AQUAFISH 0.0 INTERREG Atlantic Area 2021-2027 Project EAPA_0062/2022

Capitalization of the results of the “ARC classroom”.

WP3-SOCIAL ACCEPTANCE OF SUSTAINALE AQUACULTURE AND FISHERIES PRODUCTS.

ACTION Nº 2 – NEXT GENERATIONS ENGAGEMENT

Target audience

AA Joint Secreatriat	Interreg
Partnership	WestBIC, Fundación Bahía de Cádiz para el Desarrollo Económico, BIM Ireland's Seafood Development Agency.
Associated partners	Fundación Centro Tecnológico de Acuicultura de Andalucía, ,S2AQUA - Laboratório Colaborativo, Associação para uma Aquacultura Sustentável e Inteligente(n.a.), Instituto Português do Mar e da Atmosfera, Technopole Quimper-Cornou aille, ARDITI, L'Institut Agro, Instituto de Empleo y Desarrollo Tecnológico - Diputación de Cádiz, Groupe ESIEA, Associação KIPT.
Media	Social Media and Websites.
Public	The target audience is primarily young people and students, but also includes educators, local communities, and educational authorities interested in environmental and food-related education connected to aquaculture.

Means of delivery

E-mail	aquafish@ctaqua.es
Website	https://www.ctaqua.es/aquafish/index.html
Social media	LinkedIn: https://www.linkedin.com/showcase/aquafish0-0/posts/?feedView=all Instagram: https://www.instagram.com/aquafish0.0/

Lead partner for deliverable: **Fundación Bahía de Cádiz para el Desarrollo Económico**

Contributing partners: **BIM Ireland's Seafood Development Agency,S2AQUA -Laboratório Colaborativo, Associação para uma Aquacultura Sustentável e Inteligente(n.a.), Instituto Português do Mar e da Atmosfera, Technopole Quimper-Cornou aille, ARDITI, WestBIC, Fundación Centro Tecnológico de Acuicultura de Andalucía, L'Institut Agro, Instituto de Empleo y Desarrollo Tecnológico - Diputación de Cádiz, Groupe ESIEA, Associação KIPT.**

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CONTENTS

1. Introduction

This report aims to understand the implementation methodology of the Aquaculture Remote Classroom (ARC) project in Ireland, in order to replicate it in the other partner countries of the project, including Portugal, Spain, and France.

The ARC, developed by Bord Iascaigh Mhara (BIM), is an educational initiative designed to increase awareness of aquaculture through a mobile classroom equipped with advanced technology, including virtual reality (VR). With the expansion planned into new countries, it is critical that the project is effectively adapted to local contexts, maintaining its core methodology and ensuring its long-term sustainability.

Bord Iascaigh Mhara (BIM) developed the ARC, as part of the "*Farmed in the EU campaign*". The ARC Programme is funded through the Knowledge Gateway Scheme which is established under Union Priority 2 of Ireland's Operational Programme under the EMFF and is co-funded by the Irish Government and the EU.

This report aims to provide strategic guidelines for the capitalization of the Aquaculture Remote Classroom (ARC) project in Ireland, Portugal, Spain, and France. The ARC, developed by Bord Iascaigh Mhara (BIM), is an educational initiative designed to raise awareness of aquaculture through a mobile classroom equipped with advanced technology, including virtual reality (VR). As the project plans to expand into new countries, it is crucial to adapt it to local contexts while preserving its core methodology and ensuring long-term sustainability.

This document is divided into two parts: the first part focuses on the methodology and the technological infrastructure necessary for the ARC Classroom. The second part analyzes how the ARC Classroom model can be transferred to the specific contexts of Spain, France, and Portugal, ensuring its relevance and effectiveness in these new locations.

2. Curricular Alignment and Local Adaptation

The main objective of the ARC Classroom is to provide an innovative educational tool that combines advanced technology and relevant content to increase awareness of aquaculture. To achieve a successful and effective implementation, it is essential to adapt its contents to the national curricula and local realities in Ireland, Spain, Portugal and France. This process requires not only a strategic curriculum alignment, but also a contextualization that reflects the cultural, economic and environmental particularities of each country.

2.1 Content Contextualization:

Aquaculture is a vital activity for the economic and cultural development of many regions worldwide. Each country has unique characteristics in terms of cultivated species, traditional practices, and environmental challenges, requiring a tailored approach to maximise the educational impact of the ARC Classroom. Modifying and customising the ARC content to reflect these specific realities not only enriches the learning experience but also connects students with their local environment, fostering a deeper understanding of aquatic ecosystems and sustainability.

This process involves identifying key local species of interest, whether fish, shellfish, or algae, that play a significant role both economically and culturally. Additionally, traditional aquaculture practices that reflect local heritage and techniques are incorporated, alongside the specific environmental challenges each region faces. These adaptations ensure that the educational modules are relevant, practical, and effective, helping students understand how aquaculture contributes to sustainable development and the local economy.

Ireland

Aquaculture production in Ireland stood at 35.700t, valued at €169 million in 2023, the bulk of national production was comprised of;

Finfish (mostly Atlantic Salmon *Salmo salar)* 9.900t. Shellfish (mostly Rock oysters *Crassostrea gigas* & Mussels *Mytilus edulis*) 25.800 t.

Aquaculture is widespread throughout Ireland but is particularly important along the west and south coasts. Aquaculture production and development activities in Ireland are focused on Salmon (*S. salar*) and Trout (*O. mykiss*) , Mussels and Oysters (*C. gigas* and *O. edulis*) but there is and has been, production of other species including Clams (*R. philippinarum*) Scallop (*P. maximus*) Perch (*P. fluviatilis*) and a range of seaweeds (*P. palmata, S. latissima, A. esculenta*) The project places particular emphasis on the main species of Salmon, Mussels and Oysters but covers the efforts and activities of other aquaculture producers, past and present. Regionally important efforts are emphasised in campaigns, but standardised visual, video and graphic content is used throughout the year with local activities emphasised in class through description and discussion.

In recent years the ARC project has taken to partnering with aquaculture producers to visit schools and speak directly to pupils about the impact of aquaculture on their communities. This has extremely positive as the industry sees the benefit of the ARC project and also understand their own agency and influence in positively affecting the local perception of aquaculture.

The ARC project usually operates regional campaigns, in doing so the team will inform themselves of the most important aquaculture in the particular region and will provide a local context to pupils and visitors to provide a local or regional picture of aquaculture and its' importance in terms of production volumes, value, markets and employment.

Portugal

A thorough examination of the Portuguese education system was performed in order to assess which disciplines could have topics related to aquaculture. The Portuguese Program for Natural Sciences, Biology, Geography, Physics and Chemistry, by the Ministry of Education, was analysed from basic to high school (5th to 12th grade) within the scope of AQUAFISH, and also on the assumption that aquaculture is a multidisciplinary industry, and each discipline might have subjects directly or indirectly related to it.

As an example, aquaculture is introduced in the 8th grade, as the concept of aquaculture is explicitly addressed in the context of economic activities in the discipline of geography. In this case, students learn about the economic and environmental dimensions of aquaculture as an economic activity and its role in addressing global challenges, such as sustainable food production and population growth. Other disciplines in different school years address aquaculture, directly or indirectly, as it is shown in Tables 1 and 2.

Table 1. Educational content included in the Portuguese Educational Program for Natural Sciences (5th to 9th grade), Biology/Geology (10th and 11th grade) and Biology (12th grade) respectively, with any sort of relation to Aquaculture (Source: dge.mec.pt/curriculo-nacional-documentos-curriculares).

School year (age range)	Discipline	Topics covered
5th grade (10/11 years)	Natural sciences	• Identifying fauna and flora species that are invasive and their consequences for local biodiversity; • Formulate a critical opinion in regards to human actions that may jeopardize local biodiversity; • Interpret the influence of light, water and temperature in plant development (seaweed included); • Identify morphological and behavioural animal adaptations in response to changes in water, light and temperature (in essence, how abiotic factors affect growth, reproduction, etc.).
6th grade (11/12 years)	Natural sciences	• Elaborate balanced diets and discuss the risks and benefits of food and human health; • Interpret food labels from products familiar to students; • Identify the risks and benefits of food additives; • Explain the importance of photosynthesis for nutrient intake in plants, relating photosynthesis to cellular respiration; • Discuss the importance of vaccines and appropriate use of antibiotics.
7th grade (12/13 years)	Natural sciences	• Nothing remotely related to aquaculture. It is a year to lecture lithology, geological processes, geological periods, and others.
8th grade (13/14 years)	Natural sciences	• Interpret the influence of abiotic factors on ecosystems; • Analyse critically the impacts of human intervention on food webs, discussing measures to minimize such impacts; • Explain the importance to gather, treat and manage natural resources and propose measures to reduce and minimize water contamination proceeding by human intervention; • Distinguish eucaryotes and procaryotes at the microscope; • Explain how pollution, deforestation, fires and biological invasions can affect ecosystems; • Discuss the impacts of exploring and transforming natural resources and propose measures to reduce them and promote sustainability.
9th grade (14/15 years)	Natural sciences	• Relate to the consequences of inappropriate use of antibiotics and higher antibiotic resistance;
10th grade (15/16 years)	Biology / Geology	• Relate biological diversity with anthropic interventions that can interfere with ecosystems dynamics; • Observe cells at the microscope: characterize them and compare;

		• Distinguish cel type based on ultrastructure and dimension: cytoplasm, nucleus, mitochondria's, chloroplast, ribosome, cell wall, etc.
11th grade (16/17 years)	Biology / Geology	• Nothing remotely related to aquaculture. It is a year to lecture genetics and geology.
12th grade (17/18 years)	Biology	• Interpret information relative to biotechnological interventions that aim to resolve problems in diagnose and disease control; • Interpret information relative to biotech interventions that aim to resolve problems in food production and conservation.

Table 2. Educational content included in the Portuguese Educational Program for Geography (7th to 9th grade) and Geography A (10th and 11th grade) respectively, with any sort of relation to Aquaculture (Source: dge.mec.pt/curriculo-nacional-documentos-curriculares).

