A Framework for the Assessment of the Effectiveness of Ocean Literacy Tools and Initiatives

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A thesis submitted for the degree of Doctor of Philosophy

September 2021

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Abstract

In order to assess the effectiveness of Ocean Literacy (OL) tools, it is necessary to gather data on the usage of the tools, and their impact on the participants' ocean literacy. This is to say, their awareness, knowledge, attitudes, behaviour etc. with respect to our interactions with the ocean. The framework for assessing ocean literacy which I developed is based on a review of existing research related to the assessment of ocean and environmental literacy. Based on the DAPSIWR framework, I designed and developed an online causal mapping tool and tested the tool. No tool of this type already existed elsewhere. The causal mapping tool allows domain experts to capture DAPSIWR based causal models of topics of concern related to the ocean and to capture knowledge related to the elements of the causal maps and the links between the elements.

The mapping tool was used as the basis for mapping key stories which are used as the test cases in measuring the effectiveness of ocean literacy interventions and tools. These stories are modelled and explored using the DAPSIWR causal modelling framework. The DAPSIWR models allow for key actors and ocean literacy objectives (messages) to be identified. The actors are linked to the elements of the causal models and the ocean literacy objectives are contained in the knowledge which has been attached to the causal map. DAPSIWR models also provide vital context and narrative which can be used as part of the educational and data gathering process. The ocean literacy tools and surveys created as part of this research work are based on topics (key stories) such as Coastal Tourism or Micro- plastics (in cosmetics).

Domain experts used the causal mapping tool to create causal models of ocean literacy topics. I created surveys based on the knowledge captured in the causal models and these surveys were then used as pre- and post-surveys to measure the effectiveness of ocean literacy tools. The surveys that I developed focused on specific ocean related topics and measure the OL dimensions of Knowledge, Attitude, and Behaviour. The data gathered was analysed using correlation analysis, reliability analysis, Rasch analysis, distractor analysis, confirmatory factor analysis and paired t-tests.

The framework developed and used in this research provides an approach which can be used to model specific ocean related topics using DAPSIWR, identify the knowledge associated with the elements of the model, create topic specific surveys based on the identified knowledge, administer the surveys, automatically receive responses to the surveys, and analyse the response data to gain insights. The DAPSIWR models were used for educational purposes and in the creation of surveys on specific topics. The surveys were used as tools to measure the OL of the participants of OL interventions, before and after they took part in the intervention. The interventions were aimed at increasing OL and the participants were required to take a pre- and post-survey. The results of the responses to the pre- and post-surveys were analysed to get a measure of the effectiveness of the interventions.

I would like to dedicate this research work to my family.

To my wife, Trina, my daughter, Cara, my two sons, Fionan and Oisin, my parents, Monica and Packie Joe, my sister, Grainne, and my brothers Enda and Francie.

Thank you for everything.

Acknowledgements

First and foremost, I would like to thank my PhD supervisor, Dr Owen Molloy, for his support and guidance over the course of my PhD. His advice, suggestions, continuous encouragement and expert guidance were invaluable to me as I charted my research path. I am eternally grateful that he involved me in the European project which fully funded my PhD and provided me with the opportunity to be involved in important research related to the ocean environment.

I would like to thank the members of my Graduate Research Committee Dr Enda Howley, Dr Sam Redfern, and Dr Seamus Hill for their support and advice over the course of my PhD.

I would also like to thank my colleagues with whom I shared a research room. Caroline, Mary, Dolly, Waleed, Moha, Amzad, and Basim, it was enjoyable to be around enthusiastic and knowledgeable people.

Declaration of Originality

I declare that this thesis was composed by myself and contains my own original work unless otherwise stated in the text. This work has not been submitted for any other degree or professional qualification and appropriate credit has been given to others' work referenced in this thesis.

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Conor McCrossan

Date

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Chapter 1

Introduction

1.1 Introduction

The importance of the Ocean to the wellbeing and perhaps even survival of human life on Earth is becoming more and more obvious. As we learn more about the impact we have had on the oceans in a relatively short period of industrialisation, we are faced with a number of challenges such as plastics pollution, acidification, coral bleaching, and of course polar ice melt, to mention but a few. Within relatively few decades, humanity's impact on the Earth's ecosystems has been significant and pervasive. In a 2008 paper, Halpern et al. stated that 40% of the world's oceans had been strongly affected by human activity, but that large areas such as the poles had seen relatively little impact. However, in the past 10 years we have learnt a lot more about subjects such as micro-plastics which are causing significant concern. Recent studies by Japanese research teams found 140,000 to 290,000 plastic particles per square kilometre of sea between Australia and the Antarctic continent. There is a new sense of urgency that we must tackle these problems sooner rather than later, or indeed before it is too late.

Human activities are having an impact on how our ocean functions, the health of our ocean ecosystems, and the resources available in our ocean that are used for human existence. The quantity of micro-plastics reaching our ocean through household wastewater streams and the breakdown of plastic waste is negatively impacting marine life and the composition of the water in our ocean. The increase in the popularity of sun, sea, and sand holidays is leading to the overdevelopment of the coastline, in certain areas, which in turn is having a negative impact on the movement of sand and the survival of marine species e.g. the Mediterranean monk seal (Monk Seal, 2019). Over-fishing is depleting some ocean resources to the point where they are facing a high risk of extinction in the wild e.g. the Bluefin tuna (Bluefin Tuna, 2019). Ocean

literacy (OL) tools and initiatives are being used to create awareness of how humans are impacting the ocean and it is important that the effectiveness of these tools and initiatives are measured in order to ensure that they are having the desired effect on OL. The measurement of the effectiveness of the tools and initiatives can also provide insights into how the tools and initiatives can be improved to better inform and educate people on important ocean related topics.

It seems that nearly every day we see news articles relating to the urgency of addressing issues regarding the health of our ocean and the welfare of the species that inhabit it. In terms of the life span of the Earth, and the current ocean ecosystems, humanity's impact has been relatively brief, but devastating. Phenomena such as ocean acidification, bleaching of corals, plastics, overfishing and warming can all be directly related to human activity. From deep ocean trenches to remote Antarctic seas, we can find evidence of our impact on the ocean environment (Ocean Plastic, 2018).

1.2 Research Motivation

Rather than blindly addressing symptoms, it is vital to address causes of problems. To fix a problem, you must address the causes of that problem, rather than merely focusing on the symptoms. And to do this, we must understand causes, which can sometimes be a rather complex web of interaction between human and natural activities. Intelligent solutions require that we understand the complex systems involved in the interplay between humans and the oceans (see section 2.3 Systems Thinking). This web of interactions must be understood in order to identify those points at which we must intervene for maximum effect and the processes and activities involved must be understood in order to target interventions such that they have significant impact. There may be many such points, with different human actors involved at each one. Take for example, the micro-plastics problem. Some plastics enter the ocean through spillage accidents during shipping.

Therefore, shipping companies are obvious actors to engage in ensuring their practices minimise such risks. Further up the supply chain, we can look to consumers to choose products which do not contain micro-plastics, thereby reducing the amount that is flushed into the wastewater systems, and ultimately ends up in the marine environment. Other actors, such as manufacturers and product developers, can work together to find biodegradable alternatives to plastics for use in everyday products.

Complex supply chains often involve multiple activities and human actors (Trienekens et al., 2012), each with different requirements in terms of knowledge, influence and ability to act. For example, individual tourists and planning officers will have very different perspectives, knowledge and potential impact in terms of addressing problems caused by mass coastal tourism. The recent efforts to prevent plastic micro-beads from entering our oceans and ecosystems are a good example (Xanthos and Walker, 2017). Social media campaigns and awareness-raising helped to change individual consumer's attitude and behaviour, while governments took notice of the problem and legislated to ban micro-beads from cosmetics products (Girard et al., 2016). Meanwhile, cosmetics producers are removing micro-beads from their products and replacing them with sustainable alternatives (Microbead Ban, 2018).

The literature review revealed the lack of a suitable tool to allow domain experts to create DAPSIWR models of ocean related topics online and attach relevant knowledge to the individual elements of the DAPSIWR model and the links between the elements. The models and the associated knowledge are suitable for use in the creation of pre- and post-surveys to measure the effectiveness of ocean literacy tools and initiatives.

1.3 The ResponSEAble Project

The ResponSEAble project (ResponSEAble, 2015), which funded my PhD, was a European Horizon 2020 project focused on looking at ways to help people understand their connection to the ocean, encourage people to take more interest in the ocean, and improve their understanding of the ocean. The ResponSEAble project developed six key stories to describe significant ocean issues. The key stories were "Eutrophication and agriculture", "Ballast water and invasive alien species", "Sustainable fisheries & aquaculture", "Microplastics and cosmetics", "Coastal tourism", and "Marine renewable energy". Central to the description of those stories are comprehensive DAPSIWR causal models of the interactions between the human and ocean systems. By identifying the human actors and activities and their interfaces with the ocean, we provide a better understanding of the impact of our activities and where interventions can make the most difference.

My involvement in the project consisted of the design and development of an online Causal Mapping and Knowledge Capture tool and an Effectiveness Measurement tool, the development of pre- and post-surveys for the measurement of the effectiveness of OL tools, and the use of statistical analysis techniques for measurement of OL tool effectiveness. The online Causal Mapping tool was created to allow domain experts to model environmental systems by creating DAPSIWR based causal models of OL topics e.g. micro-plastics, coastal tourism, and sustainable fisheries. The tool allows users to choose from a classification of DAPSIWR element types which are based on a classification developed as part of the ResponSEAble project. The users of the tool can enter information related to the individual elements of the causal models and attach knowledge and actors to the elements and links between elements in the causal model. The causal models and all its associated data is stored in an online knowledge base.

Pre- and post-surveys were created to measure the effectiveness of the ResponSEAble OL tools and initiatives. The surveys were administered to the users of the tools before and after their use of the tools, and also to participants of initiatives related to the project. An example of an OL tool which had its

effectiveness measured is the microplastics OL tool described in section 6.8 “The Micro-plastics OL Tool”. The users of the tool completed a pre-survey before they used the tool, then they viewed the tool, and when they were finished, they completed a post-survey. Data analysis techniques were then used on the results of the surveys to measure the effectiveness of the micro-plastics OL tool.

