowballing.

5.3.1 Search DK1A

The literature from the search DK1A, where 17 studies are included in the review, are mainly development projects and/or classroom trials, and mainly papers from a US context. The search was for publications in peer-reviewed journals, but the search words lead to hits mainly in peer-reviewed *practitioner* journals like “Science Teacher” (https://www.jstor.org/journal/scienceteacher) or “Science Activities” (https://www.tandfonline.com/toc/vsca20/current). The scope of these journal is specifically to share examples from practice, so therefore the rather low rating of methods and/or examples where methods are not described (Annex 5.1 International Literature Review DK1A).

Therefore, there are many examples of exemplary activities focused on Ocean Literacy e.g. (Haley & Dyhrman, 2009; Thompson, Curran, & Cox, 2016; Webb & Carla Curran, 2017). Many papers refer directly to Ocean Literacy Framework and the 7 key principles of ocean Literacy e.g. described in UNESCOs Ocean Literacy for all – a toolkit (Santoro, Selvaggia, Scowcroft, Fauville, & Tuddenham, 2017). Examples of papers referring directly to the framework are (Eidietis & Rutherford, 2009; Plankis & Marrero, 2010; Schoedinger, Cava, & Jewell, 2006; Webb & Carla Curran, 2017). The framework is by UNESCO (Santoro et al., 2017) presented referring also to the UN Sustainable Development Goals, and therefore it is no surprise that many of the articles have directly or indirectly reference to central conceptualizations from the science education literature like scientific literacy, socio-scientific issues (SSI) and environmental education. Here for example a quote about aims from Gillan and Raja (2016): ”…*children understand and commit to more sustainable lifestyles*…”. This way of stating aims when discussing specific teaching designs is referring to what in the German/continental tradition of educational research is called ”bildung” related purposes.

Many of the studies/initiatives include inquiry-based activities for the students, for example by using the so-called 5E model (Eidietis & Rutherford, 2009; Gillan & Raja, 2016). There are several examples where school students are generating their own data e.g. (Webb & Carla Curran, 2017) and examples where school students are cooperating with and/or working with data from scientists (Thompson et al., 2016). Furthermore, students’ work with real time data/global data-sets is specifically emphasized by Adams and Matsumoto (2009) and Beaulieu (2015). Finally, there are reference to how students can work on models and create their own models (Webb & Carla Curran, 2017; Weersing, Padilla-Gamino, & Bruno, 2010).

Summing up, we can based on this first reading of the literature conclude that there are quite many good examples of applying the pedagogical principles of 1) technology-supported, 2) inquiry-based, and 3)data-driven science teaching. BUT we cannot conclude that there is evidence for those pedagogical principles for teaching ocean literacy, due to the methodology-concern raised above, with many studies published in the practitioner journals and without transparent methodology. But also due to the fact that many of the initiatives refer to the same original framework. Therefore, those pedagogical principles are to some degree given from that framework.

One of the discussions in the team of researchers after the first searches was, that we instead of asking the guiding question of what evidence we can find for certain pedagogical principals for teaching ocean literacy, it might be a better approach in the international project group to work on developing a pedagogical model conceptualizing Ocean Literacy *in a specific way* and *with a specific rationale*. The rationale could e.g. be: *If* we conceptualize Ocean Literacy referring to a multidimensional understanding of Scientific Literacy (more below) and with arguments for teaching science in schools referring to *social* relevance (Holbrook & Rannikmae, 2009), *then* there are good arguments for the pedagogical principles of 1) technology-supported, 2) inquiry-based, and 3) data-driven science teaching, using 4) real-time data if possible, and with 5) communication between school students and external stakeholders: the public in general and/or scientists in the field.

However, in relation to building the framework on solid ground this first search also accentuates how important it is for the project to be informed by what is *in general* known from the well-established fields of research in science education about issues like inquiry-based approaches, scientific literacy, technology in science teaching, and the work with socio-scientific issues in schools. The model represented in figure 1 was actually developed in this process (see the section below with reference to published literature-reviews in these areas).