School year (age range)	Discipline	Topics covered
7th grade (12/13 years)	Geography	• Apply Geographical Information Technologies to locate, describe and comprehend locations; • Recognize the need for international cooperation in the management of natural resources, exemplifying with real cases at different scopes; • Identify factors responsible for conflicts in regard to natural resources management, using specific terminology, at local and national scale. Note: Concepts such as cartography sketches, maps, satellite imagery, topography, georeferenced information, and others, are developed in this school year.
8th grade (13/14 years)	Geography	• Apply Geographical Information Technologies to describe and comprehend economical activities; • Participate in campaigns to promote greater awareness in terms of sustainability of economic activities in different scales; • Use field work to map economic activities. Note: In this school year, concepts such as EEZ, interior and territorial waters, continental platform, sea currents, fishing resources, quotas, upwelling, aquiculture and littoral management are approached and developed.
9th grade (14/15 years)	Geography	• Describe examples of impacts due to human activities; • Recognize the need of international cooperation in managing natural resources;

		• Participate actively for greater sustainability regarding local or regional economic activities; • Present examples of solutions for the peaceful and sustainable management of conflicts between natural resources and the local community; • Identify the main economic activities in your community through field work; • Identify technical and scientific solutions that may contribute to the reduction of environmental impact of human activities [3Rs (reduce, reuse, recycle), biodegradable products, etc.].
10th grade (15/16 years)	Geography A	• Distinguish the main types of fisheries; • Relate geology, wind direction and wave current in the establishment of ports; • Relate the pressure over the littoral area with the need to develop sustainable activities, either leisure or economic in nature; • Equate to the importance of the EEZ, identifying resources and measures in the scope of its management and control; • Apply Geographical Information Technology to describe and understand the exploration of natural resources. Note: In this school year, concepts such as EEZ, interior and territorial waters, continental platform, sea currents, fishing resources, quotas, upwelling, aquiculture and littoral management are approached and developed.
11th grade (16/17 years)	Geography A	There are no specific subjects closely related to aquaculture. Nonetheless, this school year develops concepts such as circular economy, carbon emissions, Municipal Director Plan from city halls (important in the establishment of a business), ecological footprint, which are under the scope of Aquafish.

Analysing the national curricula of other disciplines, such as physics and chemistry, the educational content was too far out of the scope of what was proposed here, thus no additional information was added.

Spain:

The aquaculture industry in Spain has seen steady growth over the last few decades, positioning itself as a strategic activity within the fishing sector. In 2023, national production exceeded 326,520 tons, valued at 760.7 million euros, reflecting the economic and social importance of this industry.

In Spain, aquaculture is a key activity that strongly connects traditional fishing practices with sustainable innovation. The Atlantic and Mediterranean coasts, especially in Galicia, Andalusia, and the Valencian Community, are the main areas of production. Among the most representative species in Spanish aquaculture are the mussel (*Mytilus galloprovincialis*) and the sea bream (*Sparus aurata*), as well as others like the European sea bass (*Dicentrarchus labrax*) and rainbow trout (*Oncorhynchus mykiss*) in freshwater aquaculture.

Marine algae also play a crucial role in Spanish aquaculture, particularly along the northern coast of Galicia, where species such as *Undaria pinnatifida* (wakame) and *Laminaria digitata* (kelp) are cultivated for both food and industrial applications.

Traditional farming in salt marshes, using brackish water, is crucial in the Bay of Cádiz. In these natural installations, seabass, gilthead seabream, sole, and shrimp are farmed using a sustainable polyculture method. This method not only helps preserve the ecological balance of the area but also aligns with sustainable aquaculture practices, ensuring the long-term health of the local ecosystem.

The Spanish aquaculture sector includes over 5,100 facilities, with 90% dedicated to shellfish farming, particularly mussels and oysters. In 2023, aquaculture provided approximately 6,301 direct jobs, with women making up 20.3% of the workforce. Innovation is a key driver, with projects in Andalusia focusing on algae production and the integration of renewable energy into fish farms (APROMAR, 2023).

- **Production by Species and Regional Distribution**

Most cultivated species in Spain (APROMAR, 2024):

- Mediterranean Mussel *((Mytilus galloprovincialis*): The main species cultivated, representing over 70% of total production, 182,790 tons, valued at 127.6 million euros.
- European Seabass (*Dicentrarchus labrax*): 24,580 tons, valued at 181.6 million euros.Gilthead Seabream (*Sparus aurata*): 13,106 tons, valued at 75.5 million euros.Rainbow Trout (*Oncorhynchus mykiss*): 16,328 tons, valued at 49.7 million euros.Atlantic Bluefin Tuna (*Thunnus thynnus*): 9,744 tons, valued at 136.2 million euros.

Aquaculture in Spain is also characterized by a commitment to traditional methods and sustainable practices. In areas like the Galician rías, mussel farming follows artisanal methods that are often protected with Protected Geographical Indication (PGI) status. These products are not only a vital source of income but also reflect the deep connection between the land and sustainable farming techniques. Incorporating these practices into the ARC educational modules will allow students to explore how tradition and sustainability can effectively coexist.

In terms of environmental challenges, Spain faces several issues related to aquaculture, particularly regarding water quality and the effects of climate change. Areas such as the Galician rías and Andalusian coasts are vulnerable to pollution, which affects the production of marine species like mussels and sea bream.

Through the ARC activities, students can engage in exercises that involve mapping mussel farming zones in Galicia, sea bream farming in the Valencian Community, or algae cultivation in northern Spain, analysing the specific geographical and environmental conditions that shape these regions. They can also explore the history and sustainable farming techniques of aquaculture farms in these areas, highlighting the importance of quality certifications and the protection of local products. Furthermore, students can investigate local environmental issues such as estuary pollution and propose practical solutions to mitigate the environmental impact of aquaculture.

Additionally, the use of environmental certifications and quality labels is crucial for ensuring that aquaculture products are sustainable. Including these topics in the educational modules will help students understand the importance of choosing responsibly farmed species, supporting the transition to more eco-friendly aquaculture practices.

With these adaptations, the ARC classroom will not only educate students about aquaculture in Spain but also foster greater awareness of sustainability, the importance of local traditions, and the environmental impact of aquaculture activities in the current context.

In Spain, the aquaculture sector has more than **5,100 facilities**, **90%** of which are dedicated to shellfish farming, particularly mussels and oysters.

- **Employment:** In 2023, aquaculture generated approximately **6,301 direct jobs**, with **20.3%** female participation.
- **Innovation and sustainability:** In Andalusia, projects have been implemented to promote algae production and the use of renewable energy in fish farms.

- **Challenges and Future Prospects**

- **Sustainability:** Implementing environmentally friendly farming systems is a top priority.
- **Diversification:** There is a focus on promoting new species such as Senegalese sole (Solea senegalensis) and marine algae.
- **International market:** The demand for high-quality products, such as farmed bluefin tuna and seabass, continues to grow in European and Asian markets.

- **Aquaculture in Andalusia and Cádiz**

Aquaculture in Andalusia and Cádiz is emerging as a sustainable economic engine, combining traditional methods, such as salt marsh farming, with modern technologies. This sector is key to the economic and social development of the region.

Andalusia plays a key role in aquaculture production, thanks to its geographical and climatic features and its extensive coasts and salt marshes.

- Seabass production: Andalusia produced 6,020 tons, representing 25% of national production.
- Seabream production: Although its share is smaller compared to other regions, Cádiz and Huelva are experiencing growth.
- Cádiz Salt Marshes: Traditional farming in salt marshes, using brackish water, is crucial in the Bay of Cádiz. In these natural installations, seabass, gilthead seabream, sole, and shrimp are farmed using a sustainable polyculture method.

France:

In France, aquaculture has a strong traditional component, with oyster and mussel farming being emblematic activities. These species are not only economically significant but also form part of the cultural heritage of various regions, particularly along the Atlantic and Mediterranean coasts. Although aquaculture is not part of the national secondary education curriculum, the ARC Classroom can address relevant topics related to agriculture, the environment, and sustainable development, linking these concepts to aquaculture to enrich students' learning experiences.

Oysters (*Crassostrea gigas*) and mussels (*Mytilus edulis*) are the most representative aquaculture species in France, alongside certain freshwater fish species such as trout (*Oncorhynchus mykiss*). Although the production volume of cultivated marine species is relatively low, their environmental and economic impact remains relevant. Algae also play an important role in some regions, being used for both food and industrial applications.

Oyster and mussel farming in France follows traditional methods that are often recognised with Protected Designation of Origin (PDO) status, reflecting the link between the territory and sustainable production techniques. These practices not only ensure product quality but also serve as an example of cultural and economic sustainability. Incorporating these

methods into the ARC educational modules will enable students to understand how traditional practices can align with modern sustainability.

France faces significant environmental challenges related to aquaculture, particularly in terms of pollution and water quality in marine farming areas. Students can explore how factors such as estuary pollution and climate change affect the production of molluscs and other species. Additionally, integrating knowledge about quality labels and environmental certifications into the modules can help students understand the importance of choosing sustainably farmed species.

To meet the educational and cultural needs of France, the ARC can include:

1. **Interactive Activities:** Develop practical exercises, such as mapping oyster and mussel farming zones, enabling students to analyse the geographical and environmental conditions required for aquaculture.
2. **Case Studies:** Explore traditional farms in regions such as Brittany and Normandy, highlighting the positive impact of sustainable practices and quality certifications.
3. **Environmental Awareness:** Design activities that allow students to investigate and propose solutions to local environmental challenges, such as estuary pollution.

With these adaptations, the ARC Classroom can not only educate students about aquaculture in France but also promote sustainability, raise awareness about environmental impact, and highlight the value of local traditions in the modern economy.

2.1.1. Incorporate Traditional Aquaculture Practices:

Traditional aquaculture practices represent a valuable cultural and economic heritage, connecting local communities to their natural environment and sustainable development. These techniques, refined over generations, have enabled the efficient cultivation of aquatic species while reflecting a profound understanding of the environment and available resources in each region. Incorporating these practices into the educational content of the ARC Classroom is essential to provide students with a historical and practical perspective on how aquaculture has evolved and how it integrates into current local contexts.

In this framework, it is crucial to research and document specific traditional methods from each country to ensure the content is relevant and representative. For instance, in Spain and Portugal, the use of salt marshes and estuaries for fish and shellfish farming illustrates the connection between traditional techniques and sustainability. In France, oyster farming and lagoon fishing are iconic activities, while in Ireland, salmon farming in marine cages reflects a modern approach rooted in traditional practices.