An Effectiveness Measurement tool was created to allow for the automatic measurement and analysis of the effectiveness of OL tools. It was used to monitor the activity of users of the ResponSEAble serious game ResponSEAble game (2020). The purpose of the ResponSEAble game was to educate users on ocean related topics including micro-plastics, coastal tourism, and sustainable fisheries. The user navigates through an archipelago, answering questions and solving challenges as they go. The content of the game is related to the health of our oceans and the ocean value chain. The questions used in the ResponSEAble game were set up in the Effectiveness Measurement tool which allowed the responses to the questions to be automatically received and stored in the Effectiveness Measurement tool’s database. There are features provided in the tool to retrieve data in specific formats to allow for insights to be gained into the effectiveness of the game.

1.4 Problem Statement and Research Questions

Ocean literacy tools and initiatives are used to increase peoples’ awareness of issues related to the impact of humans on the ocean environment and the impact the ocean has on human life. It is important that the effectiveness of these OL tools and initiatives are measured to ensure that they are having the desired effect. The research hypothesis for this research is “Customised topic-specific Ocean Literacy surveys can be created and used to measure the effectiveness of targeted OL initiatives and tools. The creation of a framework, including an online causal mapping tool, will help domain experts to create models of OL topics of concern. The models and their associated

knowledge can then be used as a basis for the development of questions which can be used in pre- and post-surveys to measure the effectiveness of OL initiatives and tools".

This research is based on the following four research questions:

- **RQ1:** Can we create a new integrated framework that models, and captures systems and knowledge which can be used to measure the different Ocean Literacy (OL) dimensions for specific topics?
- **RQ2:** What measurement mechanisms and analysis techniques are useful to use with this framework?
- **RQ3:** Can we use this framework and tools to evaluate the effectiveness of ocean literacy initiatives and tools?
- **RQ4:** What insights can we obtain from the analysis of the survey response data to help design better OL tools and initiatives?

Figure 1.1 shows the process consisting of the creation of the DAPSIWR causal model by the domain experts, the capture of knowledge related to the causal model topic, the creation of surveys based on the knowledge, the use of data analysis techniques to analyse the usefulness of the surveys, and the use of the surveys as pre- and post-surveys to measure the effectiveness of OL tools and initiatives.

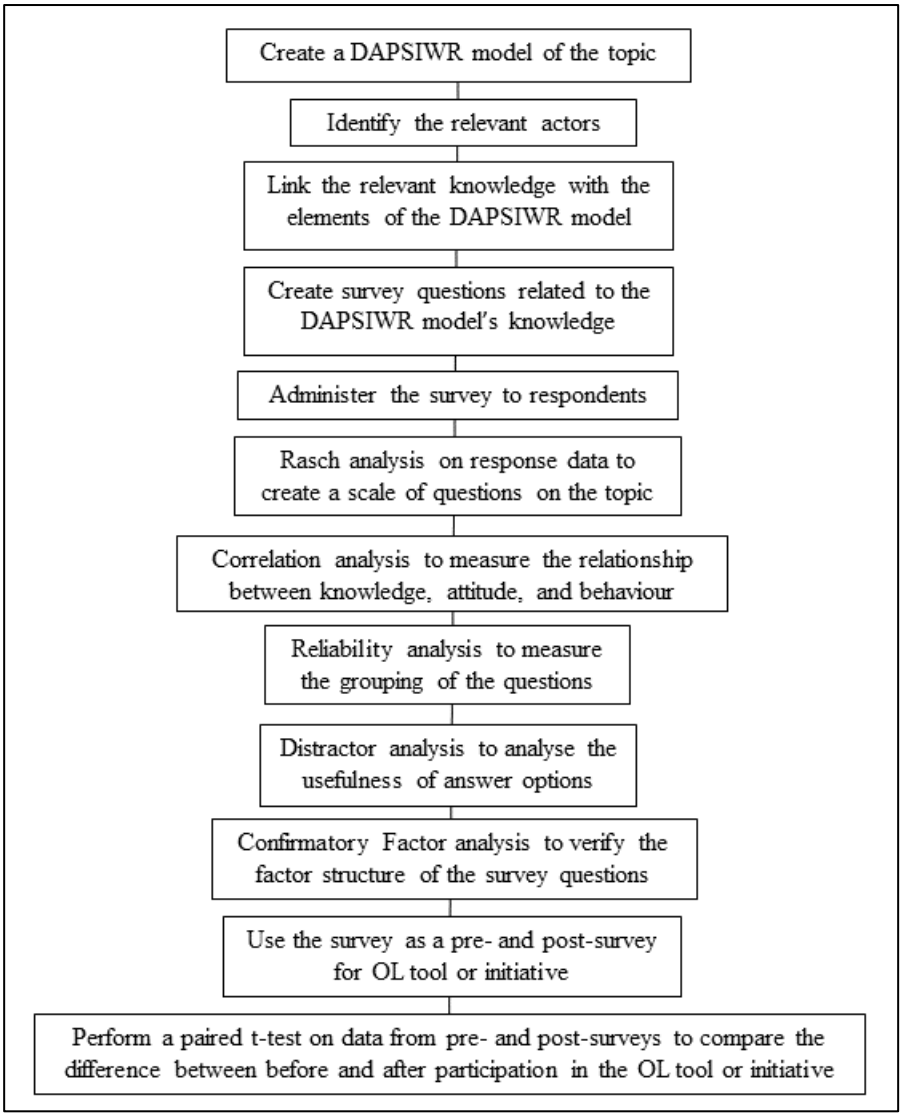

Figure 1.1: Process from causal map creation to analysis of the effectiveness of OL tool or initiative

1.5 Research Objectives

Table 1.1 contains the research objectives for this research. It also shows how the research questions are related to the research objectives. For example, research question one is related to research objectives one and two.

Research Question	Research Objective
RQ1: Can we create a new integrated framework that models, and captures systems and knowledge which can be used to measure the different Ocean Literacy (OL) dimensions for specific topics?	(i) Investigate Environmental and Ocean Literacy dimensions. (ii) Create a framework and an online causal mapping tool which can be used to identify knowledge and assist with the creation of topic specific surveys.
RQ2: What measurement mechanisms and analysis techniques are useful to use with this framework?	(iii) Find what approaches are taken to measure Environmental and Ocean Literacy dimensions, and the data analysis procedures that can be used to generate useful information from responses to questionnaires and surveys.
RQ3: Can we use this framework and tools to evaluate the effectiveness of ocean literacy initiatives and tools?	(iv) Use the online causal mapping tool to create DAPSIWR causal models of specific OL topics. (v) Use the models to create and administer surveys for use as pre- and post-surveys for OL tools and initiatives.
RQ4: What insights can we obtain from the analysis of the survey response data to help design better OL tools and initiatives?	(vi) Use the survey response data to explore the difficulties involved in measuring the effectiveness of ocean literacy tools and interventions, especially where they relate to quite narrow and specific topics such as Micro-plastics and Coastal Tourism. Also, use the survey response data to identify weaknesses in the questions with respect to the survey goals.

Table 1.1: Research questions and research objectives

1.6 Research Contributions

The main research contributions of this research work are the:

- literature review that was performed to identify the existing research work related to ocean and environmental literacy and their measurement
- framework to measure the effectiveness of OL tools and initiatives
- development and use of the online causal mapping tool and associated knowledge base (which did not exist elsewhere)
- process of building causal maps using the online causal mapping tool
- development of pre- and post-surveys on specific OL topics related to micro-plastics and coastal tourism, based on DAPSIWR models.

1.7 Publications

Some of the contents of this thesis have been published in the publications listed below.

- Conor McCrossan and Owen Molloy, "*Measuring Individuals' Knowledge, Attitude, and Behaviour on Specific Ocean Related Topics*" in the 11th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (KMIS), Vienna, Austria, September 2019

- Conor McCrossan and Owen Molloy, "*An Online Causal Mapping Tool for Environmental Systems Education*" in the 9th Edition of the International Conference New Perspectives in Science Education, Florence, Italy, March 2020. DOI: 10.26352/E319_2384-9509

- McCrossan, Molloy, and Ashley, "A Framework for the Assessment of the Effectiveness of Ocean Literacy Initiatives" in a collected work provisionally entitled "Ocean Literacy: Understanding the Ocean", edited by Kostis C. Koutsopoulos & Jan Stel, to be published in the Springer book series Key Challenges in Geography.

1.8 Thesis Outline

Figure 1.2 provides an outline of the chapter structure of this thesis.