5.3.2 Search DK1B

The second search lead to identifying more studies from more high ranking, international research journals than the first search. All in all, 8 references are included in the review from this search. Four of these are Masters and PhD dissertations (see Annex 5.2 International Literature Review DK1B).

Following up on the findings emphasized above there are studies documenting effect on STEM interest and subject understanding from (high school) students' ict-hosted data-collection (Black, 2018). STEM is short for Science, Technology, and Mathematics. The studies include several publications, including a PhD dissertation, from Géraldine Fauville. The title of the dissertation from 2018 is "*Digital technologies as support for learning about the marine environment*". The teaching context of the studies for the dissertation was a Swedish high school, in a project focusing on ocean acidification. The students used a virtual lab, had a virtual lecture and an was involved in asynchronous discussion with a marine scientist on an online platform. Fauville concludes, that students' interaction and dialogue with scientists allow these high school students to explore a wider range of ideas (Fauville, 2017, 2018). The holistic expertise of the marine scientist seems to allow the students to explore and reason around a very wide range of ideas and aspect of natural sciences that goes beyond the range offered by the school settings. She highlights also the affordances of the virtual lab of making the invisible visible for the students (Fauville, 2018). Furthermore, the potentials of citizen science are emphasized by Fauville, and is also a theme in other studies (Fauville, 2018; Steel, Lovrich, Lach, & Fomenko, 2005).

These studies refer to high school students, but the identified literature also include studies focusing on primary and lower secondary school students. Irvine (2011) for example refer to 4th-6th grade students using an underwater camera and having real-time discussions with scientists. In the studies with high school students by Fauville is used an online platform called VoiceThread (www.voicethread.com), enabling users to upload images, video or documents, to record and save audio, video or text comments and to collaborate around these artefacts. It can be added that there in Fauville (2017) is reference to another study where Voice Thread was used by sixth graders in a science inquiry project on photosynthesis and CO_2 emission.

Another PhD dissertation is Robinson (2011). This thesis built on developing and trying out an online curriculum including the use of social media. The title of this thesis by Julie Ann Robinson is "*A multi-Source evaluation model for the pilot of Digital Ocean: Sampling the Sea—Preliminary results and lessons Learned*" A unique multi-source model was developed by e.g. the doctorand to test two hypotheses related to students' ocean literacy learning outcomes. Additionally, a process evaluation examined the transdisciplinary research project from the perspective of achieving the proposed eight goals outlined by the developers. The pilot is concluded to have achieved many successes in areas of innovation and in the launch of an online, integrated ocean science and social media high school curriculum about sustainable seafood. However, the project development team encountered many technological challenges and transdisciplinary research issues. Overall, participation was extremely low, and only a small portion of teachers and students actually accessed or used the curriculum and activities. However, data collected for those teachers and students who did use the system indicate small but statistically significant increases in some learning outcomes related to the five domains, including sustainable seafood knowledge. Robinson also highlights, that the affective dimension, not only the cognitive, is important (Robinson, 2011).

Among the studies from this search is a comparative questionnaire study analyzing the ocean literacy of a sample of pupils in the UK and in Portugal, as well as the pupils' modes of gaining information about ocean-related topics by using different media sources of information (such as TV, radio, computer, mobile platforms, magazines, or books) (Leitão, Maguire, Turner, Guimarães, & Arenas, 2018).

The participants in the survey by Laitão et al. (2018) are students grade 7, 8, 9 (12-14 years) in six schools in Portugal and three schools in the UK. The study suggests that, regarding the preferred source to get information about the ocean, the computer is clearly the preferred media, while the radio is the least chosen option by pupils in both countries. Moreover, findings show there is no significant association between the choice of media source and ocean literacy levels. The overall results suggest that the more the pupils know about the ocean the more important is for them and the more they feel personal responsibility for its well-being.