Ireland:

In Ireland, aquaculture plays a vital role in the local economy and the sustainable management of marine resources. One of the most representative practices is the farming of Atlantic salmon (*Salmo salar*), which combines traditional techniques with modern technologies to ensure the production of high-quality food while respecting marine ecosystems. This approach, deeply rooted in coastal communities, demonstrates how tradition and sustainability can work together to benefit both the economy and the environment.

Salmon farming in Ireland begins with the use of **hatcheries**, where juvenile salmon are raised in carefully controlled conditions. These facilities optimise survival rates and ensure healthy growth during the early stages of the fish's lifecycle. This initial phase highlights Ireland's commitment to quality and sustainability in aquaculture.

Once the salmon reach an appropriate size, they are transferred to **floating marine cages**, strategically located in coastal waters. These cages leverage ocean currents to provide oxygenation and create an environment as natural as possible while allowing for constant monitoring of water quality, temperature, and other critical factors affecting the health of the fish. This system, combining traditional and modern approaches, ensures a balance between productivity and environmental stewardship.

Care and feeding are also key aspects of the farming process. Balanced diets are used to minimise environmental impact and promote sustainable growth. Traditional methods are applied to the transport and handling of the salmon, designed to reduce stress and maintain product quality from farm to market.

Incorporating these traditional practices into the ARC Classroom content enables students to understand not only the technical aspects of aquaculture but also its cultural and economic significance for Ireland's coastal communities. Through interactive activities such as virtual tours of salmon farms, spatial planning exercises, and case studies on sustainability, students can explore how these practices contribute to sustainable development and community welfare.

The ARC Classroom also highlights the relationship between aquaculture and environmental conservation, helping students appreciate the industry's efforts to minimise its ecological footprint. This includes responsible water management and strategies to protect marine biodiversity, fostering a greater understanding of sustainable aquaculture practices.

Salmon farming in Ireland is an outstanding example of how traditional aquaculture practices can evolve to meet modern demands for sustainability and quality. Integrating this knowledge into the ARC Classroom not only educates students about the processes involved but also fosters a deeper appreciation for the connection between local traditions, the economy, and the environment. This holistic approach helps prepare future generations to value and protect marine resources while promoting sustainable development.

Spain:

In Spain, aquaculture plays a crucial role in the economy, with Andalusia and specifically Cádiz being key regions due to their historical and environmental significance. These areas are home to traditional aquaculture practices that stand out for their history, their deep connection to the natural environment, and their sustainable methods. Below is an overview of these practices and their role in educational content.

Examples of Traditional Aquaculture Practices in Spain (Andalusia and Cádiz)

1. **Earthen ponds of the Bay of Cádiz:**

- **Description:** Intertidal zones with brackish waters used for raising fish by harnessing natural tides. These ecosystems date back to Roman and Moorish times, where salt production and fish farming coexisted.
- **Cultivated species:** Seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*), sole (*Solea senegalensis*), mullet *(Liza ramada),* sand smelt *(Atherina boyeri,* meagre *(Argyrosomus regius),* shrimp (*Palaemonetes varians*), and eels (*Anguilla anguilla*).
- **Farming method:** Sustainable polyculture, where different species coexist in the same environment. Natural feeding cycles and minimal artificial intervention are key components.

- **Historical Significance:** These earthen ponds were originally used as salinas (salt flats) and later adapted for aquaculture. Today, they are a symbol of sustainable marine farming in Spain.

2. Salt Pans and Shellfish Harvesting:

- **Description:** Manual harvesting of molluscs (*Sepia officinalis*) and shellfish a, such as clams (*Scrobicularia plana, Ruditapes decusatus*), and crabs (*Callinectes spidus, Carcinus maena*s), in the salt flats and marshlands. This artisanal practice is deeply rooted in Spanish culture, particularly in Cádiz, and forms a cornerstone of local gastronomy.
- **Cultural Importance:** The region is famous for its traditional seafood dishes, such as *tortillitas de camarones* (shrimp fritters), which highlight local species like the marsh shrimp.

3. Oyster Farming in "Trestles" (Raised Tables):

- **Description:** Raised structures in intertidal areas used to cultivate oysters, particularly the Pacific oyster (*Magallana gigas*), which has become a staple in Spanish aquaculture.
- **Process:**
    1. Seed deployment.
    2. Periodic redistribution of stock in smaller-capacity bags.
    3. Gradual reduction in the number of oysters per bag—from thousands to fewer than 200—to ensure optimal size and quality.
- **Key Locations:** San Fernando, Puerto Real, and Chiclana de la Frontera are known for their oyster farms, which export both locally and internationally.

4. Longline Mussel Farming:

- **Description:** Mussel farming using submerged longlines where mussel seeds naturally attach and grow. This method is especially popular in Galicia but also present in Andalusia's coastal waters.
- **Stages of the Process:**
    1. Larval settlement and seed attachment.
    2. Growth phase, where the mussels reach a suitable size.
    3. Sorting and repackaging to optimise uniformity.
    4. Final harvest and packaging.
- **Key Species:** Mediterranean mussel (*Mytilus galloprovincialis*).

5. Almadraba (Tuna Trapping System):

- **Description:** A traditional tuna fishing method unique to Spain, particularly in the Strait of Gibraltar and Cádiz.
- **Process:** Large nets are set in strategic locations during the migratory route of Atlantic bluefin tuna (*Thunnus thynnus*), allowing the capture of these prized fish as they head toward the Mediterranean to spawn.

- **Cultural Importance:** The **almadraba** is not just a fishing method but an integral part of local history, with annual *ronqueo* (tuna carving) ceremonies attracting visitors and showcasing the artisan cutting of tuna into various cuts used in Spanish cuisine.

Traditional aquaculture practices, such as the almadraba and esteros, are not only historically significant but have also been passed down through generations, preserving fishing traditions in various regions of Spain. Beyond their cultural relevance, these techniques offer considerable environmental value, as salt marshes and estuaries serve as natural habitats for biodiversity and function as carbon sinks, contributing to environmental conservation efforts.

Economically, the aquaculture industry in Andalusia, particularly in the Cádiz region, plays a crucial role in supporting local communities and strengthening the regional economy. By focusing on sustainable aquaculture products, this industry promotes local well-being while ensuring the protection of the marine environment.

Incorporating these traditional practices into the ARC Classroom enables students to understand the cultural, economic, and ecological significance of Spanish aquaculture, especially in Andalusia and Cádiz, offering a comprehensive perspective on sustainable food production and marine ecosystem preservation.

Significance of Traditional Aquaculture in Spain:

- **Cultural Heritage:** Traditional practices such as the almadraba and esteros are recognised for their historical importance and have been passed down through generations.
- **Environmental Value:** Salt marshes and polyculture systems in esteros serve as natural habitats for biodiversity and act as carbon sinks, contributing to environmental conservation efforts.
- **Economic Impact:** The aquaculture industry in Andalusia, with its focus on sustainable seafood, supports local communities and strengthens the regional economy.

Incorporating these practices into educational materials ensures that students understand the cultural, economic, and ecological significance of Spanish aquaculture, particularly in Andalusia and Cádiz. By studying the evolution of these techniques, learners gain insights into sustainable food production and the protection of marine ecosystems.

Portugal

Aquaculture production in Portugal mainland focuses essentially on the rearing of marine fish species, accounting for about 43.9% of the total national aquaculture production, and mollusc production, which accounted for about 53.9% of total national aquaculture production in 2018 (INE, 2024). The main marine fish species reared in Portugal's mainland are gilthead seabream (*Sparus aurata*), european seabass (*Dicentrarchus labrax*), turbot (*Scophthalmus maximus*) and sole (*Solea* spp.) (INE, 2024). Gilthead seabream and european seabass are mainly produced in traditional systems in semi-intensive or extensive regimes, while turbot and sole are produced in intensive aquaculture systems. Regarding mollusc production, the main species are clams (*Ruditapes decussatus*), oysters (*Magallana angulata*; *Ostrea edulis* and *Magallana gigas*) and mussels (*Mytilus* spp.). The production of molluscs in Portugal's maninland is mainly carried out in extensive systems. Extensive rearing of molluscs is essentially carried out in natural beds, in their natural substrate (mud or sand) or in ropes (mainly for mussels' production) (Rocha *et al.*, 2022).

Since the initial stages of development of the industry in Madeira, the main species cultured has been gilthead seabream (*Sparus aurata*). Subsequent projects have been made in terms of trials to see if other species could be implemented and economically exploited. Such species include the amberjack (*Seriola dumerili*), the sargo (*Diplodus sargus*), and the mahi-mahi (*Coryphaena hippurus*). In the case of amberjack and sargo, these species passed the trial phase and were effectively produced. Specifically for the case of the amberjack, production revealed that the company exploiting them did not have the resources to deal with setbacks, revealing weaknesses on its management and production processes.

There are other species that can be considered for the future which are the sea urchins (*Sphaerechinus granularis*), and the limpets (called by the common Portuguese name "lapas"), namely *Patella candei* and *Patella aspera*, gastropods common in Madeira's intertidal area, and a local delicacy. Trials have been made, protocols tested (Luís *et al.*, 2023; Luís *et al.*, 2023; Nunes *et al.*, 2024), and hopefully in the future commercial exploitation can commence. These species have very good prospects of being excellent choices since their demand is continuously high, and the commercial aspect of this endeavour would be assured.

Traditional aquaculture practices.

In Portugal's mainland, most establishments are located and have further expanded in coastal areas, such as estuaries and coastal lagoons, along the country's mainland coastline. The aquaculture of marine organisms in the mainland is essentially carried out in estuaries and wetlands along the coast, especially in the centre and south of the country, resorting to extensive and semi-intensive rearing methods. The species reared, although being marine species, frequently enter estuaries and other coastal systems at some point during their development, and are, thus, well-adapted to the environmental conditions. This fact, along with the availability of juveniles for the grow-out and the high market value of such species, makes them the first choices for aquaculture production in coastal systems in Portugal (Bernadino, 2000; Ramalho & Dinis, 2011). Although offshore farms are starting to be implemented, there are still very few establishments operating, and the production from these facilities is yet notably low. As for intensive aquaculture systems, there were 12 establishments operating in Portugal in 2022, mostly aimed to produce turbot (INE, 2024).