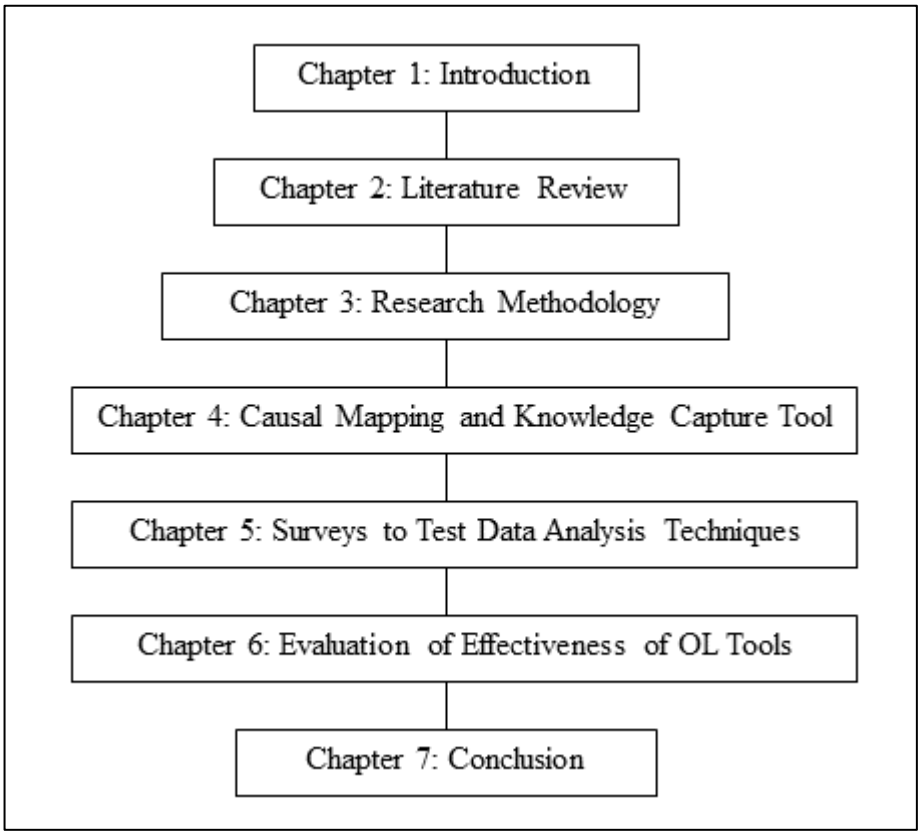

Figure 1.2: Outline of thesis chapter structure

The first chapter contains an introduction to this thesis which consists of a discussion related to the importance of the ocean and the effects humans are having on the ocean, followed by the motivation for this research and a description of the ResponSEAble project which funded my PhD. The problem statement, research questions, research objectives, and research contribution are then described, and the chapter closes with a list of my publications and an outline of the contents of this thesis.

Chapter two presents a review of the literature relevant to this research. It begins with a section on ocean literacy which includes environmental literacy models and ocean literacy dimensions. This is followed by sections on the DAPSIWR framework and system thinking. Causal mapping in a learning

environment and existing causal mapping tools are then discussed which is followed by a description of the ocean literacy framework. The various aspects of measuring ocean literacy are then described consisting of agreement scales, behaviour scales, approaches to the measurement of OL, creating surveys and questionnaires, validating instruments, and targeting groups. The following two sections are on the measurement of specific topics and the measurement of the effectiveness of OL tools and initiatives. The chapter closes with a discussion of the relevant data analysis approaches, which are, descriptive analysis, Rasch analysis, reliability analysis, distractor analysis, confirmatory factor analysis, correlation analysis, and paired t-tests.

Chapter three is the methodology chapter for this thesis, and it discusses the methods and tools used to perform this research. It commences with sections on research methods, the research process, and the literature review process. This is followed by a discussion of the data gathering process and the online causal mapping tool and the chapter closes with a description of each of the data analysis procedures used in this research.

Chapter four of this thesis is on the online causal mapping and knowledge capture tool which I created. The first two sections describe the online causal mapping tool and the DAPSIWR classification which is used in the tool to provide element types for the domain experts to use to create DAPSIWR elements. The functional requirements, architecture, technologies, and the design of the tool are then described. The chapter closes with a section on the implementation and testing of the tool, and DAPSIWR based causal maps created using the tool.

Chapter five covers the surveys on three OL topics which I created, administered, and analysed as an experiment in surveying and data analysis. The three OL topics were micro-plastics, coastal tourism, and sustainable fisheries. The chapter starts with a description of the contents of the surveys and the knowledge, attitude and behaviour questions contained in the surveys. This is followed by the results obtained from the administration of the three surveys and the chapter closes with a discussion of the results of the data

analysis on the survey responses.

Chapter six is about the evaluation of the effectiveness of OL tools. The first two sections describe the micro-plastics and coastal tourism OL tools created in the ResponSEAble project. This is followed by a description of the DAPSIWR models created on the topics of micro-plastics and coastal tourism using the online causal mapping tool. This is then followed by sections on the relevant knowledge attached to the DAPSIWR causal maps by the domain experts, the micro-plastics survey I created based on the knowledge attached to the micro-plastics causal map, and the micro-plastics OL tool which I created based on the micro-plastics knowledge. The results section contains the results of the data analysis on the responses to the micro-plastics survey and its use as a pre- and post-survey to measure the effectiveness of the micro-plastics OL tool. The chapter closes with a discussion on the results of the data analysis of the responses to the micro-plastics survey.

Chapter seven is the concluding chapter of this thesis and contains my conclusions in relation to the research questions, research objectives, and research contributions. Towards the end of the chapter there is a section on proposals for future work which would be useful to perform to continue this research.

Chapter 2

Literature Review

2.1 Introduction

This chapter begins with a section on ocean literacy including environmental literacy models and ocean literacy dimensions. This is followed by sections on the DAPSIWR framework and systems thinking. The use of causal mapping in the learning environment and causal mapping tools are then discussed followed by a section on the ocean literacy framework. Then there is a section on measuring ocean literacy which includes the topics of agreement scales, behaviour scales, approaches used to measure OL, creating surveys and questionnaires, validating instruments, and targeting groups. This is followed by a discussion on measurement of specific topics and the associated problems, and a section on measuring the effectiveness of OL tools and initiatives. The chapter closes with a section on existing data analysis approaches which includes descriptive analysis, Rasch analysis, reliability analysis, distractor analysis, confirmatory factor analysis, correlation analysis, and paired t-tests.

2.2 Ocean Literacy

Ocean literacy is a term used to describe the knowledge a person possesses about the ocean, and their attitude and behaviour towards the ocean. The commonly used definition of Ocean Literacy (OL, 2015), which is to understand "… the influence the ocean has on you and your influence on the ocean" is useful, but ultimately we need to be clear about the meaning of the word "understand" in this context, and push for not just improved understanding, but the modifications in the attitudes and behaviour needed for change. OL initiatives, focused on specific topics related to the ocean, can be used to improve knowledge and change attitude and behaviour and it is important to have a way of measuring this change.

2.2.1 Environmental Literacy Models

The five essential components of environmental literacy outlined by the Environmental Literacy Ladder (ELL, 2007) are Awareness, Knowledge, Attitudes, Skills, and Collective Action. Each of the components are seen as steps on a ladder towards environmental literacy, as shown in figure 2.1.

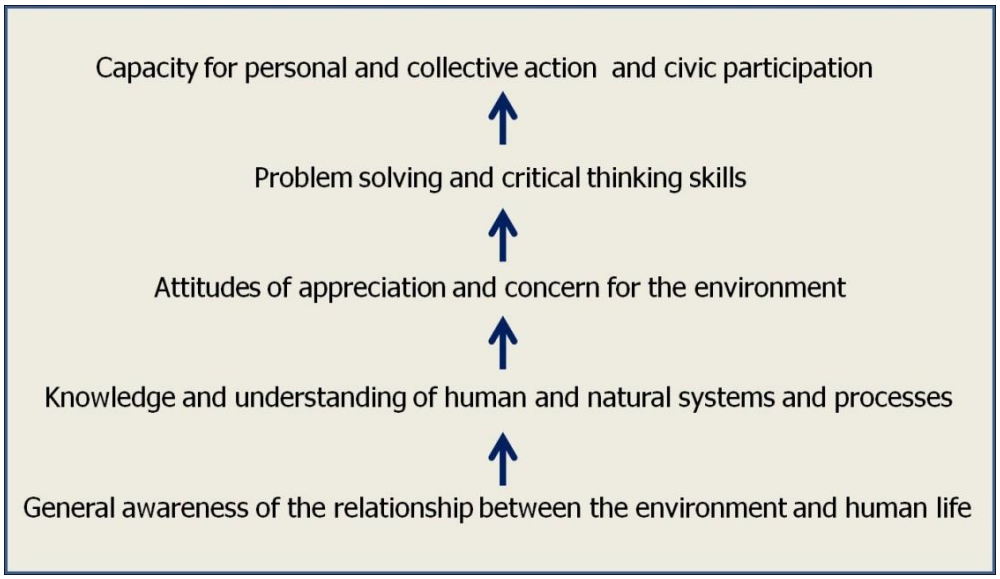

Figure 2.1: The Environmental Literacy Ladder

The General Ecological Behaviour (GEB) scale is a widely used instrument used for the measurement of six domains of behaviour in relation to the environment. The six domains contained in the GEB scale are Energy conservation; Mobility and transportation; Waste avoidance; Consumerism; Recycling; and Vicarious, social behaviours toward conservation (Kaiser and Wilson, 2004). The Two Major Environmental Values model (2-MEV) scale measures values related to Preservation (PRE) and Utilization of the environment (UTL) (Bogner, 2018). The Preservation items are related to humans' interactions with the environment, feelings towards pollution, and environmental protection. The Utilization items are related to construction, the use of resources, and pollution.

The purpose of the research performed by Bogner et al. (2015) was to validate the "2 Major Environmental Values" (2-MEV) model using a large dataset of 10,676 children collected over an eight-year period. The 2-MEV model measured children's environmental perception by scoring individual values. An example of one of the preservation items used on the 2-MEV scale is "I always turn off the light when I do not need it anymore". Maurer et al. (2020) used a pre- and post-test design to measure the effect of a classroom project called "Green Awareness in Action" which was designed to change energy consumption patterns to pursue green behaviour. The instrument used was a combination of a set of 15 multiple choice environmental knowledge questions, adapted from their pilot study; 20 items from two scales including the 2-MEV scale; and 21 items from the General Ecological Behaviour scale.

The Inclusion of Self (INS) scale measures participants' connectedness with nature (Liefländer et al., 2013). The INS scale is a graphical item scale which contains seven circle pairs which overlap to a differing degree, from complete separation to complete connection. The participant is required to choose one circle pair to indicate their level of connectedness with nature. Bissinger and Bogner (2018) applied a recently proposed environmental literacy model to an intervention focusing on tropical rainforests and climate change. The model comprised of the three dimensions knowledge, environmental attitudes, and pro-environmental behaviour. The questionnaire comprised of a set of 13 knowledge questions and three established scales. The scales were the General Ecological Behaviour scale, the 2-MEV scale, and the Inclusion of Self scale.