Finally, there is a study from a museum setting (Radeta, Cesario, Matos, & Nisi, 2017) examining gaming versus storytelling with the aim of understanding children's interactive experiences in a museum setting Radeta et al. (2017) argues referring to previous research that storytelling and game-based approaches benefits museums by promoting joyful and exciting experiences, which have the potential to support meaningful learning. They state that the use of mobile devices to enhance and enrich museum visits has a long history, but the idea that interactive playful mobile experiences can play an equal role is a more recent approach at museums. The data collected suggest that children are 27% more excited when using the game application compared with the story driven one. Moreover, it is concluded that children's excitement peaks when encountering selected artefacts presented in the museum exhibit. Finally, children's learning nearly doubled (44%) when using the game-based experience versus the story.

Summing up, there are from the studies identified in this search examples of more solid methodology being applied, but still it is clear that the research field is very un-mature. Basically, the pedagogical principles of technology-supported, inquiry-based and data-driven science discussed after search DK1A is confirmed. Here e.g. with some solidly documented studies of how school science can be combined with citizen science. As mentioned, the affective dimension - not only the cognitive – is discussed, but it is also emphasized that students' content-knowledge is important for them to be engaged in the socio-scientific discussion. Referring to the experiences from Robinson (2011), is can also be advised, that "less can be more", when it comes to the complexity of the technology. A lesson learned can be to make the technology approach quite simple.

5.3.3 Search DK1C

Search DK1A and B both showed a frequent reference to what in the field of research in science education is often called Socio-Scientific Issues (SSI). Noticeable, *without* including search words referring to SSI, environment etc. This third search followed up by including these search terms to gain more insight in this specific field. The combination of SSI and ICT in the searches did not provide any hits, therefore this DK1C was without search word referring specifically to ICT, though this was the focus when setting out to perform this part of the review.

Like for the other searches an overview with a summary from all 12 included studies, including four PhD dissertations (T. Greely, 2008; Kim, 2014; Linsky, 2012; M. E. C. Marrero, 2009), is presented in Annex 5.3 International Literature Review DK1C.

The first results presented here is from a literature review about research on learning and teaching ocean and aquatic sciences (Tran, Payne, & Whitley, 2010). Based on the studies in the review the authors provide three major suggestions. 1) A *systems approach* to critical concepts and processes, such as the water and carbon cycles, may support students' ocean literacy. They emphasize that systems thinking has great explanatory and predictive power. 2) Understanding global processes from a systems perspective requires types of thinking skills that are challenging to develop. Strategies that can support systems thinking include a) ensuring that teachers have advanced pedagogical knowledge to scaffold student thinking; b) designing activities that give students control to create and manipulate models (virtual and physical); and c) providing opportunities for students to talk with peers to reflect on, articulate, and share their thinking.

The third suggestions, 3) is to include informal learning environments like aquariums, museums and science centers, because such sites can provide access to objects, organisms, and phenomena that create personal connections for the learners. Tran et al. (2010) emphasize the aim of students' understanding of the cycles (water, N, C…) as complex systems, and connected to this they refer to `systems thinking skills´ (Tran et al., 2010, p. 24), that can be defined as the students´ capability to , 1) use models, and more specifically to create, manipulate and revise models. This appears to help the students to think about complex systems. Furthermore, 2) it is recommended that students design their own models, and use this to test out their ideas followed by rethinking and revising, and 3) to use computer-based learning environments such as virtual environments.

They emphasize the students´ personal and emotional connection to the science phenomena they are inquiring into, so to sum up based on the review they have the 3 major suggestions of 1) a systems approach, 2) acknowledging this is challenging, so providing opportunities for students to talk, articulate and share their thinking, and 3) informal learning environments provide access.

In many of the studies specific programs or approaches has been tried, providing some data on ”effect” (i.e. in the mentioned PhD dissertations).