Aquaculture in Madeira, Portugal, has been traditionally done in floating cages in the south coast of the island since the mid-90's. It started with a government project with a submerged cage, at the eastern-most point of the island (Baía d'Abra, Caniçal), and then progressed to the standard floating cages on the ocean surface that we have in the present in Machico, Ribeira Brava and Calheta municipalities.

However, an exception to the previous was a company formed in the late 90's that operated in the north coast Madeira in Seixal, Porto Moniz, by using tanks on land. Recirculation pumps would keep water coming in and out of the tanks, and production was done at beach level. Due to the harsh conditions and unforgiving location, the company eventually closed after roughly 10 years of operation.

France

In France, aquaculture is deeply intertwined with cultural heritage and local economies, particularly in coastal regions. Oyster farming (Crassostrea gigas) and mussel farming (Mytilus edulis) are the most iconic practices, reflecting centuries of tradition while incorporating modern sustainable techniques. These activities are not only economically significant but also culturally emblematic, representing the connection between local communities and their natural environment. Understanding and preserving these traditional practices is essential for promoting sustainable development and fostering a sense of cultural identity.

Oyster farming is a cornerstone of French aquaculture, especially in regions such as Brittany and Normandy. The process begins with the **deployment of oyster seeds** on specialised structures such as trestles in coastal lagoons and estuaries. As the oysters grow, they are redistributed into smaller bags and placed on additional trestles, gradually reducing the density from thousands of oysters per bag to fewer than 200.

This meticulous process ensures optimal size and quality, reflecting the precision and care associated with traditional methods.

Mussel farming in France typically employs **longline systems**, where mussels are cultivated on suspended ropes that take advantage of natural tidal movements and nutrient-rich waters. This method has been refined over generations to ensure efficient production while maintaining the health of marine ecosystems.

France also has a long history of **lagoon fishing**, particularly in the Mediterranean region, where traditional methods of catching fish and shellfish coexist with modern aquaculture practices. These activities, often linked to specific geographic areas, are recognised with designations such as Protected Designation of Origin (PDO), highlighting their cultural and economic value.

French aquaculture faces several environmental challenges, including pollution in estuarine areas and the effects of climate change, such as rising sea levels and ocean acidification. These issues impact the productivity and sustainability of oyster and mussel farming. To address these challenges, the industry has adopted quality labels and sustainability certifications, ensuring environmentally friendly practices and helping consumers make more informed choices about the products they purchase.

Incorporating these realities into the ARC Classroom allows students to understand the balance between traditional practices and the need for environmental conservation. By exploring case studies and analysing sustainability initiatives, students gain insight into how French aquaculture is adapting to contemporary environmental demands.

Including traditional aquaculture practices in France within the ARC Classroom curriculum provides students with a deeper understanding of the cultural and economic significance of these activities. Interactive modules, such as virtual tours of oyster farms in Brittany or mussel farming in Normandy, help students explore the production processes in detail. Activities like mapping challenges allow students to analyse the geographic and environmental factors that influence aquaculture locations, while case studies highlight the importance of sustainability certifications.

The ARC Classroom also encourages students to investigate the role of aquaculture in supporting rural and coastal economies, emphasising its importance in creating jobs and sustaining local communities.

French aquaculture is a model of how traditional practices can coexist with modern sustainability requirements. Oyster and mussel farming, as well as lagoon fishing, illustrate the deep connection between local communities and their environment. Incorporating these practices into the ARC Classroom not only educates students about aquaculture but also fosters an appreciation for its role in cultural preservation, economic development, and environmental stewardship. This approach ensures that future generations understand the importance of balancing tradition and innovation in achieving sustainable aquaculture.

2.1.2. Address Region-Specific Environmental Challenges:

Region-specific environmental challenges play a crucial role in the sustainability of aquaculture and its impact on local ecosystems. Factors such as water quality, climate change, pollution, and human pressures like coastal tourism vary significantly between countries and regions, requiring a tailored approach to address these issues. Identifying and understanding these challenges not only allows students to explore their effects on aquaculture but also to analyse the strategies implemented by the industry to mitigate these impacts.

Integrating these topics into the ARC Classroom provides a unique opportunity for students to investigate the environmental challenges of their region and understand the innovative solutions being developed to address them. By contextualising these issues, the educational modules can highlight best practices in environmental management, such as marine biodiversity conservation, ecosystem carrying capacity, and efficient use of water and spatial resources.

This educational approach not only fosters environmental awareness but also promotes the development of critical skills such as analysis, problem-solving, and creativity by engaging students in proposing innovative solutions that contribute to the sustainable future of aquaculture.

Ireland

Aquaculture in Ireland is a key industry for the local economy and the sustainable development of coastal communities. However, this sector faces several region-specific environmental challenges that require careful management and innovative strategies to ensure long-term sustainability. Factors such as extreme weather conditions, water quality, and marine biodiversity conservation significantly impact aquaculture production, particularly in the farming of salmon and mussels. This report examines the key environmental challenges, the measures implemented by the industry to address them, and proposed educational activities to incorporate these topics into the ARC Classroom.

Key Environmental Challenges in Ireland

One of the most significant challenges for aquaculture in Ireland is **extreme weather conditions**, including storms, heavy rainfall, and abrupt seasonal changes. These conditions affect the stability of marine cages and can cause fluctuations in water temperature and oxygen levels, negatively impacting fish health.

Water quality is another critical issue. Pollution from nutrients and waste can disrupt marine ecosystems and reduce the productivity of aquaculture farms. Maintaining ecological balance in coastal areas is essential for the sustainability of operations.

Additionally, **marine biodiversity conservation** is a priority in Ireland. The expansion of aquaculture must be balanced with the protection of sensitive habitats and native species to avoid negative impacts on the ecosystem.

Finally, **carrying capacity management** is essential to prevent overpopulation in marine cages and the overuse of marine areas, which could lead to habitat degradation and disease outbreaks.

Measures Implemented by the Industry

The aquaculture industry in Ireland has adopted several measures to mitigate these challenges. To address extreme weather conditions, farms use resilient cages designed to withstand storms and continuously monitor changes in water quality and temperature.

To maintain water quality, sustainable management practices are employed, such as controlling fish density and installing natural filtration systems to reduce organic waste. Crop rotation in marine areas is also encouraged to allow ecosystems to regenerate.

In terms of biodiversity, the industry collaborates with researchers and environmental organisations to monitor sensitive habitats and protect endangered species. Strict regulations on marine space usage and carrying capacity ensure that operations do not exceed the sustainable limits of the ecosystem.

Proposed Educational Activities

Incorporating these challenges and solutions into the ARC Classroom can enhance students' learning experience by connecting them with real-world issues facing Irish aquaculture.

1. **Mapping Exercise:** Students can analyse marine areas used for aquaculture and identify high-risk environmental zones. This activity helps them understand how factors such as climate and carrying capacity influence farm locations.

2. **Case Studies:** Practical examples of Irish salmon farms that have implemented successful sustainability measures can be presented, highlighting their water management and biodiversity conservation practices.
3. **Sustainability Debates:** Students can participate in discussions on balancing aquaculture growth with environmental protection, proposing their own ideas for mitigating environmental impacts.
4. **Innovative Project:** Design a sustainable marine cage model that incorporates advanced technologies to address Ireland's environmental challenges, considering climate conditions and local regulations.

The environmental challenges facing aquaculture in Ireland present both a challenge and an opportunity to advance more sustainable practices. By incorporating these topics into the ARC Classroom, students will not only learn about the issues facing the industry but also develop critical and creative skills to propose innovative solutions. This educational approach ensures that future generations are better equipped to contribute to the sustainable development of aquaculture and the protection of Ireland's marine ecosystems.

Spain:

The environmental challenges faced by aquaculture in Spain vary across regions, but some issues are common, while others are specific due to geographical and climatic conditions. In **Andalusia**, and particularly in the **Bay of Cádiz**, these challenges have a significant impact on the sustainability of the sector and the conservation of aquatic ecosystems.

Key Environmental Challenges in Spain

- **Climate change:** Rising water temperatures and ocean acidification across the country are negatively affecting marine species such as mussels and oysters.
- **Pollution:** Fertilisers and industrial waste in coastal waters, particularly in regions like Galicia and the Mediterranean coast, impact aquaculture sites.
- **Overfishing:** The coexistence of traditional fishing and aquaculture can lead to imbalances in wild fish populations.

Environmental Challenges in Andalusia

The climatic characteristics and coastal ecosystems in **Andalusia** significantly influence aquaculture systems:

- **Water scarcity:** This is especially relevant in provinces such as Cádiz and Huelva, where recurring droughts reduce the availability of fresh water for land-based production systems.
- **Salinisation:** The intrusion of saltwater into aquifers and marshes is a serious issue due to the overuse of water resources and rising sea levels.
- **Seasonal changes:** Fluctuations in rainfall and high summer temperatures can stress farmed species and cause the proliferation of undesirable organisms, such as algae.

Environmental Challenges Specific to Cádiz

The province of **Cádiz** faces unique challenges due to its marine environment and its dependence on coastal tourism:

- **Salt marshes and estuaries:** These ecosystems, essential for traditional aquaculture, are vulnerable to increased salinity and agricultural and tourism-related discharges.

- **Coastal tourism:** In locations such as **Chiclana de la Frontera**, **San Fernando**, and **El Puerto de Santa María**, tourism infrastructure can disrupt the natural cycles of aquaculture production areas, affecting salt marshes (*esteros*).
- **Climate change and tides:** Stronger tidal currents and rising sea levels can alter the composition of water in the salt marshes, affecting the cultivation of species such as seabass, gilthead seabream, and shrimp.

Measures Implemented by the Industry

Teaching activities highlight the measures taken by the aquaculture industry to address these challenges, demonstrating the sector's expertise and preparedness:

- **Carrying capacity regulation:** Ensuring appropriate stocking density to prevent resource depletion and maintain ecological balance.
- **Water management:** Implementation of systems to control salinity and temperature in the salt marshes to protect farmed species.
- **Sustainable technologies:** The use of renewable energy and water quality monitoring systems to minimise environmental impact.
- **Animal welfare:** Practices that focus on the proper handling of species to minimise stress and ensure healthy growth.