The New Environmental Paradigm scale has become the most widely used measure of environmental concern in the world (Dunlap, 2008). It contains 12 items which measure concern related to the themes of the existence of ecological limits to growth, the importance of maintaining the balance of nature, and rejection of the notion that nature exists primarily for human use.

Maurer and Bogner (2020) used Confirmatory Factor Analysis (CFA) to model environmental literacy with environmental knowledge, values and

reported behaviour. CFA can be used to measure how consistent survey questions are in measuring the dimension they were designed to measure e.g. environmental attitude. Their knowledge items were multiple choice questions focused on energy and they used the 2-MEV scale to measure values, and the GEB scale to measure behaviour. Their results showed a linear relationship between environmental knowledge and values, values and reported behaviour, and knowledge and reported behaviour. Teksoz et al. (2012) presented an Environmental Literacy Components Model to explain how attitudes, responsibility, concern, knowledge, and outdoor activities related to each other. They administered an environmental literacy survey to 1,345 University students and the resulting Structural Equation Model (SEM) revealed that high levels of environmental knowledge stimulate environmental concern, attitude, and personal responsibility. SEM is a set of methods used by scientists to create a model of some observable or theoretical phenomenon and the model contains information on the relationships between the components of the model e.g. correlation measurements.

In the Theory of Change (ToC, 2019) framework, the motivating factors for behaviour change include awareness, knowledge, attitude, and interpersonal communication. The measurement of these dimensions can be used to inform the creation of aims and indicators in a Theory of Change (ToC) pathway created for an intervention. The ToC pathway illustrates the sequence of events needed for an activity to lead to a desired outcome (Biggs et al., 2017). An example of a ToC aim in relation to an intervention to increase awareness about micro-plastics in the ocean could be that “Knowledge of the sources of micro-plastics in the ocean will have increased”. The ToC indicator in this case would relate to the difference between knowledge scores for pre- and post-surveys.

2.2.2 Ocean Literacy Dimensions

According to Umuhire and Fang (2016), existing research typically derives the definition of Ocean Environmental Awareness from the concept of Environmental Awareness. It includes a person's ability to realise an existing connection between human activities and the state of the ocean, and a person's attitude towards a safe and healthy marine environment. The understanding of the impact of human activities was the subject of a European-wide survey of societal awareness and perceptions about marine litter. The survey was part of the MARLISCO project, described by Veiga et al. (2016), and it examined existing understanding related to marine litter including the perceived risk related to marine litter and behaviour intentions to engage in solutions.

Attitude towards the ocean and environment includes beliefs, perceptions, concerns, and feelings related to self-efficacy, or the individual's belief that they can make a difference. In their statement regarding the construct of environmental attitudes, Schultz et al. (2004) included beliefs a person holds regarding environmentally related activities or issues. The Affective dimension of environmental consciousness proposed by Sánchez and Lafuente (2010) included indicators to measure endorsement of a general pro-environmental worldview, support for pro-environmental solutions to specific problems, and the perception that the environment is under serious threat. Their Dispositional dimension was related to personal attitudes towards individual action and the willingness to assume costs of environmental policies. The behavioural elements of environmental activism and individual behaviours were included in the Active dimension of environmental consciousness proposed by Sánchez and Lafuente (2010).

In order to examine the contribution of higher education institutes to their students' Environmental Literacy (EL), Arnon et al. (2015) administered an EL survey to 1147 students at an Israeli college. The survey measured the students existing environmental background, environmental values and attitudes, environmental behaviour, and environmental knowledge. They found the students to have a moderate level of EL and they also found that

the variation in students' pro-environmental behaviour was better explained by environmental attitudes than by their environmental knowledge. Part of the questionnaire used by Umuhire and Fang (2016) gathered information related to the sources of ocean related information used by the respondents. Part of the pan-European survey used by Gelcich et al. (2014) concerned the trust respondents had in different information sources related to the marine environment.

Yoon Fah and Sirisena (2014) included the dimensions of environmental knowledge, attitudes, and behaviour in their study to assess EL. They used a Path Diagram to show the influence of environmental knowledge and attitudes on environmental behaviour (figure 2.2). A path diagram is a diagram which contains variables and information related to which variables cause changes in other variables. The path diagram, in figure 2.2, shows a value of 0.485 for the relationship between attitude and behaviour, and a value of 0.277 for the relationship between knowledge and attitude. These values were calculated using correlation analysis. The path diagram also shows the factor loading of the survey items on the trait being measured e.g. a factor loading of 0.562 for item a1 measuring attitude. The factor loadings were calculated using confirmatory factor analysis.

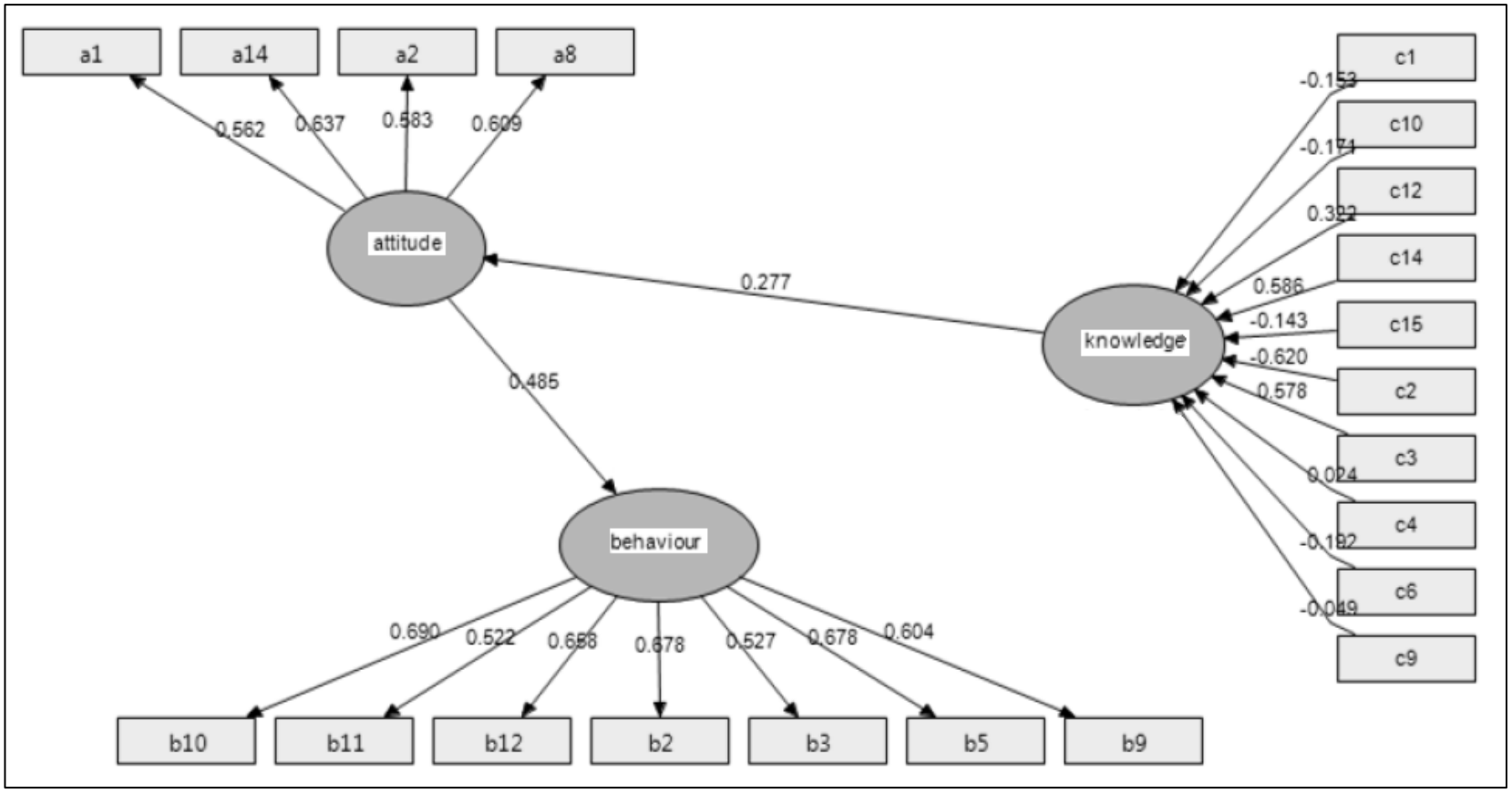

Figure 2.2: Path Diagram of the influence of knowledge and attitudes on behaviour (Yoon Fah and Sirisena, 2014)

2.2.3 Ocean and Environmental Definitions

Table 2.1 contains definitions related to the ocean and the environment. The ocean literacy framework was developed by scientists and educators from the ocean sciences education community. It built on existing work to define OL, assess what the public knows about the ocean, and redress the lack of ocean related content in education standards, instructional materials, and assessments. The definition of Ocean Environmental Awareness (OEA), in research performed by (Umuhire and Fang, 2016), is derived from the concept of environmental awareness. It is the ability to realise an existing connection between human activities and the state of the ocean, and to then favour a safe and healthy marine environment. The characteristics of OEA include recognition of the social value of a safe and healthy marine environment, ability to identify the source of threats to the marine environment, and an understanding of the need to take part in prevention, protest, creation, and other collective actions related to the ocean.