There is both a dissertation and a paper referring to the ACES program (M. E. C. Marrero, 2009; M. E. Marrero & Mensah, 2010). The tittle of the dissertation is "*Uncovering students' conceptions of the ocean: A critical first step to improving ocean literacy".* More about the ACES program can be found here: http://www.signalsofspring.net/aces/about.cfm :

"The goal of Signals of Spring — ACES [Animals in Curriculum-based Ecosystem Studies] is to improve environmental and ocean literacy and to capture the interest of your middle and high school students, grade 7 and higher. Students will learn science within the context of the ocean, with high-quality curriculum-based activities, as they use satellite data to develop authentic inquiry skills".

The paper (M. E. Marrero & Mensah, 2010) focuses on the question "I*n what ways do students engaged in an ocean literacy-focused curriculum draw upon scientific concepts of the ocean when considering personal and societal decisions related to it?*". They conclude, that their findings contradict previous ones that students do not rely on what they learn in science class when making decisions. The 7th grade students in the study were according to the authors able to apply ocean concepts pertaining to physical and biological processes to personal and societal decision making related to pollution, food choice, and on a sample of SSI-based tasks. The results suggest that students are empowered by the knowledge of the ocean gained through the ACES curriculum and that using SSI may be a way to help students achieve ocean literacy.

A commentary by Marrero (2019) is also included in the review table (Annex 5.3 International Literature Review DK1C). She is at present serving as President for the National Marine Educators Association, so her utterances can be expected to mirror a contemporary focus in education for Ocean Literacy: Two quotes from the commentary: "*Many of our 21st-century socio-scientific issues, such as climate change, plastic pollution, and oil and gas exploration, will require solutions developed by ocean literate citizens. The path to ocean literacy, "an understanding of the ocean's influence on you, and your influence on the ocean"* (Carley et al., 2013)*, begins in the classroom", " ….model these processes by* *engaging students in analyzing authentic ocean data, solving problems through ocean-based engineering design challenges, or researching newly discovered species".*

Following the line of inquiry from above about students' outcomes from particular experiences are a PhD dissertation about a marine aquarium summer camp (Kim, 2014). The title is "*Connecting children to the ocean: Understanding elementary students' changes in ocean literacy during a marine aquarium summer camps experience*". Quantitative analysis of survey data revealed appreciable changes in students' marine science knowledge and in their orientations. In particular, students' marine science knowledge and naturalistic, aesthetic, and recreational orientations increased while utilitarian and negativistic orientations decreased after participating in AquaCamps. Qualitative data analysis elucidated AquaCamps program components that influenced these changes. The analysis also revealed additional sources including family members and multimedia, which affected changes in students' ocean literacy. A noteworthy finding of this study is students' limited understanding of their connections to the ocean and marine organisms as a whole.

Another paper about specific activities for students is a SSI-case of mangrove depletion (Luther, Tippins, Bilbao, Tan, & Gelvezon, 2013). The paper is published in the practitioner journal "Science Activities (see more under DK1A). So, the paper is about what have been done, but without data. They argue in the paper that students can explore scientific concepts relating to mangrove ecosystems while fostering moral and ethical reasoning.

And one more (Tsai, 2018), here however about online argumentation. The study proposes the SSIs-Online-Argumentation Pattern (SOAP) to develop a pedagogical strategy enabling students to participate in online argumentation of SSIs. Two quasi-experiments were conducted to investigate the variations in scientific competencies and sustainability attitudes of students following the SOAP strategy. The results showed that the SOAP strategy led to differences in high school students' scientific competencies. The mean scientific competency of the experimental group was higher than that of the comparison group in the post-test and in the delayed test. Specifically, for the constructs identifying scientific issues and using scientific evidence, the difference between the two groups did not reach significance in the post-test and in the delayed test.

Another of the four dissertations "*Teachers' conceptualizations and classroom inclusion of ocean literacy following an intensive marine science professional development program*" (Linsky, 2012), focus on a specific professional development for teachers. The program is an intensive marine science professional development program in Hawai`i known as Project ISLE (Integrated Science Learning Experiences). She among others concludes, based on qualitative data, that the teachers' personal backgrounds had a large influence on their individual conceptualizations and classroom inclusion of ocean literacy.