Proposed Educational Activities

1. **Mapping challenge:**

   Students will create a spatial map of aquaculture areas in the **Bay of Cádiz**, identifying zones at environmental risk and proposing mitigation strategies, such as buffer zones and waste reduction plans.

2. **Case study:**

   A study of a salt marsh in **San Fernando** or **Puerto Real**, evaluating the effects of increased salinity and seasonal changes and proposing an action plan to minimise these impacts.

3. **Innovation plan:**

   Development of a project proposing measures to reduce the effects of climate change, incorporating technologies such as water recirculation systems and pumps powered by renewable energy.

Incorporating the environmental challenges specific to **Spain**, **Andalusia**, and **Cádiz** into educational content allows students to understand the complexity of aquaculture and the need to adopt sustainable measures to balance production and conservation.

Portugal

As it is well known, the United Nations body for assessing the science related to climate change, the IPCC (Intergovernmental Panel on Climate Change), states that extreme climate events will become far more frequent and with increased intensity as well.

Events such as heat waves with record-breaking temperatures and prolonged droughts, which are fuel for increased wild fires, sudden rainfall events with catastrophic human and social-economic consequences, increased weather storms affecting commercial ships and fishing activity, sea level rise which is prominent in an island where most inhabitants live in its shoreline, and impacts in wildlife in general, from disrupting blossom season, which in turn affects pollenizers, disturbing reproductive stages of certain species, migration time and patterns, availability of food, and others, will continue to be a point of contention in an increasingly changing landscape.

Considering Portugal's mainland, the key challenges are related to the impact of costal tourism on aquatic ecosystems and the impacts of climate change. The impacts of climate change, mainly in south of Portugal, are related to water scarcity, due to a change of its cycle by a rise in evaporation and a decrease in rainfall.

Considering the context of the Archipelago of Madeira, the main challenges are related to increased urban development, expanding into rural areas and increasing our footprint in local ecosystems that had little to no human intervention up to recent years, the consequences of tourism, and the impacts related to climate change.

Madeira has witnessed, since Portugal joined the EU in 1986, a remarkable social and economic development. Once one of the poorest regions in Portugal, Madeira now stands as one of the most developed and sought-after part of the territory. Quality of healthcare, education (with a local university, schools and learning institutes across the island), local infrastructure such as roads, ports, airports, excellent services in general, an ongoing digital evolution, Madeira has profoundly changed in the last 40 years. This comes, however, with challenges that should be addressed and mitigated as much as possible.

The island is home to one of the last remnants of an ancient forest that was abundant millennia ago in southern continental Europe, the laurel forest called Laurissilva. It has been designated as a UNESCO World Heritage since 1999 and together with Azores, Canarias and Cabo Verde, this ecoregion is designated by Macaronesia. From other common links, the presence of this forest stands as the most significant asset. Emerging threats from expanding urban areas, biological invasions and increased pressure due to tourism, has a toll on this environment that needs constant monitoring and protection.

In addition, considering the ocean surrounding us, Madeira has considerable challenges to address. The increased development of Madeiran society comes with a burden also to marine ecosystems. Additional ships travelling to and going from the island's ports for commercial purposes, posing a threat regarding marine invasive species populating the island, increased touristic activities for whale watching and coastal tours that can disrupt groups of cetaceans and local pristine littoral environments, and increased eutrophication along the coast due to river runoffs, all pose a risk to the well-being of our marine ecosystems.

We should also take into consideration the aquaculture industry, which has expanded in the recent years in south coast of the island. The Management Plan for Marine Aquaculture in Madeira (POAMAR), approved in 2016, has conceded areas for private investments in the form of floating cages in intensive regimes along the south coast, deemed excellent and with significant potential for this industry (Torres & Andrade, 2010).

Although only three fish farms are installed, with production tallying around 1500 tons annually of gilthead seabream (Sparus aurata) (DREM, 2022; DREM, 2023), it does not pose any serious issue, since dispersion in open marine waters is high, but many more could be built. Such increased biomass may come associated with prevalent disease and parasitic outbreaks, and greater decaying organic matter from fish faeces and uneaten feed in the islands' southern shoreline means that impacts can surely arise, and monitorization programs are important to reduce and mitigate these impacts. As such, the local government has taken a step in overseeing this industry, with the approval of the Regional Legislative Decree n.º 5/2023/M, which comes to introduce an Environmental Monitoring Plan, essential in setting standards for continual scrutiny.

France

Aquaculture in France is an integral part of its coastal economy and cultural heritage. However, the industry faces specific environmental challenges that impact the sustainability of traditional practices, particularly the farming of oysters (*Crassostrea gigas*) and mussels (*Mytilus edulis*). Issues such as estuary pollution, climate change, and the health of marine ecosystems require innovative management strategies to ensure the long-term viability of aquaculture. This report explores the key environmental challenges, measures implemented by the industry, and educational activities designed to integrate these topics into the ARC Classroom.

Key Environmental Challenges in France

One of the primary challenges in French aquaculture is **estuary pollution**, caused by agricultural runoff, industrial discharge, and urban development. These pollutants affect water quality, leading to stress on oyster and mussel populations and potentially compromising production levels.

Climate change is another critical issue, as rising sea levels, ocean acidification, and changes in water temperature directly impact shellfish farming. These factors can disrupt growth rates, reproduction, and the overall health of cultivated species.

Additionally, **habitat degradation** in coastal and lagoon areas presents a significant challenge. The expansion of aquaculture must be managed carefully to protect these ecosystems, which are vital for biodiversity and act as natural buffers against environmental changes.

Measures Implemented by the Industry

The French aquaculture industry has adopted several measures to address these challenges. To combat estuary pollution, collaboration with local governments and agricultural sectors has been established to reduce runoff and improve water management practices. Regular monitoring of water quality ensures early detection of issues, allowing farmers to take timely action.

To mitigate the effects of climate change, the industry is investing in research to develop more resilient species and farming techniques. For instance, selective breeding programmes focus on oysters that can tolerate higher temperatures and changes in water chemistry.

Efforts to protect habitats include the use of environmentally friendly farming methods, such as longline systems for mussels that minimise disruption to the seabed. Additionally, strict zoning regulations ensure that aquaculture activities do not encroach on sensitive areas.

Proposed Educational Activities

Integrating these environmental challenges and solutions into the ARC Classroom will help students understand the complexities of aquaculture in France and foster critical thinking about sustainable practices.

1. **Water Quality Analysis:** Students can explore how pollution affects estuaries and propose solutions to improve water quality, such as natural filtration systems or sustainable land use practices.
2. **Case Studies on Climate Change:** Use real-world examples from French oyster and mussel farms to demonstrate how climate change impacts production and highlight the innovative solutions being developed.
3. **Mapping Challenges:** Students can map areas of aquaculture activity in France, identifying zones at risk from environmental factors and proposing sustainable strategies for spatial planning.

4. **Biodiversity Projects:** Design projects where students investigate the importance of coastal habitats and develop proposals for their protection while maintaining aquaculture productivity.

French aquaculture faces unique environmental challenges that require a balance between traditional practices and modern sustainability measures. By integrating these issues into the ARC Classroom, students will not only learn about the environmental complexities of aquaculture but also develop the skills needed to propose innovative solutions. This approach ensures that future generations appreciate the cultural and economic significance of aquaculture while actively contributing to the protection of marine ecosystems in France.

2.1.3 Integration of Cultural and Economic Themes:

Aquaculture not only plays a crucial role in environmental sustainability and food production but is also deeply connected to the cultural and economic aspects of local communities. Each country has unique practices that reflect its history, traditions, and relationship with marine resources. Integrating these cultural and economic elements into the ARC Classroom's educational content allows students to understand the broader impact of aquaculture beyond production, highlighting its influence on gastronomy, tourism, and regional economies.

Moreover, aquaculture offers significant opportunities to revitalise rural and coastal communities facing challenges such as population decline or economic contraction. By exploring how aquaculture can generate employment, attract tourism, and preserve cultural traditions, students can identify its potential as a driver of sustainable development.

This holistic perspective not only promotes an understanding of the socio-economic benefits of aquaculture but also fosters a deeper connection between students and local communities, preparing future generations to value and sustainably leverage this vital sector.

Ireland

In Ireland, aquaculture is not only a vital contributor to the economy but also a significant part of the country's cultural and social fabric. The farming of Atlantic salmon (*Salmo salar*) and mussels (*Mytilus edulis*), along with the export of these high-quality products, plays a crucial role in sustaining rural and coastal economies. Moreover, aquaculture connects directly to Ireland's culinary traditions and cultural identity, creating opportunities for economic growth and community revitalisation. This section explores the cultural and economic significance of aquaculture in Ireland and proposes ways to incorporate these elements into the ARC Classroom to enhance student understanding.

Economic Impact

Aquaculture in Ireland contributes significantly to the national economy, particularly through the export of salmon and mussels. The high demand for these products in international markets not only strengthens Ireland's position in the global seafood industry but also provides a lifeline for rural communities. Coastal regions, where aquaculture activities are concentrated, benefit from increased employment opportunities, infrastructure development, and economic diversification.

The impact is particularly evident in small coastal towns, where aquaculture sustains local economies by creating direct jobs in farming, processing, and logistics, as well as indirect jobs in related sectors such as transport and equipment supply. By stabilising income sources in these areas, aquaculture helps mitigate the challenges of rural population decline and supports community resilience.

Cultural Significance

Aquaculture in Ireland is deeply intertwined with the country's culinary traditions and cultural identity. Salmon and mussels are iconic staples in Irish cuisine, celebrated in traditional dishes and showcased in local festivals and markets. For instance, seafood festivals along the west coast highlight the importance of aquaculture, attracting tourists and fostering pride in local produce.

This cultural connection extends beyond food, as aquaculture reinforces Ireland's reputation for quality and sustainability. Certification schemes and eco-labels, such as Origin Green, underscore the country's commitment to environmentally responsible practices, enhancing Ireland's global image while instilling a sense of local pride.

Educational Integration in the ARC Classroom

To effectively communicate the cultural and economic importance of aquaculture in Ireland, the ARC Classroom can integrate a variety of activities and resources:

1. Case Studies on Economic Impact:

Students can analyse how aquaculture benefits rural economies, using real-world examples from Ireland's coastal communities. This could include examining data on employment rates and the economic contributions of salmon and mussel exports.