Definition	Aw	Kn	At	Cm	Bv	Example of Measurement
Ocean Literacy: "An understanding of the ocean's influence on you and your influence on the ocean" (OLF, 2015)	✓	✓				Measurement of knowledge related to the ocean (Fauville et al., 2018), (Greely, 2008)
Ocean Environmental Awareness: "The ability of a person to realise an existing connection between human activities and the state of the oceans and then favour a safe and healthy marine environment." (Umuhire and Fang, 2016)		✓	✓		✓	Measurement of Chinese students' "ocean environmental concerns, ocean environment knowledge and willingness to participate in ocean related activities" (Umuhire and Fang, 2016)
Environmental Advocacy: "Environmental advocacy involves individuals and groups working locally, nationally, and internationally to protect and improve the earth's environment" (Haddad, 2017)				✓	✓	"A survey of 1215 nonstudent Ecological Society of America members" measuring ecologists' engagement in advocacy activities and attitudes on the relationship between environmental advocacy, values, and science. (Reiners et al., 2013)

Environmental Consciousness: refers "to specific psychological factors related to individuals' propensity to engage in pro-environmental Behaviours" Sánchez and Lafuente (2010)		✓	✓		✓	"The data obtained from a survey on environmental attitudes and behaviour conducted in 2004 among Andalusians is used as an empirical basis for the proposed operationalization." Sánchez and Lafuente (2010)
Operational Environmental Literacy (EL): Relates to the routine evaluation of impacts and consequences of actions, advocating action positions, and taking actions that work to sustain or enhance a healthy environment (Roth, 1992)	✓	✓	✓	✓	✓	A study "to determine students' views about operational environmental literacy activities and the effects of these activities on students' responsible environmental behaviour" (Fidan, 2016)
Nominal EL: A person developing an awareness and sensitivity towards the environment (Roth, 1992)	✓					
Cultural EL: "The ability to know the received wisdom about some cultural event or institution rather than to make meaning for yourself" (Stables, 1998)	✓	✓				

Functional EL: "Indicates a person with a broader knowledge and understanding of the nature of and interactions between human social systems and other natural systems" (Roth, 1992)	✓	✓	✓			

Table 2.1: Definitions related to the ocean and the environment
Aw: Awareness, Kn: Knowledge, At: Attitude, Cm: Communication, Bv: Behaviour

Environmental advocacy can take the form of a social movement or as a component of policy development, and existing environmental advocacy theories focus on differences in the dynamic interaction of agents, interests, and institutions (Haddad, 2017). Common environmental advocacy strategies include public protest, lobbying, lawsuits, letter writing campaigns, policy papers, media campaigns, joint projects with government, grassroots public education, public art, and organisational networks.

Sánchez and Lafuente (2010) developed a definition of environmental consciousness which included the affective, dispositional, cognitive, and active dimensions. They employ the concept of environmental consciousness to refer to psychological factors which relate to an individual's inclination to engage in pro-environmental behaviour. The affective dimension includes indicators to measure endorsement of a general pro-environmental worldview, support for pro-environmental solutions to specific problems, and the perception that the environment is under serious threat. The dispositional dimension includes personal attitudes towards individual action from a self-efficacy point of view, the perception of individual responsibility and a willingness to assume the costs of environmental policy implementations. The cognitive dimension measures the levels of knowledge an individual possesses in relation to environmental problems. The active dimension includes group environmental activism (e.g. belonging to an environmental group and environmental protests), low cost behaviours (e.g. recycling) and

higher cost behaviours (e.g. green consumerism and reducing car use).

The idea of cultural environmental literacy was developed by Stables (1998). It refers to the ability to understand the significance attached to cultural icons including living natural objects, national parks, and forests. It also includes the ability to recognise the significance of natural images in human culture (e.g. the American bald eagle and the white dove of piece) and it also allows for an understanding of why landscapes are the way they are and how landscapes are shaped (e.g. climate, glaciation, and patterns of historic land ownership). The idea of cultural environmental literacy was based on existing research into cultural literacy which was linked with the development of the USA literacy curriculum during the 1980s.

As part of research into the operationalisation of environmental literacy, Roth (1992) identified three levels: nominal, functional, and operational environmental literacy. Nominal refers to a person being able to recognise basic terms used when communicating about the environment and provide basic definitions of the meaning of the terms. A person at the nominal level is developing an awareness and sensitivity towards the environment, a respect for natural systems, and a concern for the impact of humans on natural systems. Functional refers to a person with a broader knowledge and understanding of the interactions between human social systems and other natural systems. A person at the functional level has developed the skills to analyse, synthesise, and evaluate information about the environment. Operational refers to a person who has moved beyond functional literacy in terms of both the depth and breadth of understanding. Their skills include the ability to evaluate the impact and consequences of actions, choose between alternatives, advocate action positions, and take action that work to sustain or enhance a healthy environment.

Affect and environmentally responsible behaviour were included as components of environmental literacy by McBride (2011). The Affect component, in this case, is an attitude which is environmentally sensitive or appreciative. According to Fidan (2016), the areas that an individual with

operational environmental literacy should have competency in include environmental attitudes, acting responsibly in relation to the environment, and having feelings of responsibility about reducing environmental hazards.

Roadmap EL (2011) summarizes, in short, that environmental literacy is understanding, problem-solving, citizenship, and action in relation to the environment. As part of one of the key considerations for an adapted definition of ocean literacy for Canada, OL Strategy (2018) included those that feel ocean literacy is beyond awareness and understanding i.e. it is about fostering and enabling behaviour change and requires action. Daniš (2013) states that the components possessed by environmentally literate people are interconnected, affect each other, and evolve progressively in the environmental literacy continuum. The components include knowledge and understanding, cognitive skills and abilities, affective dispositions, and behavioural strategies.

2.3 The DPSIR/DAPSIWR Framework

The DPSIR framework was developed by the European Environmental Agency, and it describes the interactions between society and the environment (DPSIR, 2013). DPSIR stands for Driver, Pressure, State, Impact, and Response. It provides a way of looking at a topic and identifying the drivers, pressures etc. associated with the topic. The framework (figure 2.3) has evolved to co-exist in many variations, depending on the type of system being modelled (Elliott et al., 2017). Drivers are driving forces which cause changes in society and the environment e.g. the need for food. Pressures are factors that originate from human activity and induce environmental change e.g. over-fishing. State can refer to a wide range of features including the characteristics of ecosystems, quantity and quality of resources, and human living conditions e.g. the age distribution of remaining fish stocks. Impacts are changes in environmental functions including resource access, and water and air quality e.g. reduction in the resilience of fish populations.

Responses are policy actions which are triggered by the perception of impacts, and they attempt to prevent, eliminate, compensate for, or reduce the consequences of the impact e.g. the implementation of fish quotas.

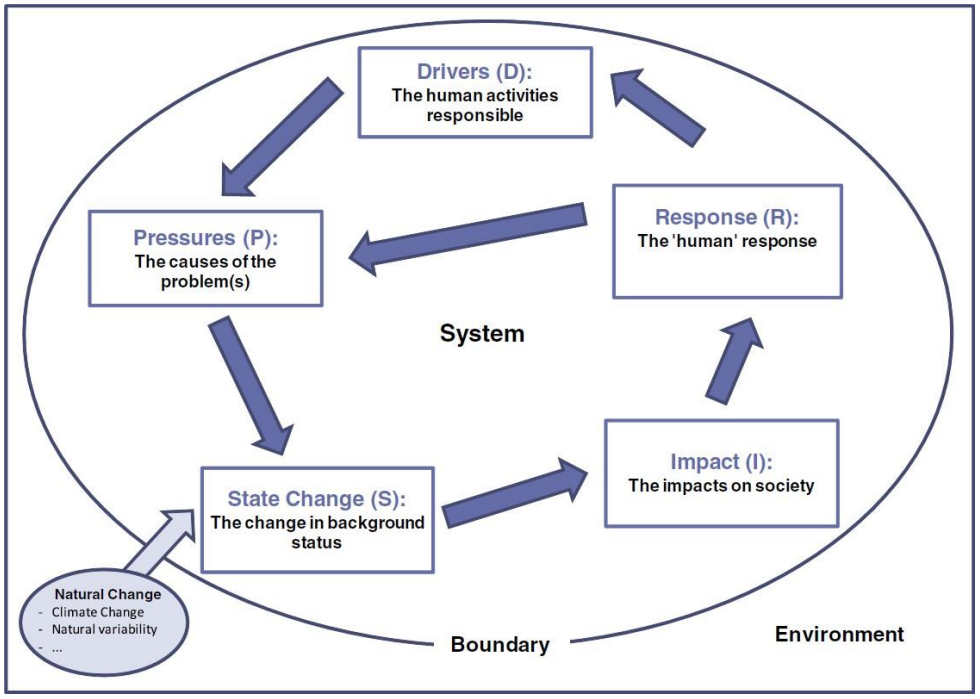

Figure 2.3: The DPSIR Framework (Atkins et al., 2011)

A DPSIR-type model is just one way of capturing what is happening in a specific human-ocean system. An alternative to the DPSIR framework is the Opportunities framework, which focuses on available assets and how they can be sustainably used for human and economic development (Opportunities framework, 2021). It answers questions related to what resources are available, opportunities that exist to promote poverty reduction and sustainable development, challenges to capitalising on the opportunities, and policies that should be implemented to capitalise on opportunities etc.

Mukuvari et al, (2016) used the DPSIR framework to assess the recovery of a degraded marine ecosystem. The ecosystem was the Benguela Current Large Marine Ecosystem which has been degraded by overfishing between 1960 and 1990. The DPSIR framework was used to identify 27 indicators

which were then analysed. The driver indicators identified were unemployment, GDP contribution of fisheries, value of catch, and total allowable catches allocated versus scientific advice. Their research built on existing research which used the DPSIR framework to support multi-species and multi-discipline research for a marine ecosystem. The results showed that 11 of the indicators showed a positive trend which meant that the ecosystem was recovering, 7 showed that the degradation was continuing, and 9 showed a neutral status.

The systems approach, taken by Atkins et al. (2011), integrated the DPSIR framework with ecosystem services and societal benefits to create a specific framework for supporting decision making in the marine environment. They performed a case study, to illustrate the use of their framework, on the management of marine aggregates extraction in UK waters. The drivers they identified were aggregate extraction for building materials and aggregate extraction to meet infrastructure demands. The pressures were removal of bed material and increased suspended sediment, and the state changes were removal of benthos (fish food), damage to seabed habitats, and change to sediment structure. Based on the combination of DPSIR, ecosystem services, and societal benefits, they proposed a set of 15 postulates for the sustainable management of the marine environment.