Garay, Wotkyns, Lowry, Warburton, Alderkamp, and Yager (2014) both focus on students and teachers , for the teachers more specifically teachers and researchers working together. This is not a specific study, but a commentary, where they illustrate how ASPIRE teacher–scientist partnerships helped engage students with actual and virtual authentic scientific investigations. They state that crosscutting concepts of research in polar marine science can serve as intellectual tools to connect important ideas about ocean and climate science for the public good. More about ASPIRE here: [ASPIRE: The Amundsen Sea Polynya International Research Expedition](#).

There are 3 references where research is connected to the final dissertation (T. M. Greely & Lodge, 2009; T. Greely, 2008; T. M. Greely & Lodge, 2009). The tittle of the dissertation is "*Ocean literacy and reasoning about ocean issues: The influence of content, experience and morality*". The Survey of Ocean Literacy and Engagement (SOLE), was used, together with another survey and some qualitative research instruments, to measure teens understanding about the ocean. SOLE is a 57-item survey instrument aligned with the Essential Principles and Fundamental Concepts of Ocean Literacy (NGS, 2007). The study analyzed underlying factors and patterns contributing to ocean literacy and reasoning within the context of an ocean education program, the Oceanography Camp for Girls (OCG). The study measured a) what understanding teens currently hold about the ocean (content),b) how teens feel toward the ocean environment (environmental attitudes and morality), and c) how understanding and feelings are organized when reasoning about ocean socio-scientific issues (e.g. climate change, over fishing, energy). Based on a quantitative analysis she concludes, that content knowledge and environmental attitudes significantly contributed to ocean literacy. She states, that findings provide empirical evidence that connects field studies with ocean literacy, and continues referring to, that current guidelines for ocean literacy address cognitive understanding but lack multimodality. The need for ocean literacy that goes beyond content to include reasoning and actions is relevant towards preparing students, teachers and citizens to regularly contribute to decisions about ocean issues.

Summing up from this third search there are many studies of effect from specific programs. And again, many studies referring to the same Ocean Literacy Framework. The fact that research in the field is to a high degree concentrated around some of the same actors, e.g. Meghan Marrero, referred to here, is confirmed by a bright new Springer publication (Fauville, Payne, Marrero, Lantz-Andersson, & Crouch, 2019). The names can be recognized from this review.

In relation to the aim of the review the review (Tran et al., 2010) is quite interesting. The principles referred to above from this review must be really relevant in relation to developing pedagogical principles. We will not repeat it here, as it is elaborated above, just highlight in particular what we interpret as an iterative approach to students´ *model-based inquiry*. We suggest that model-based inquiry, where students are engaged with the content by collaboratively geerating, testing and revising explanatory models, could be a central conceptualization in the project (Windschitl, Thompson, & Braaten, 2008).

5.3.4 Search DKD for AR/VR and other digital technologies

A search in ERIC and Teacher reference center database (Annex 5.4 International Literature Review DKD)revealed a number of resent international literature reviews focusing on VR (Jensen & Konradsen, 2018; Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017) and AR (Bacca, J., Baldiris, S., Fabregat, R., Graf, S., 2014; Drljevic, Wong, & Boticki, 2017; Koutromanos, Sofos, & Avraamidou, 2015; Ozdemir, Sahin, Arcagok, & Demir, 2018; Radu, 2014; Saltan & Arslan, 2017; Wu, Lee, Chang, & Liang, 2013) in education that we can rely on in our state-of-the-art.

One review points to that the examples of VR in education is currently largely skewed towards those for simulations and training purposes (Jensen & Konradsen, 2018). Increased immersion and user-motivation were the most commonly reported motivations identified in the review. However, the most commonly provided justification for increased user-motivation was that authors believed simply utilizing these technologies in education would be enough to motivate students. By far the most frequently reported issue identified in the review was that of software usability. Users reported a multitude of issues, including counter-intuitive interfaces, confusing objectives, and that they would even get lost in the virtual environments, lack of realism provided by the educational VR implementations.