2. Interactive Mapping Exercises:

Students can identify aquaculture hotspots across Ireland, exploring how geographic and environmental factors influence the industry's development. This activity highlights the link between local resources and economic growth.

3. Cultural Exploration Projects:

Projects could involve researching traditional Irish seafood dishes, their historical roots, and the role of aquaculture in preserving these culinary traditions. Students could also investigate how local festivals promote aquaculture and support tourism.

4. Building Challenges:

Using block-building exercises, students can visualise the socio-economic impact of aquaculture on rural communities, demonstrating how the industry supports jobs, infrastructure, and community development.

5. Debates on Sustainability and Growth:

Students can engage in discussions about balancing aquaculture's economic growth with environmental conservation, fostering critical thinking about long-term sustainability.

In Ireland, aquaculture represents more than just a means of food production; it is a cornerstone of cultural heritage and a driver of economic resilience. By incorporating these cultural and economic aspects into the ARC Classroom, students will gain a deeper appreciation for the industry's role in supporting communities and shaping Ireland's identity. This holistic approach not only enhances their understanding of aquaculture but also inspires them to consider its potential for sustainable development in the future.

Spain

Aquaculture in **Spain** plays a key role in coastal economies and is closely linked to the cultural and gastronomic identity of its regions. Integrating this rich heritage into the ARC Classroom can enhance students' understanding of the sector's significance beyond its productive aspects, fostering awareness of its socio-economic and cultural importance.

Relevant Cultural and Economic Aspects:

1. **Traditional seafood consumption:**

The consumption of fish and shellfish is deeply ingrained in the Mediterranean diet. In regions such as **Andalusia**, iconic dishes such as *tortillitas de camarones* (shrimp fritters) from Cádiz or *almadraba* bluefin tuna from Barbate reflect the local gastronomic wealth based on seafood products.

2. **Fish markets and local economy:**

Local fish markets, such as the **Central Market of Cádiz** and the **Sanlúcar de Barrameda Market**, are key hubs for the sale of fresh aquaculture products. These markets not only promote local consumption but also support the livelihoods of coastal communities.

3. **Gastronomic tourism linked to aquaculture:**

Tourism in towns such as **El Puerto de Santa María**, **San Fernando**, and **Chiclana de la Frontera** is closely tied to the culinary offerings of fish and shellfish cultivated in salt marshes (*esteros*). Visits to salt flats and specialised seafood restaurants contribute to economic revitalisation and strengthen the cultural identity of the region.

Demographic Challenges and Development Opportunities

Rural and coastal communities, especially in Andalusia, face demographic challenges such as population decline and ageing. The ARC Classroom can highlight how sustainable aquaculture projects in areas like the salt marshes of Cádiz provide economic opportunities, create jobs, and attract tourism. By learning about these initiatives, students can understand how aquaculture can support rural development and contribute to community revitalization, reducing socio-economic pressures in these regions.

By incorporating these cultural, economic, and social dimensions, the ARC Classroom not only teaches students about aquaculture but also provides a holistic view of how the sector impacts local identities, economies, and communities.Rural and coastal communities in Spain, particularly in **Andalusia**, face challenges related to **population growth and decline**. Migration to large cities, job losses, and an ageing population place significant socio-economic pressures on these areas.

Aquaculture presents an opportunity to revitalise these communities by creating jobs and diversifying economic activities. For example, in **Cádiz**, sustainable aquaculture projects in the salt marshes have created new employment opportunities and attracted tourism, contributing to the socio-economic development of towns that previously depended solely on fishing.

Portugal

Aquaculture in Portugal plays a vital role not only in environmental sustainability and food production but also in the cultural and economic life of coastal and rural communities. With its extensive coastline and rich maritime traditions, Portugal has developed aquaculture practices that reflect its historical relationship with marine resources. Integrating these cultural and economic elements into the ARC Classroom's educational content allows students to appreciate the broader impact of aquaculture, particularly its influence on regional gastronomy, tourism, and local economies.

Aquaculture in Portugal is intrinsically linked to the country's culinary heritage. Fish and shellfish, such as seabream (*Sparus aurata*), seabass (*Dicentrarchus labrax*), and clams (*Ruditapes decussatus*), are staples in Portuguese cuisine. Iconic dishes like "Açorda de Marisco" and "Amêijoas à Bulhão Pato" highlight the importance of aquaculture products in the national diet. Additionally, the farming of bivalves, particularly in the Ria Formosa region, showcases the integration of traditional methods with sustainable practices, preserving cultural identity while contributing to local livelihoods.

Economically, aquaculture supports rural and coastal communities by creating jobs and diversifying income sources. Regions like Algarve and Setúbal are hubs of aquaculture activity, providing employment in farming, processing, and related industries. The sector also bolsters Portugal's seafood exports, enhancing its global reputation for high-quality products. Beyond production, aquaculture attracts tourism, with visitors drawn to activities such as farm tours and seafood festivals, further boosting local economies.

Aquaculture offers significant potential to address challenges faced by Portugal's rural and coastal communities, such as population decline and economic contraction. By generating stable employment opportunities and promoting economic resilience, aquaculture can help sustain these regions. Additionally, the promotion of eco-tourism tied to aquaculture farms, particularly in areas like the Ria Formosa and Sado Estuary, allows visitors to engage with traditional practices and appreciate their cultural and environmental value.

Preserving traditional aquaculture methods, such as clam and oyster farming, also contributes to cultural heritage. These practices not only provide income but also maintain Portugal's maritime identity, strengthening the connection between local communities and their natural resources.

To effectively integrate Portugal's cultural and economic aspects of aquaculture into the ARC Classroom, the following approaches can be adopted:

1. **Gastronomy and Cultural Projects:**

Students could research traditional Portuguese seafood dishes and trace their connection to aquaculture. This could include exploring the history of clam farming in the Algarve or preparing presentations on how aquaculture supports Portugal's culinary traditions.

2. **Case Studies on Regional Economies:**

By examining areas such as the Ria Formosa, students can analyse how aquaculture contributes to local economies, from job creation to export revenues.

3. **Tourism and Sustainability Activities:**

Students can explore how aquaculture supports eco-tourism in Portugal. Activities could include designing a promotional campaign for a sustainable aquaculture farm or investigating the environmental benefits of combining tourism with aquaculture.

4. **Interactive Mapping Exercises:**

Mapping aquaculture hotspots in Portugal, such as Setúbal and the Algarve, allows students to explore geographic and environmental factors influencing aquaculture practices.

5. **Problem-Solving Challenges:**

Students could propose innovative solutions to enhance the sustainability of aquaculture in Portugal while preserving its cultural and economic significance.

In Portugal, aquaculture embodies a harmonious blend of tradition, culture, and economic resilience. By incorporating these themes into the ARC Classroom, students gain a comprehensive understanding of how aquaculture sustains local economies, preserves cultural identity, and fosters sustainable development. This holistic approach prepares students to appreciate the socio-economic benefits of aquaculture and encourages them to explore its potential as a driver of positive change in their communities.

France

In France, aquaculture is not only a significant economic activity but also an essential part of the country's cultural and gastronomic heritage. The farming of oysters (*Crassostrea gigas*) and mussels (*Mytilus edulis*) is deeply rooted in French traditions, particularly in regions like Brittany, Normandy, and the Mediterranean coast. These activities have shaped local economies, supported regional identities, and contributed to the global reputation of French cuisine. This section explores the cultural and economic importance of aquaculture in France and suggests ways to integrate these aspects into the ARC Classroom to enrich students' understanding.

Economic Impact

Aquaculture plays a vital role in supporting France's coastal economies. Oyster and mussel farming, which are among the most prominent aquaculture activities, generate significant employment in production, processing, and distribution. Regions such as Brittany and Normandy are renowned for their high-quality shellfish, which are exported globally, bolstering the local and national economy.

In addition to direct economic contributions, aquaculture supports a wide range of ancillary industries, including transport, equipment manufacturing, and tourism. The thriving aquaculture sector in France attracts visitors who are eager to experience the seafood culture firsthand, creating further opportunities for economic growth in coastal regions.

Cultural Significance

France's aquaculture industry is deeply intertwined with its culinary heritage. Oysters and mussels are iconic elements of French cuisine, celebrated in traditional dishes such as moules-frites and served at festive occasions, especially during the holiday season. The cultural significance of these products extends to local festivals and markets, such as the famous oyster festivals in Cancale and Arcachon, which not only promote regional pride but also attract tourists from around the world.

Moreover, aquaculture regions like Marennes-Oléron have received Protected Designation of Origin (PDO) status, emphasising the link between traditional farming practices and the unique qualities of the products. These designations highlight the importance of preserving cultural heritage while promoting sustainable practices in aquaculture.

Educational Integration in the ARC Classroom

To effectively convey the cultural and economic importance of aquaculture in France, the ARC Classroom can integrate a range of activities and resources:

1. **Case Studies on Regional Economies:**

Students can investigate how aquaculture contributes to local economies in key regions such as Brittany and Normandy. They could analyse employment data and explore the role of exports in sustaining these communities.

2. **Interactive Mapping Activities:**

Students can map aquaculture hotspots in France, identifying how geographic and environmental factors influence the location and success of oyster and mussel farming.

3. **Cultural Research Projects:**

Students could research traditional French seafood dishes, the history of oyster farming, or the cultural significance of festivals related to aquaculture. These projects could include creating presentations or organising mini-exhibitions showcasing French aquaculture traditions.

4. **Tourism and Economy Activities:**

Students can explore how aquaculture regions attract tourism and contribute to the local economy. This could involve analysing case studies of towns like Cancale, where aquaculture and tourism are deeply intertwined.

5. **Block-Building Challenges:**

Through block-building exercises, students can model the socio-economic impacts of aquaculture, showing how it supports industries, jobs, and infrastructure in coastal areas.

In France, aquaculture is far more than an economic activity—it is a symbol of cultural pride and a pillar of regional identity. Incorporating these cultural and economic aspects into the ARC Classroom allows students to appreciate the multifaceted role of aquaculture in French society. By understanding its contributions to local economies, culinary traditions, and tourism, students gain a broader perspective on how aquaculture supports sustainable development and enriches cultural heritage. This approach inspires them to consider the broader implications of aquaculture for both communities and the environment.