Gari et al. (2015) reviewed the applications of the DPSIR framework to several social-ecological systems, with emphasis on the coastal environment. Examples of the applications they reviewed were the use of DPSIR to explain the causal chains of environmental consequences of an offshore wind farm, to identify the social and economic pressures in an estuary, the assessment of the impacts of development activities on the coastal environment, and examining the effects of human mobility. They found that DPSIR is a useful tool to analyse and assess environmental problems and bring together different scientific disciplines e.g. environment managers.

Based on existing studies and their own experiences in applying the DPSIR framework, Tscherning et al. (2012) developed two criteria that they believe are crucial for policy development research. The first criterion was the development of conceptual models which integrate knowledge from different disciplines, specialists, and policy makers, and those affected by their decisions. The second criterion was the potential to explain the results of analysis of research to different disciplines, specialists, stakeholders, and the public. They concluded that studies employing DPSIR may provide effective solutions for real world problems by taking into account knowledge integration, stakeholder involvement, and the provision of alternatives e.g. the alternative approaches available for watershed management.

The DAPSIWR framework is based on the DPSIR framework with "Activity" and "Welfare" elements included. The elements of the DAPSIWR framework are Drivers, Activities, Pressures, State (change), Impacts on the environment, Impacts on welfare, and Responses (Patrício et al., 2016). Including "Activity" and "Welfare" elements in the framework allows the activities related to the topic to be modelled, as well as the impacts of the topic on human welfare. Drivers can be basic human needs e.g. the need for food or recreation. An activity is an action that is performed based on an existing driver e.g. fishing based on the need for food or tourism based on the need for rest and relaxation. A Pressure relates to a pressure on the environment due to an activity e.g. the abrasion of the seabed from the use of trawling as a fishing practice. A State change is an observable change in ecological characteristics e.g. reduced fish stocks. An example of an Impact on the environment is algal blooms due to eutrophication. Welfare refers to impacts on human health and well-being e.g. less fish available for human consumption and a reduction in the fishing stocks available which impacts the welfare of the fishing sector and fishermen. A Response can be a government policy to prevent or mitigate drivers, activities, pressures, or impacts e.g. marine protected areas policies.

Karageorgis et al. (2005) used the DPSIR framework to assess the conditions of the catchment area-coastal zone continuum of the inner Thermaikos Gulf in the southern Balkan Peninsula. Some of the drivers they identified were related to the political situation in the Balkans, and the citizens' lifestyle which is driven by major EU/national legislative frameworks. An example of the elements of the DPSIR framework which were identified by Karageorgis et al. (2005) were the Driver "Greek development policy for the area", the Pressure "increased water demand for drinking water and irrigation", the State "the flow of the Axios river", the Impact "eutrophication and algal blooms", and the Response "a water management law titled: Legislative for waters".

In the approach applied by Omann et al. (2009), the DPSIR framework was used to analyse the issues of climate change (pressure) and biodiversity loss (state). The driving forces of climate change that were identified in their research were energy use, transport practices, land use practices, trade, and tourism. An example of the DPSIR elements which were identified by Omann et al. (2009) are the Driver "human economic activity causing greenhouse gases emissions", the Pressure "increase in the atmospheric concentration of greenhouse gases", the State "biodiversity", the Impact "functions, goods, and services for human survival and well-being", and the Response "reduction in greenhouse gases emissions". Their findings concluded that the DPSIR framework was useful to analyse the relationship between climate change and biodiversity, human activities are increasing greenhouse gases, and further increases in global surface air temperatures are expected.

Scriban et al. (2019) used the DPSIR framework to analyse the forest restitution governance process and its impact on resource management outcomes. The impacts that were identified related to the structural patterns of state and private forests, the extraction rates of trees, timber prices, and owners' perceptions of the restitution process. They found that the DPSIR framework can be used to integrate and correlate scattered information from different sources (e.g. official reports, public documents, and field research), and it allows for the analysis of a complex process in a structured manner.

2.4 Systems Thinking

As the famous systems-thinking educator, Donella Meadows, said "the behaviour of a system cannot be known just by knowing the elements of which the system is made" (Meadows, 2008). Hmelo-Silver et al. (2017) used a conceptual representation in a classroom intervention to support students reasoning about ecosystems. The conceptual representation was called the Components-Mechanisms-Phenomena (CMP) and was designed to enable students to construct coherent mental models. CMP was intended to support students in framing system thinking around a particular phenomenon or pattern e.g. eutrophication. It encouraged students to generate or recall plausible mechanisms (e.g. competition for food) and to explore the parts or components of the system. Their work was grounded in sociocultural theory, which suggests that learning is mediated by tools and artifacts in an activity system. The three major units focused on were an aquarium, a pond, and the ocean. Students were introduced to a driving problem and were then asked to create models. Some of the activities the students were required to perform were to design an aquarium, determine the number of fish in the aquarium, explain fish death in a pond, and identify mechanisms to increase carbon sequestration. Carbon sequestration is the process of capturing and storing carbon. They found that after the intervention, students were able to reason more completely about ecosystems.

The main objective of the research performed by Assaraf and Orion (2005) was to evaluate the development of junior high school students' system thinking skills related to earth systems. As part of their research, they identified eight characteristics of system thinking which included the ability to organise the systems' components and processes within a framework of relationships, the ability to identify dynamic relationships within the system, and the ability to understand the cyclic nature of systems. Three of the tools used in their research were drawing, word association, and concept mapping. The students were asked to draw the water cycle and include as many items as possible. The word association tool was used to evaluate the students'

ability to identify system components and processes by asking the students to write down all the concepts they were familiar with in relation to the water cycle. The students were also asked to create concept maps at the beginning and end of the learning cycle. This involved three stages where the students chose 15 concepts from a given list, created sentences including two concepts, and then created their concept map. Two of the ways to improve students' abilities to develop system thinking, suggested by Assaraf and Orion (2005), were the use of the outdoor learning environment to create a concrete model of a natural system, and the use of knowledge integration activities throughout the learning process.

Rates et al. (2016) investigated students' understanding of complex systems and if an agent-based simulation could improve their understating. An agent-based simulation consists of a number of agents and the interactions between the agents. Their intervention included a 3-hour gameplay of the UVA Bay Game which was created to simulate the Chesapeake Bay watershed in the USA. After their involvement in the simulation the students had improved their understating of Emergence, Order, and Trade-offs. Emergence relates to the unpredictability of the system where behaviour at the system level appears different to the behaviour at the micro-level. Order refers to the different orders that can exist in a system (e.g. top-down or bottom-up) and trade-offs are related to the balance of parameters in the system.

Nguyen et al. (2011) applied system thinking concepts and tools to the development of learning laboratories for sustainable development. A learning laboratory consists of a process and a setting where policy makers, managers, local people, and researchers collaborate to learn together to understand and address complex problems. The setting for the research was the Cat Ba Biosphere Reserve (CBBR) in northern Vietnam. The CBBR is an archipelago which has significant biodiversity value and is home to a number of rare and endangered species. Nguyen et al. (2011) used causal loop modelling to determine the components and interactions between the policy, social, environmental, and economic dimensions of the CBBR. The result of their research has laid a theoretical foundation and practical framework for

creating a biosphere reserve as a learning environment, using system thinking and modelling.

The study performed by Brandstädter et al. (2012) examined whether particular features of concept mapping practices affected the valid assessment of students' system thinking. The study applied 3 variations of concept mapping practices: (i) highly directed computer mapping, (ii) highly directed paper-pencil mapping, and (iii) non-directed paper-pencil mapping. The concept maps were created using the software package MaNET® and the results showed that the computer-based approach positively influenced student performance in concept mapping when compared with the paper-pencil approach. The purpose of the study performed by Evagorou et al. (2009) was to investigate the impact of a simulation-based learning environment on 11-12 years old students' development of system thinking skills. The Stagecast Creator visual programming language was used to simulate the ecosystem of a marsh. Sheehy et al. (2000) developed two computer simulations to investigate system thinking and environmental problem-solving skills possessed by children aged between 8 and 11 years. The simulations were computer based and consisted of a generic storyboard into which different problems could be coded. The findings showed that through efficient use of resources and recycling strategies the older children in the study outperformed the younger children.

2.5 Causal Mapping in a Learning Environment

In research performed by Jeong and Lee (2012), students constructed causal maps to graphically explain their understanding of how selected factors influence learning in collaborative environments. The students' causal understanding was measured by comparing the causal maps they constructed with the causal map created by the instructor. Aubrecht et al. (2019) introduced and described multiple types of graphical tools which can be used to support system thinking in chemistry education e.g. Causal loop diagrams.

According to Aubrecht et al. (2019), the advantages of causal loop diagrams include that they are a straightforward way to introduce system dynamics using only the concepts of the variables of interest and the causal relationships; and the student's ability to create a causal loop diagram only depends on their content knowledge.

Cox et al. (2019) used task-based think-aloud interviews to analyse the cognitive strategies used by students when constructing a causal diagram. They found that four different strategies were used, and each strategy resulted in the construction of an acceptable causal diagram. The overall objective of the research performed by Videira et al. (2009) was to develop and implement a participatory modelling methodology to support the scoping stages of river basin planning and management processes. The case study was aimed at developing a causal diagram depicting a shared view of the current perceived problems, pressures, and impacts; building a simulation model; and drafting a participatory action plan. Urwannachotima et al. (2019) used a group model building approach to engage stakeholders in the creation of a causal map of the dynamic interrelationships between a sugar-sweetened beverage tax, sugar consumption, and dental caries. A group of seven dentistry and health professionals developed a causal loop diagram which was then presented and discussed.

2.6 Causal Mapping Tools

A number of tools exist for creating causal loop diagrams and causal maps. VP Online Diagramming (2019) provides an online diagramming tool which allows users to create various types of diagrams online. Some examples of the diagrams which can be created using VP online are causal loop diagrams, class diagrams, sequence diagrams, and flow charts. When the user is creating a causal loop diagram, they are presented with a set of diagram elements e.g. Data process, Loop, Start state, Stop state, and Data store. These elements are focused on the creation of causal loop diagrams, but they are non-domain

specific. In the case where a user is creating a DAPSIWR based model of an OL topic, it would be more beneficial to have a set element types which are DAPSIWR based and focused on the ocean.