A study by Parong & Mayer (2018) suggest that immersive VR significantly increase student motivation, interest, engagement, and affect, but does not improve students learning of basic scientific knowledge. However, the effectiveness of VR can be increased by prompting students to use generative learning strategies, such as summaries, without diminishing the learner's motivation, interest, engagement, and affect while using immersive VR. Another study (Makransky & Lilleholt, 2018) suggest that immersive VR has significant potential for use in lab simulations like "Labster". To improve learners' satisfaction and perceived learning outcomes the study implies to design VR environments that are enjoyable and motivating by creating a high level of usability and good VR features, which give students a sense of presence. The second is to ensure that students have a high level of autonomy through a sense of control and active learning, and to make sure that students see the cognitive benefits of the VR lesson. Embodied Mixed Reality Learning Environment (EMRELE) was found to lead to greater learning gains by Johnson-Glenberg et.al. (2014).

In a review by Radu (2014) benefits such as increased content understanding and student motivation when using AR was found, while challenges were about usability difficulties and ineffective classroom integration. Among the factors influencing student learning is in particular highlighted that the content can be represented in multiple ways, i.e., as sound, visualization and animation facilitating students' ability to experience phenomena that are otherwise impossible or infeasible, e.g., due to spatial scales. Wu et al. (2013) point to the following affordances: learning content in 3D perspective, ubiquitous, collaborative and situated learning, learners' sense of presence, immediacy, and immersion, visualizing the invisible and bridging formal and informal learning.

A study by Hsiao & Wang (Hsiao, Chang, Lin, & Wang, 2016) study show that key characteristics of the "manipulative" AR, such as the simultaneity of virtual and real objects, high interactivity, and hands-on experience, made a greater positive impact on the students' academic achievement and motivation.

The results of the literature review on use of AR games in education (Koutromanos et al., 2015) found only a limited number of augmented reality games, however the majority focused on science. The study concluded that the AR games showed a positive effect both on the participation and involvement of students in learning and on learning outcomes.

An interesting study by Chen & Wang (2018) uses a game-type AR to construct a mixed-reality environment that facilitates conceptual learning among 5th and 6th graders. The study reports discrepancies in presence and perception among learners and evidence of a relationship between presence and learning achievement in AR-mediated learning environments. Low presence in an AR-mediated learning environment is correlated with low learning achievement. The study suggests that enhancing interactive experience could increase learner presence in an AR-mediated learning environment, consequently improving learning outcomes, especially among low-presence learners. Laine et.al. (2016) reports on a proof-of-concept storytelling learning games for science using AR and context-awareness. Student appreciated the game's features and its storytelling approach, implying there is a benefit to embedding pedagogical problems in a digital narrative that supports social collaboration and immediate feedback. On study (Atwood-Blaine & Huffman, 2017) indicate that male and female students achieved and perceived AR-gameplay at a science centre differently. Interestingly, females outperformed males on every measure of game achievement.

There are some other studies focusing on AR in informal learning. A study by Yoon et.al. (2018) took place in a science museum in the US for students grades 5 through 8 focusing on AR as one of several tools for scaffolding. The greatest affordance of the AR-scaffold was found to be the ability to access hidden information. The most helpful aspect of the text-based scaffolds was in their ability to provide instructions on what was expected. Finally, for the collaborative scaffolds, the most useful aspect was the ability to receive feed- back on one's own understanding. It was not one genre of scaffold, but all three scaffolds working together that pushed the group to learn more. Another study by Tscholl & Lindgren (TSCHOLL & LINDGREN, 2016) showed that mixed-reality environments at science centres appear to support significant social interaction, while still offering children playful and engaging experiences.