2.2 Identification of National Curricula:

The ARC Classroom is an innovative educational tool designed to raise awareness about aquaculture through relevant content and advanced technology, such as virtual reality. However, to ensure its long-term sustainability and positive impact, it is essential for the ARC modules to be tailored to the national curricula and cultural, economic, and environmental specificities of each country. This will not only enhance its educational relevance but also enable the project to act as a bridge, connecting aquaculture with local communities.

In this context, a comprehensive analysis of the national curricula of Ireland, Spain, Portugal, and France has been a crucial step.

In **Ireland**, the ARC modules closely align with science, geography, and personal, social, and health education curricula. Through activities such as virtual visits to salmon farms and interactive mapping exercises, students explore how marine biology and sustainability connect to their local environment, linking these topics seamlessly with their academic framework. This approach ensures that the ARC enriches existing learning objectives while sparking interest in the aquaculture sector.

Similarly, in **Spain**, the educational curriculum integrates subjects such as natural sciences, geography, history, and technology, with a particular focus on sustainability. Through the study of key species such as mussels and seabream, as well as traditional practices like the *esteros* in Cádiz, students can connect theoretical knowledge with local examples. Moreover, Spain's specific environmental challenges, such as salinization and coastal tourism pressure, are embedded into activities designed to foster critical thinking and problem-solving.

In **Portugal**, the educational curriculum connects learning with marine biodiversity and sustainable innovation. Students not only study species such as sole and bivalves but also analyze the impact of tourism on aquaculture practices. This multidimensional approach combines case studies with hands-on activities, providing a deeper understanding of the environmental and economic effects of aquaculture in the region.

Finally, in **France**, the cultural richness of oyster and mussel farming is interwoven with the analysis of contemporary challenges such as climate change and estuarine pollution. Students learn not only about France's aquaculture traditions but also about how sustainability can secure the sector's future. The inclusion of quality and sustainability labels in educational modules highlights the importance of making responsible consumption choices, connecting education to everyday life.

The contextualisation of content, combined with curricular alignment, has been carefully designed to reflect the specific realities of each country. However, to ensure these approaches are effective, the next step is to conduct pilot programmes in selected schools. These trials will provide valuable feedback from students and teachers, enabling final adjustments to optimise the modules. Additionally, collaboration with local experts, such as aquaculturists and educators, will ensure that the content is both accurate and culturally relevant.

In conclusion, the expansion of the ARC Classroom to Spain, Portugal, and France aims to adapt this educational tool to local academic standards while also fostering a positive impact on the perception and development of aquaculture. While the program is already implemented in Ireland, its capitalization in other countries presents an opportunity to integrate innovative technology with a sustainability-focused educational approach. In this way, the ARC not only strengthens students' connection to their environment but also contributes to building a more responsible and balanced future.

In Ireland an approach was taken where the key learning objectives of the Department of Education and Skills (the national Ministry of Education) would be prioritized in order to assist teachers to achieve key learning and development targets but through the context of aquaculture, this was done to avoiding adding any unnecessary burden on teachers or learners, to avoid reducing the useful learning time that is already a limited resource, but instead to provide an opportunity to meet existing objectives in the context of learning about aquaculture at the same time. The ARC experience addresses strands of the of SESE Science, SESE Geography and SPHE Education curriculum.

Within the Irish curriculum framework, the ARC Classroom addresses the concept of aquaculture through a practical and multidisciplinary approach. The following are the key topics covered in the ARC modules:

What is Aquaculture?

- Its definition and comparison with traditional agriculture.
- Overview of the main types of aquaculture in Ireland.

Virtual Reality Farm Visit – Professor O' Mara takes you on a virtual tour of the Irish coast to see Aquaculture as it's done on many Irish fish farms. This includes a description of current farming practices in each sector with a detailed account of biology, ecology and environmental factors.

Geographic and Environmental Influences

- Geographic and climatic suitability of Ireland.
- The requirements for each of the three main types of aquaculture.
- Water quality, tides, tourism, and environmental impact.

Geography Exercise. Map reading, deduction, analysis and decision making. Pupils will learn how geography influences aquaculture and why farms emerge in specific bays and locations.

Socio-Economic Impact

- Historical analysis of population distribution in Ireland and its impact.
- Economic impact and employment opportunities.

- Significance of primary industries in a community's development.

Socio Economic exercise. Pupils will use building blocks to demonstrate how aquaculture can support other activities, businesses and jobs in the community.

Nutrition and Health

- Overview of the food pyramid and importance of seafood in fulfilling a balanced diet.
- Global food resources and population growth.

The Big ARC Quiz

- A team event where the day's learnings come to life and knowledge is tested in a fun quiz show format.

3. Implementation Methodology

In order to evaluate the ARC programme research was carried out among the cohorts detailed in the table below.

Evaluation cohorts and methods

Cohort	**Approach to data gathering**
Teachers that took part in ARC school visits and ARC webinars.	Online surveys
The team involved in development and delivery of the ARC programme: • • ARC Project Manager at H2 Learning • • Artistic and creative service provider who designed the ARC content, branding and learning tools at Rocket Science • • ARC Facilitator Team	Interviews
Stakeholders in the wider aquaculture and marine sectors from the following organisations: • • Atlantaquaria, Galway • • Bantry Marine Research Station • • Irish Farmers Association • • Údarás na Gaeltachta • • Inshore Ireland Publishing	Interviews

A teacher evaluation survey, designed by H2 Learning was sent to schools that had visits from the ARC between 2019 and March 2020 and this data was made available for the evaluation. A similar survey was designed by Begley and Associates and sent by H2 Learning to teachers that took part in webinars in May 2021. The results of the surveys are detailed in Section 3 (See Appendix 1 for surveys).

Interview questions for the team involved in ARC programme development, delivery and management explored their overall experience, what works well, challenges encountered, and suggestions for improving or expanding the project.

Stakeholder interview questions were developed in collaboration with the client to discuss their engagement with the ARC to date. Their views on the potential value of the ARC project in terms of the aquaculture sector, schools and communities and suggestions or recommendations for improving or expanding the project were also explored.

Interviews with stakeholders were conducted during June and July 2021 by video call and were audio recorded. Participants were provided with a report on the interview for review and sign off. A thematic analysis of the content of the interview reports was conducted and is set out in Section 4 (See Appendix 2 for interview guide questions).

Conclusions and recommendations were generated following an analysis of the data gathered and a review of the project materials.

4. Technology and Resources

4.1 Technology Standardization

The following equipment is recommended:

Modifiable seating that can be easily deployed into a theatre setting for all the participants and that can be used for group activities, the ARC employs custom built seating for 36 participants, seats are large units capable of accommodating 2-3 students each.

6 x packable tables are used on the ARC to accommodate group learning activities, these can be packed flat and stored when not in use.

4 x storage units are used on the ARC to store and easily pack away learning materials when not in use, these are used as tables by the facilitators during the normal teaching day.

Display screens of conventional quality (TV sets), screens must be light and robust. Mounting and installation must be of high quality as regular vehicle movements cause significant vibrations. The ARC utilizes 5 screens, the space available will dictate options for others. No specific brand is recommended as the quality is generally similar across manufacturers. ARC has used *LG* screens and performance has been very good.

An audio system of standard 2 speaker format will suffice and will depend on the space available and the number of users. A function for simple and rapid changing of volume or muting or switching off is useful. Installation must consider the possibility for interference from adjacent devices.

Induction loop and microphone. This device will be necessary for users who have various hearing impairments and who use various cochlear devices and supports. Ensuring appropriate access to users with disabilities is important and usually a regulatory requirement and must be considered at the design phase.

The ARC utilizes a custom specified and designed computer. Any teaching unit using presentations, video, audio and graphics will require a computer of good quality and the device must have a powerful and high-quality Graphic Processing Unit (GPU often referred to as a '*graphics card*') to ensure that video, audio and graphics and visual performance is appropriate. The ARC employs an *nvidia* GPU within the computer. No specific type is recommended but a laptop computer is not recommended due to size limitations and difficulties with upgrades and modifications vs. a conventional personal computer.

Virtual reality and augmented reality are critical tools to enable learners to experience aquaculture and related topics without having to leave the school setting.

It is unlikely that significant numbers of students can visit farms, factories and other production sites for a variety of reasons. The use of technology to provide influential experiences to young learners is critical to make the experience impactful in the classroom.

Educational content and learning tools are critical resources for learners, the ARC employs a range of learning materials, the materials being developed with the specific intention of allowing group activities and active learning to occur.

The VR system employs 360° footage of mussel, oyster and salmon farms with an audio track to guide the user. The footage was shot using a compact 360° camera and the imagery processed to create an immersive experience. Over the years the footage has evolved, it comprises of underwater footage, ground level and ariel drone footage.

Figure 1: Demonstration of VR headsets aboard the ARC 2024.

Initially the ARC was equipped with a small number of *Occulus* Go headsets, each with individual controllers. This proved extremely difficult to use in practice, there were insufficient units for users and this forced a 'change-over' procedure, the use of individual controllers caused many issue for staff and for users and led to a mediocre user experience.

The ARC now employs *Occulus* Go headsets (purchased 2018) and *Pico G2* units (2020), a wireless router to enable the headsets to be managed centrally and a tablet for centralised control by the team. A kiosk mode and a central control system was developed and deployed, this enabled the team to provide the VR headsets to learners and to control the start and completion of the experience for all users simultaneously.

During 2020 a significant quantity of *Pico* G2 headsets were purchased, a special licence for *VR Synch* was acquired and deployed, the ARC now has 25 headsets, a *Samsung* control tablet with a *VR synch* lifetime licence for up to 50 units and an upgraded router.

There are a wide range of headsets available (*Occulus, Pico, Samsung* etc.) and the unit choice may differ between users. It is best to avoid complex and expensive licencing requirements if possible.

A high-quality router that is capable of managing the connections between the number of headsets and the computer and the control tablet is critical to ensure smooth functioning of the system. An under specified router resulted in VR failures aboard the ARC during 2022.

The selection and purchase of appropriate VR headsets is critical to the smooth functioning of the system. Conventional VR headset use is normally in the home, the use of a high number of sets in a location without Wi-fi presents challenges, many headsets require internet connections to manage licencing, this should be avoided as it is not feasible to ensure internet connectivity in the field. It is critical to develop a system that allows all the VR headsets to be synched and controlled centrally especially when catering to the needs of multiple young users who have high energy levels and can be distracted easily. It is also recommended to minimize the burden on users by disabling functions and buttons on the headsets to prevent users stopping or altering the presentation. The ARC utilizes headsets that have had most of the functions on the headset disabled after purchase, this was done by a specialised contractor who had the necessary skills to do so, such alterations will likely invalidate the warranty on the headsets but will make the user experience better.