Vensim (2015) provides a desktop application for the creation of causal loop diagrams. The information related to each of the elements, of the diagrams, is displayed in text on the diagram which only allows for a small amount of information to be displayed for each element. When we are creating DAPSIWR based models it is important to be able to record information related to the elements of the model, attach knowledge to the elements of the model, and to attach knowledge to the links between the elements. The Microsoft Visio drawing programme was used by Fairweather (2010) to reproduce a digital format version of causal maps drawn by individual farmers. The causal maps drawn by the farmers were based on how they thought their farm ecosystem worked. The causal connection map data for each farmer was stored in an Excel spread sheet. Storing the map data in an online database, rather than in a spread sheet, would allow for the creation of a knowledge repository which can be searched for specific information. An example of the type of specific information which could be retrieved from DAPSIWR based knowledge, stored in an online database, could consist of the names and descriptions of the Activity DAPSIWR elements of a model on the problem of eutrophication in the ocean.

Kumu (2019) is an online tool which allows users to organise complex data into relationship maps which can then be viewed interactively by others. The Kumu tool is useful to organise complex data into visually appealing relationship maps. All of the causal mapping tools I reviewed have useful features but none of them were specific to a domain (e.g. the ocean) and they are not linked to an online knowledge repository. In contrast, the online Causal Mapping tool, developed in this research, is based on a classification, and links the causal map elements with their associated knowledge which is stored in an online knowledge base.

2.7 The Ocean Literacy Framework

The Ocean Literacy Framework (OLF) is a popular framework used by educators and scientists. It consists of the seven essential principles of OL and a set of 28 conceptual flow diagrams that represent a way of breaking down the major concepts and supporting ideas of the principles (OLF, 2015). Each of the seven Ocean Literacy Principles (OLPs) contain fundamental concepts and they can be used by educators and policymakers to influence teaching and learning about the ocean in schools, museums, aquariums etc. (OLP, 2013). Each of the seven OLPs have a conceptual flow diagram for each of the educational grade bands K-2, 3-5, 6-8, and 9-12.

The grade levels used in the OLF are based on the North American K-12 education levels which cover the range of school children ages from 4-year-old children to 19 year-old teenagers, approximately. The conceptual flow diagrams can be used: (1) as a suggestion on the sequence of instruction, (2) a way of organizing ideas, and (3) an indicator of how learning is progressing. The following is an example of the different levels of idea complexity related to grade levels contained in the conceptual flow diagrams: Principle 6 Grades K-2 ID C4, is “Storm drains and rivers carry pollutants, trash, and sediments from inland and coastal areas to the ocean”, whereas Principle 6 Grades 9-12 ID D18, is “Nitrogen and phosphorous entering the ocean from agricultural runoff, sewers and urban storm drains, can lead to increases in the growth of algae and zooplankton”. The OLF provides a comprehensive framework of concepts and ideas related to ocean literacy.

Based on the conceptual map for Principle 1 “The earth has one big ocean with many features” and the Grade 9-12, the suggested concepts on which students can be educated on are “Geologic Features”, “Properties of ocean water”, “Ocean circulation”, and “Sea Level”. The OLF framework was used as a direct model for the Earth Science Literacy Initiative (Wysession et al., 2012). The document developed by the initiative was used to define the core ideas of a middle school textbook program and a new set of K-12 science education standards. The NMEA Special report #3 (NMEA, 2010) contains

ideas from teachers on using the OLF. The approaches used by the teachers include a fifth-grade resource teacher using the OLF to develop an enrichment program for accelerated students and incorporating the OL principles when planning classroom instruction.

While the Ocean Literacy Framework (OLF, 2015) is useful in categorising the topics and providing a framework for teaching ocean topics, it does not focus to any great extent on the joint human-ocean systems which reveal the real detail behind our interactions with the oceans. The content of the OLF is mainly focused on awareness and knowledge in relation to the ocean, and its definition of an ocean literate person includes the ability to communicate about the ocean in a meaningful way and make informed and responsible decisions regarding the ocean. In my framework, we include the attitude, communication, and behaviour of an individual as a measure of their OL.

2.8 Measuring Ocean Literacy

Measurement of ocean literacy involves the measurement of a number of dimensions which are related to the level of OL possessed by respondents e.g. knowledge, attitude, behaviour. The most commonly used method to measure the level of OL is the use of questionnaires and surveys to gather data from respondents. The early stages of the overall survey design process should include a careful review of the literature, consultation with experts in the field, a review of previous surveys, and research to identify question items which are best suited for the specific purpose (Iarossi, 2005). Pilot testing the survey can give valuable feedback on problems with the wording of the questions, how the respondent reacts to the questions, and whether the questions themselves are appropriate. After the questionnaire has been finalised, it can be coded, and the data entry form developed. Survey data coding is the process of taking the responses to the questions and categorising them into groups. For example, in the case of multiple-choice knowledge questions, correct answers are coded using a one and incorrect answers are coded with a zero. According to Iarossi, (2005), the data entry form will have an interface

that is a replica of the questionnaire, and it will contain a number of built-in consistency checks to disallow invalid entries.

Some of the existing approaches to measuring knowledge related to the ocean include the Survey of Ocean Literacy and Experience (SOLE) (Greely, 2008) and the International Ocean Literacy Survey (IOLS) (Fauville et al., 2018). Both surveys include similar questions related to general knowledge about the ocean, e.g. how much of the earth is covered by the ocean, ocean circulation, the depth of the ocean, ocean resources, and the supply of salt to the ocean by rivers. The two surveys have questions which focus on different topics related to the ocean. The topics the SOLE survey focuses on include coastal erosion, sources of pollution and trash, and the ocean's impact on weather. The topics the IOLS focuses on include the movement of sand by waves and ocean currents, impacts of global warming, the generation of oxygen, ocean acidification, and the effects of climate change on the ocean.

The items in both the SOLE and IOLS surveys were created from existing surveys to evaluate OL and the IOLS also had contributions from members of the National Marine Educators Association and ocean scientists from several countries. In order to validate the contents of the SOLE survey, it was reviewed by an expert panel which included 1 high school marine science teacher and 4 marine science professors. It was then piloted among a subset of marine science graduate students and a subset of high school students. The IOLS was validated by testing it in a variety of languages and populations. A pilot study was conducted for the IOLS by administering the survey to 417 U.S. 16- to 18-year-old students using the online survey software Qualtrics. The measurement of individuals' ocean literacy, provided by the IOLS, relates to how well the participants scored on the knowledge questions which make up the IOLS.

The environmental knowledge factor included in the study performed by Maurer and Bogner (2020) consisted of system-, action-related, and effectiveness knowledge. System-related knowledge refers to basic knowledge in terms of recognising environmental problems e.g. the problems

caused by humans. An example of a system knowledge question queried the participant's knowledge on how carbon dioxide causes environmental problems. Action-related knowledge refers to the ability to act in a pro-environmental way based on environmental knowledge. An example of an action-related question queries knowledge related to how to save energy most efficiently while cooking. Effectiveness knowledge includes the ability to assess the potential of different behaviours to protect the environment and an example of a question of this type refers to which types of transport are the most environmentally damaging. I performed a review of the existing standardised scales used to measure ocean and environmental literacy. The existing scales were then used to create a table (see appendix 1) of the types of questions used to measure ocean / environmental awareness, knowledge, and attitude. The table was then used during the creation of the questions used in the surveys for this research. As shown in appendix 1, there are a number of different types of questions used to measure OL. The types of questions include multiple choice, agreement scale, yes or no, true or false, and open answer questions.

Agreement scales typically include 3 to 10 points which the respondent can choose from to indicate the extent to which they agree with a statement. Using scales with higher numbers of points allows the respondent to more accurately indicate the level of their response. The type of questions used in the SOLE and IOLS are multiple choice questions where the respondent is required to choose the correct answer from a list of possible answers.

Hawkins et al. (2016) used "Yes or No" and "Open Answer" questions to gather data on respondents' familiarity with environmental policies e.g. marine protected areas. They also used questions which required the respondent to indicate, on an attitude scale, their opinion on the state of the seas around Britain, and their satisfaction with marine conservation zones. The survey pack was mailed to 2000 UK citizens in 2005 and 2015, and to 2500 in 2010. The participants were randomly selected to represent in proportion all social and economic segments of UK society. The advantages of using multiple choice questions over open answer questions are that they

take less time for the respondent to answer and there is less work involved in analysing the answers. The disadvantage of using multiple choice questions is that the respondent can guess an answer from the list provided.

2.8.1 Agreement Scales

Agreement scales are used to measure respondents' attitudes towards the ocean. The Survey of Ocean Stewardship used by Greely (2008) and the New Environmental Paradigm scale (Dunlap, 2008) gathered data related to the attitudes of respondents towards the ocean. Jacobs et al. (2015) used a 7- point Likert scale, ranging from "totally disagree" (1) to "totally agree" (7), to obtain respondents' level of agreement on the different possible causes of contaminants in the marine environment. CLAMER (2011) included questions to check the sources of respondents' information related to the impacts of climate change on coastlines and the sea. It also used questions to gauge respondents' attitude towards environmental issues e.g. environmental impacts of aquaculture, overfishing, pollution at the coast, and changes in the distribution of marine wildlife. Chen and Tsai (2016) asked respondents to indicate their level of agreement with positive and negative statements related to the marine environment. The positive statements focused on the health of the ocean and the negative statements focused on the interaction between humans and the marine environment.

2.8.2 Behaviour Scales

Behaviour scales are a variation on agreement scales, and they require the respondent to indicate the extent to which they perform certain actions. Chen and Tsai (2016) used a 5-point scale to ask respondents to indicate their behaviour related to communication with their friends on marine environmental protection and purchasing environmentally friendly seafood products. CLAMER (2011) asked respondents about actions they take to reduce and cope with climate change. The actions included reducing energy

use at home, buying locally sourced food, and taking part in protests on environmental issues.