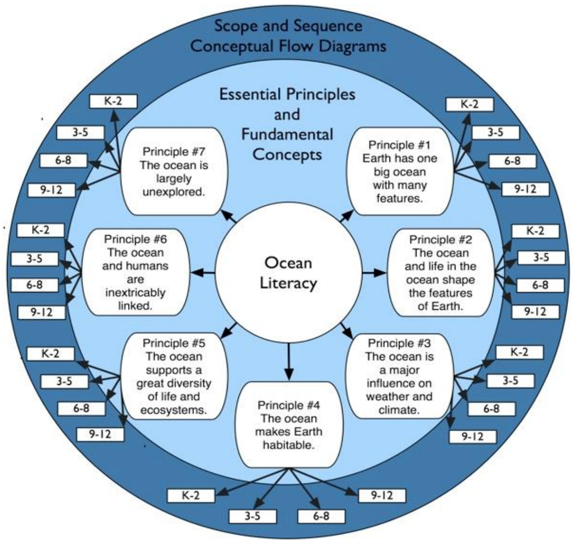
A developmental study also highlighting the affordances of AR-scaffolding is an inquiry-based middle school curriculum on ecosystem science that invites students into immersive experimentation (Dede, Grotzer, Kamarainen, & Metcalf, 2017). The AR-scaffolding tools supports deeper learning This includes a case-based approach situated in an unfolding eutrophication scenario in which students makes observations over space and time, "speaking" with virtual characters and gather information in the field guide. Multiple varied forms of representation convey perceptual, graphical, and experimental data, enabling students to investigate relationships between variables.

5.4 Snowballing – including published literature reviews – and perspectives in relation to pedagogical principles identified across searches

Some of the "extra" references referred to, like (Carley et al., 2013; Fauville et al, 2019; UNESCO, 2017) are identified in a range of snowballing searches. The report from UNESCO (2017):"Ocean literacy for all – a toolkit" e.g. provides materials that might inspire the work with practitioners. This is elaborated elsewhere in the report, here just to repeat that a main approach is arguments for the activities referring to what we have called "bildung" above, specifically referring to UN sustainable development goals and highlighting

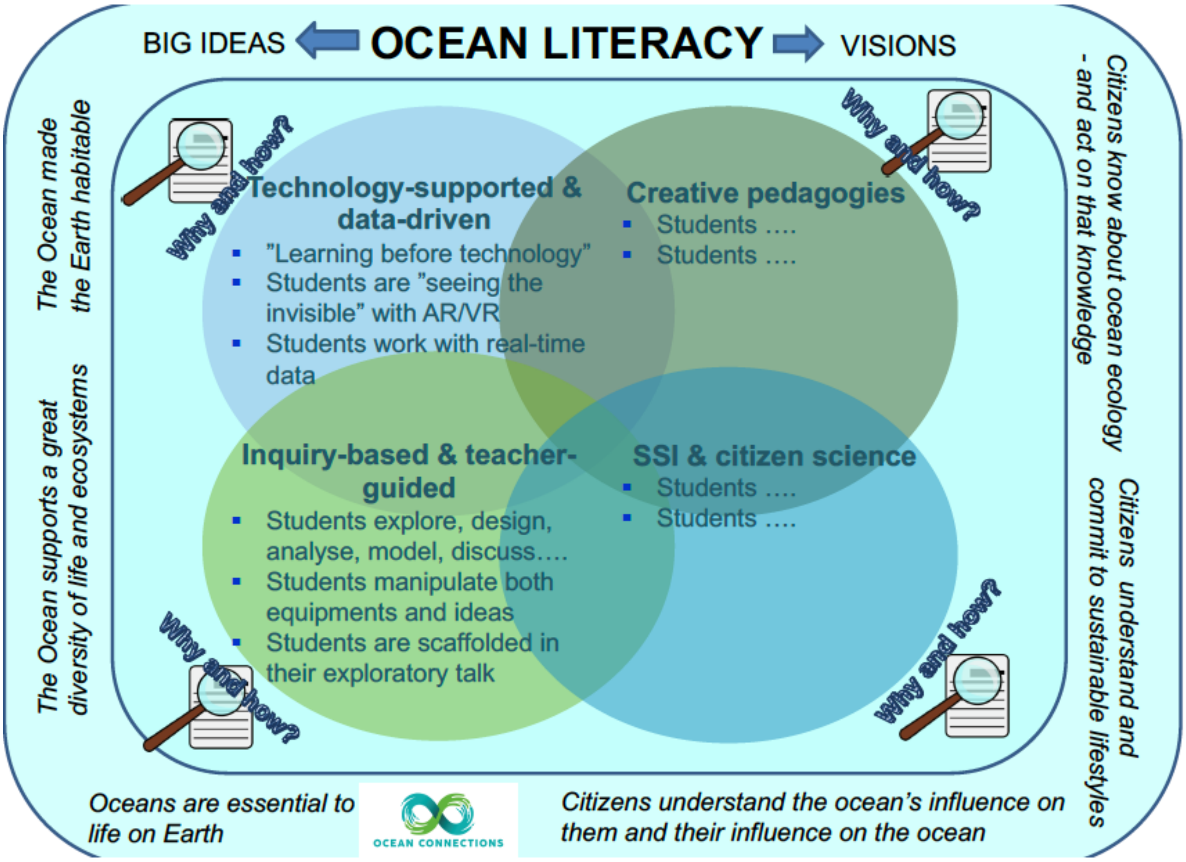
"*The need for ocean literacy in a changing blue planet*" and the arguments referring to students in particular and citizens in general for "*building a civic relationship with the ocean*".