General aquaculture and geographic education.

The bulk of the educational content is delivered via a presentation with visual information, images, graphics, animations and videos. The ARC employs 5 large screens that can be used to show a wide variety of content. No text is used in the presentations and the specific information is delivered by one of the ARC facilitators, this allows the message to be tailored to specific locations, i.e. additional discussion of mussel farming in areas of mussel production, it also enables delivery to be abbreviated or elongated as needed for operational reasons.

This section of the learning day comprises of 110 minutes of learning activities,

1. What is aquaculture?
2. VR Headset use to 'tour' farms
3. Geographic and Environmental Influences

Figure 2: Demonstration of ARC Display screens 2024.Map Reading (Introduction to aquaculture and the marine space)

The ARC delivers content that aligns with elements of the national curriculum for geography.

The ARC employs a simple but effective tool to teach learners how marine space is important to many stakeholders. The tool is a set of layered maps that the learning group progressively layer over each other to build up an overview of a fictional bay.

The key requirements to locate farms are taught to the learners, as well as the needs of other stakeholders (navigators, tourists, local communities). The learning group are tasked with selecting a site for an oyster farm, a mussel farm and a salmon farm having gained an understanding the various factors on the map layers and how together they impact aquaculture. The maps are reuseable, and prompts and clues are provided on the screens in the classroom to help students complete the exercise. 6 sets or maps are on the vehicle and students are usually grouped in teams of 4-6 depending on numbers attending.

Figure 3: Demonstration of Multi-layered Map device used for teaching about aquaculture and marine space

Figure 4: Visual prompts for Map Reading Challenge

Socio-Economic Impacts (Jobs & People).

The ARC employs a building block challenge to teach learners about the positive impact that aquaculture. The game consists of an inverted triangle that begins with a base representing a new aquaculture business, each block and layer that is added describes the typical jobs that are created and includes the indirect jobs that are supported by aquaculture. Students are tasked with completing the device fully in a short time, the completion is competitive, the pieces can only be assembled in the correct manner and order. 6 sets are provided and assigned to groups of 4-6, as with the mapping exercise prompts are provided on the screens.

Figure 5: Building Block device used for teaching Socio-economic impacts.

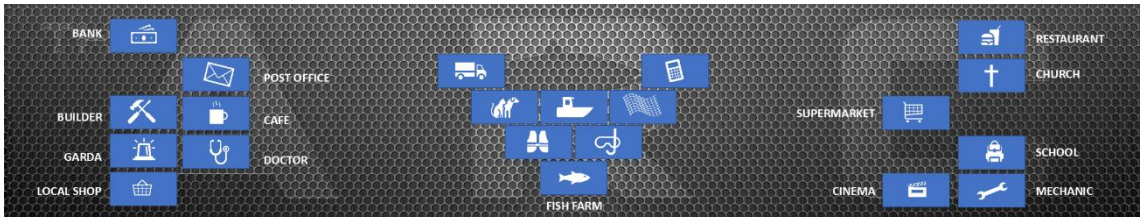

Figure 6: Visual Prompts for Socio-economic impacts challenge

The Big Quiz

The ARC learning day concludes with a quiz that allow students to demonstrate what they have learned during the learning activities. The quiz comprises of a 'game-show' format where 6 wireless 'Buzzers' that are given to teams of pupils, the facilitators ask approximately 20 questions and the teams have to be first with the 'Buzzer' to get an opportunity to answer the questions.

This is a useful tool to allow the facilitators to assess if the students have learned and retained the appropriate knowledge. The ARC employs a custom modified system based on a home entertainment system, the system employs 6 x 'Buzzers', a light machine to indicate the team that 'Buzzed' first, and a remote control device for the facilitators to reset, start, pause, stop the challenge.

Schedule	Content
Start: 09:30am (60 minutes)	**Part 1: What is Aquaculture (PowerPoint with photos/graphics, no text)** • Definition and comparison with traditional agriculture. • Overview of the main types of aquaculture in Ireland. • Description of current farming practices in each sector with a detailed account of biology, ecology and environmental factors.
Start: 10:30am (15 minutes)	**Activity: VR headset.** Travel virtually to Oyster, Mussel and Salmon farm.
Small Break (15 mins)	
Start: 11.00am (35 minutes)	**Part 2: Geographic and Environmental Influences (PowerPoint with photos/graphics, no text)** • Geographic and climatic suitability of Ireland. • The requirements for each of the three main types of aquaculture. • Water quality, tides, tourism, and environmental impact.
Start: 11:35am (15 minutes)	**Activity: Map reading** Pupils explore how geography influences aquaculture and why farms emerge in specific bays and locations. This is a hands on group activity.
Start: 11:45am (35 minutes)	**Part 3: Socio Economic Impact (PowerPoint with photos/graphics, no text)** • Historical analysis of population distribution in Ireland and its impact. • Economic impact and employment opportunities. • Significance of primary industries in a community's development.
Start: 12.20pm (10 minutes)	**Activity: Building block puzzle** Pupils use building blocks to demonstrate how aquaculture can support other activities, businesses and jobs in the community
Lunch Break (30 minutes)	
Start: 1:00pm (25 minutes)	**Part 4: Nutrition and Health (PowerPoint with photos/graphics, no text)** • Overview of the food pyramid and importance of seafood in achieving a healthy balanced diet. • Global food resources and population growth. • Video: Salmon of knowledge story telling video
Start 1:25pm (20 minutes)	**Part 5: Sustainability (PowerPoint with photos/graphics, no text)** • Introduction to the term sustainability • Overview of sustainable aquaculture practices
Start 1.45pm (15 minutes)	**Part 6: The Big Quiz** Interactive Quiz using an electronic interactive buzzer system.
Finish 2pm (extra 5 min for Q&A with students)	

Figure 7: Timetable of ARC activities for one day at Primary (Elementary) School.

4.2 Maintenance and Technical Support:

Provide a comprehensive maintenance and technical support plan to ensure the continued operability of the ARC, needs to include the following aspects:

- Establish a Preventive Maintenance Schedule
- Implement Real-Time Technical Support
- Plan for Technological Equipment and Software Maintenance
- Technical Training for Staff
- Financial and Resource Support Strategy
- Performance Monitoring and Evaluation

This includes training local technical staff and the availability of resources for repairs and technology upgrades.

5. Monitoring and Evaluation

In 2021 BIM decided to evaluate the ARC programme to inform future planning and development and commissioned Sinéad Begley and Associates in to assist with the process. The scope of the evaluation was agreed as follows:

- Review available background information, online lessons and other resources.
- Compile available quantitative data on participants, school profile, geographical spread and number of visits.
- Analyse the data gathered in 2019 through the teacher feedback survey, while the ARC was visiting schools.
- Design and conduct a similar survey of teachers attending webinars in May 2021.
- Interview key stakeholders, identified in consultation with the client e.g., facilitators delivering the ARC programme and stakeholders in the aquaculture and marine sectors.
- Analyse data gathered to form the basis of recommendations for the future of the programme.

6. Monitoring and Evaluation

Devise an ARC programme strategy that sets out the programme mission, vision, objectives and targets in terms of programme reach, target audiences, evaluation metrics and stakeholder engagement.

Convene a facilitated programme planning session with the ARC Team to explore suggestions received through this evaluation in terms of programme content, staffing, administration, and potential development for new audiences.

Consider suggestions made by teachers in relation to ARC school visits and the webinars in future programme planning, for example, integration of more hands-on and inquiry led activity, use of models, props, artefacts and biofacts, integration of Irish language content, simplifying language and development of post visit resources and projects.

Involve teachers in developing and testing of content in terms of appeal, age appropriateness and curriculum relevance.

Make a list of references or sources for content available to demonstrate the robust scientific basis for programme content.

Develop a range of flexible, blended and modular learning packages, using existing and additional content as required, and consider events, communities of practice, projects or competitions to extend school engagement with the ARC beyond a once off visit.

Continue to explore ways of extending reach to young people through programmes in post-primary schools and extended use of social media.

Balance the programme reach to include schools in urban, rural and inland areas as well as coastal schools.

Define the role of the ARC in community engagement and develop a plan e.g., tailored community programmes for festivals or in areas that the ARC visits.

Consider suggestions made by stakeholders in terms of programme content, reach and potential collaboration to raise awareness of diverse job opportunities.

Learn from international best practice in terms of education and public engagement with aquaculture in countries like Norway, Scotland, Faroes and Iceland.

Showcase the ARC to stakeholders in the wider marine and education sectors and explore opportunities for collaboration and networking to raise awareness of the programme and leverage support.

7. Conclusion

ARC schools visits and webinars have been very well received and teachers that provided feedback indicated that the experience impacted positively on both their own and their students' interest in and understanding of aquaculture.

• The ARC facilities, programme content, facilitators and overall experience were highly rated by teacher survey respondents. The programme provided curriculum relevant opportunities for pupils to develop knowledge about aquaculture in an Irish context, including an understanding of the socioeconomic and nutritional benefits, and to use skills including critical thinking, communication, collaboration, and problem solving in real life contexts.

• While opposition to salmon farming and the public perception of aquaculture present challenges for the sector, most of the feedback from teachers that responded to the ARC evaluation surveys is positive.

• The appetite among schools for the programme is reflected in expressions of interest in visits from over 500 schools, engagement in webinars (276 schools and 6,992 pupils) and online lesson views (1,992 views).

• Capacity of the ARC in terms of the number of schools that can be visited in an academic year is a limiting factor for meeting current demand and for programme expansion.

• While webinars and supplementary online content and resources can extend reach and length of engagement, they do not provide the same level of excitement or immersive experience as the ARC visiting the school.

• Expectations in terms of capacity for school visits needs to be managed and clear criteria for prioritising specific schools, geographical areas or communities for engagement would be useful in this regard.

• Stakeholders interviewed see the ARC as having the potential to provide accurate, accessible information about the aquaculture sector (and possible careers) not only to schools but to the wider community.

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