It is highlighted above after report from search DK1A, that we gradually realized that it could be recommendable to include also some background knowledge from major reviews and meta-studies in central areas in the field of science education. For example, when inquiry based approaches are recommended *without* discussing what is known also about *challenges* when applying such methods, we have to look into evidence from else-where when developing the pedagogical framework. We would argue that we, in the Ocean Connections project, need to be crystal clear in our rationales: Where do we refer to highly inspiring practitioners reports like "the toolkit-report", or some of the studies mentioned above with specific methodology, and where do we refer to more solid research? What kind of evidence is backing "the pedagogical framework" we are developing in the project?



We can for sure be inspired very much from the solid work in practice combined with interesting new, but not yet "mature" research, e.g. informing the new Springer publication (Fauville et al., 2019). But, there is no reason that we in the project do what is already done in the field. An area where there based on this review seems to be a gap to contribute to fill in is to thoroughly argue about a pedagogical understanding of Ocean Literacy building on the well-established fields. Just an example from the more solid evidence base is the reference to the importance of students both manipulating equipment and ideas when working with inquiry in science (Lunetta, Hofstein, & Clough, 2007). On the reference list are further references about Scientific Literacy (Roberts, 2007; Roberts & Bybee, 2014), the use of digital technology (Higgins, Xiao, & Katsipataki, 2012; Krajcik & Mun, 2014; Waldrip & Prain, 2012), and SSI and environmental education (Dillon, 2012; Zeidler, 2014).The model, with the seven principles (figure above), could be supplemented with a pedagogical framework acknowledging these principles, which are very much about big ideas referring to the subject matter to be learned, but putting the *pedagogical principles* in the foreground.

A preliminary version of how this might look like is illustrated here. It is a very first draft and without the insights from the full review, but just to illustrate what we mean by putting the pedagogical principles in the foreground. Such principles, like the ones identified here, of designing for 1) technology-supported, 2) inquiry-based, and 3) data-driven science teaching, using 4) real-time data if possible, 5) supported by virtual, augmented reality to e.g. illustrate the invisible, and with 6) communication between school students and external stakeholders: the public in general and/or scientists in the field, and 7) a systems approach to critical concepts and processes, such as the water and carbon cycles, and a focus on 8) model-based inquiry where students design their own models, and use this to test out their ideas followed by rethinking and revising, need to be in the center of a pedagogical framework. This of course built upon big ideas like the seven principles and the "bildung-related visions", and it have to be illustrated with concrete examples from practice.



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