2.8.3 Approaches to OL Measurement

An example of research undertaken to measure the levels of OL possessed by students in educational institutions is that performed by Plankis and Marrero (2010). They performed 2 studies that examined the ocean and environmental literacy of 464 K-12 students in 5 states in the United States. The first study used a collective case study to examine the ocean literacy of a classroom of students in New York and a classroom in California. The students under study were engaged in a literacy-focused program to learn about ocean science topics. The students received questionnaires at the beginning and end of the year. The questionnaires asked about the student's experiences with the ocean and how they perceived the ocean affects their lives. The second study used a "Students' Ocean Literacy Viewpoints and Engagement" instrument which contained knowledge and concern questions related to the ocean. The post-test version of the instrument contained open- ended opinion questions to expand upon the students' viewpoints and engagement.

Table 2.2 contains information related to approaches to the measurement and analysis of ocean/environmental literacy. With the help of a marketing agency, Jacobs et al (2015) used a web-based survey to measure the awareness of causes of contaminants in the marine environment and concern about marine environmental contamination in five European countries. The countries were Belgium, Ireland, Italy, Spain, and Portugal. An English master questionnaire was developed and translated into the languages of the countries involved. They used a 7-point agreement interval scale to measure consumers' level of agreement on the different possible causes of contaminants in the marine environment. They also used a 7-pont Likert scale, which ranged from totally disagree to totally agree, to measure the level of concern regarding marine environmental problems.

Measuring	Q/A types	Analysis approach	Resulting information
Jacobs et al (2015): Perceived consumer effectiveness, awareness of causes of contaminants in the marine environment, and concern about the marine environment.	7-point agreement scale; Closed answer.	Confirmatory factor analysis, Multiple group analysis, one-way ANOVA analysis with F-tests, Satorra–Bentler adapted chi-square test, square root transformation.	Summation of agreement scores for awareness, mean score for concern, Cross-cultural differences in concern, awareness, and perceived consumer effectiveness.
Hawkins et al. (2016): Knowledge of UK sea health and management.	3-point scale; Yes or No; Closed answer and Open answer; Yes, no or don't know.	Compare percentages of participants who answered in a certain way over the years, Chi squared tests.	Explore changes in public awareness and attitudes, across 3 surveys, over a 10-year period. Relationships between awareness and other factors examined.
Chen and Tsai (2016): Three main facets of environmental awareness: environmental attitude, knowledge concerning major marine and coastal issues, and environmental behaviour.	5-point Likert scale.	Descriptive statistics, Analysis of variance (ANOVA), partial correlations.	Differences regarding gender, year in college, place of residence, taking marine courses, etc. The association between attitude and knowledge compared with behaviour.
Umuhire and Fang (2016): Three aspects of Ocean Environmental Awareness (OEA): concern, knowledge, and action.	Multiple-choice, True or False.	Factor analysis.	Percentages of respondents answering positively used to quantify level of concern, knowledge, and willingness to participate.

Gelcich et al. (2014): Perceptions, Level of Knowledge, Concern and Priorities regarding marine impacts; trust in different information sources; and priorities for policy and funding.	5-point Likert scale, Open-ended, Likert-type scale responses and free elicitations of word associations.	Bayesian hypothesis tests, Word cloud, Bayesian discrete choice cumulative logit link model for multinomial responses.	Box plots of publics' level of trust in sources of information from the media and other organizations, Word cloud of most important environmental matters, Relationship between the public's perceived level of information and perceived concern regarding ocean impacts, Relationship between the public's perceived awareness and priorities regarding research on climate change impacts at the coastline or sea.
Mogias et al. (2015): Assess the level of ocean literacy possessed by Greek pre-service teachers, ocean stewardship attitudes, beliefs about protecting the ocean.	5-point Likert-type scale, Multiple-choice, Close-ended.	Rasch model for dichotomous items and Principal Component Analysis, linear logit scale.	Relationship between ocean content knowledge and information sources; Ocean Content Knowledge with Background Factors and Ocean Stewardship Attitudes; and Ocean Content Knowledge and Ocean Stewardship Attitudes.
Boubonari et al. (2013): Assess Greek pre-service primary teachers' knowledge, attitudes, and self-reported behaviour towards marine pollution issues.	5-point Likert scale.	Descriptive statistics, exploratory factor analysis, Cronbach's alpha, t-test and one way analysis of variance (ANOVA).	Information on background factors; knowledge; attitudes; behaviour; relationships between background factors and knowledge, attitude, and behaviour factors; and relationships between knowledge, attitudes, and behaviour.

Lewis (2008): Knowledge of general environmental issues from a local, regional, and national perspective.	True or False, Yes or No, Check all that apply, Much-some-very little scale, and open- ended.	Descriptive statistics and means and frequency procedures.	Respondents' awareness of what agencies exist in Fargo-Moorhead, Level of knowledge of local and national water quality issues, understanding of land conservation techniques, and action and attitude of personal conservation of resources.
McBride (2011): Written responses of ecologists and other environmental scientists, on the nature of ecological literacy and the pathways to achieve it.	Open-ended questions.	Data coding, Binomial coding schema, Factor analysis, Principal component analysis, Scree plots, Factor rotation, Factor scores, Cluster analysis, and Pearson's Chi-square.	Conceptual categories of ecological literacy and categories of respondents' recommendations for pathways toward ecological literacy.
Hollweg et al. (2011): Review of instrumentation studies that pertain to measures of one or a small number of environmental literacy components: environmental knowledge, dispositions, competencies, and behaviour.	Constructed response items and Selected response items.	Organisation for Economic Co-operation and Development's modelling technique was used to scale the data.	The relative difficulty of the task was estimated by considering the proportion of students getting each question correct and the relative proficiency of the students was estimated by considering the proportion of test items they answered correctly.

Jin (2010): Measure K-12 students' understanding of energy as it relates to socio-ecological events that contribute to global climate change.	Interview questions following the answers provided by the interviewee. Low-level, transition-level and high-level questions. Assessment item pairs for different stages of education.	Interviews divided into "account units", student responses grouped based on "account units", and then groups examined closely to identify effective progress variables and informal entities students used to construct explanations. Coding rubrics were created and used to code all the written assessment data.	Learning progression-based framework that described the ways students' reason in their explanations of socio- ecological events. A set of distribution graphs to show the distribution of students' account units at each achievement level.

Table 2.2: Approaches to the measurement and analysis of information related to the ocean/environment

Hawkins et al. (2016) used a survey containing multiple choice questions and 3-point scale questions to assess public knowledge and attitude in the UK regarding marine protection in the UK. The survey consisted of up to 17 questions and was mailed to UK citizens in 2005, 2010, and 2015. An example of one of the multiple-choice questions contained in the survey was "Are you familiar with the concept of declaring parts of the sea as marine protected areas? And the respondent was provided with the option 'yes' or 'no' to answer the question. An example of one of the open answer questions contained in the survey was "What percentage of the total area of UK coastal waters would you estimate is currently declared as marine protected areas?".

The survey used by Umuhire and Fang (2016) measured students ocean environmental concerns, ocean environment knowledge and willingness to participate in ocean related activities. Their survey consisted of four sections with the first section consisted of questions related to the respondent's background and demographics including questions on gender, age, grade, college, and home country. The second section contained questions on the respondent's knowledge and concern in relations to the ocean, including use of coastal areas and ability to identify threats to the ocean environment. The

third section was related to willingness to participate, and the fourth section was related to the respondents' source of information related to the ocean.

In general, questionnaires containing multiple choice questions are used to measure respondents' knowledge about the ocean. Agreement scales are used to measure respondents' attitudes towards the ocean and issues that impact the ocean, and behaviour scales are used to measure the extent to which respondents behave in a pro-ocean-environmental way.

2.8.4 Creating Surveys and Questionnaires

The different approaches used to create questionnaires and surveys related to the ocean and the environment include input from community-wide participation (Fauville et al., 2018), basing the survey content on the essential principles of ocean literacy (Greely, 2008), a review of previous studies (CLAMER, 2011), and an update/modification to a previous survey (Freeman et al., 2012). The approach taken to develop the International Ocean Literacy Survey (IOLS) (Fauville et al., 2018) involved researchers contributing existing whole surveys or individual multiple-choice items which were compiled, reviewed, culled for redundancy and edited. New items were generated by the authors of the IOLS, members of the National Marine Education Association, and volunteer ocean scientists from several countries. The content of the survey of ocean literacy and engagement, developed by (Greely, 2008), was based on the essential principles and fundamental concepts of ocean literacy (OLF, 2015), and an existing survey developed for an oceanography camp for girls. The design of the questionnaire, developed by CLAMER (2011) was a collaborative effort between a polling organisation and all members of the Climate Change and European Marine Ecosystem Research (CLAMER) "public perception" working group. The initial design of the questionnaire was informed by a literature review of public perception studies on climate change and marine environments. Freeman et al. (2012) based the design of their survey on an existing survey and modified it to make it suitable for use in Israel and Germany. The survey was also modified to

facilitate comparisons between the two populations. The modifications were related to the differences in cultural, geographic, and political contexts between Germany and Israel e.g. hesitancy on the part of German participants while answering questions on employment and income.

2.8.5 Validating Instruments

The existing approaches used to validate instruments which perform measurements related to the ocean and the environment include Pilot studies, Inviting feedback from translators, Rasch analysis, Confirmatory Factor Analysis (CFA), Expert review, Pre- and post-tests, Content Validity, Face Validation, Construct Validity, External Validity, and Predictive Validation (Rahi, 2015). Fauville et al. (2018) performed initial tests on their IOLS for the purpose of validating the instrument in a variety of languages and populations. They performed a pilot study where their survey was administered to 417 16- to 18-year-old students. The pilot study helped to identify items that were outside the range of appropriate difficulty or appeared to have responses driven by something other than OL. Based on the results, they made changes to the survey to create a more cohesive instrument that better aligned with the concepts of OL. During the process of converting the survey into 16 languages, translators were invited to provide feedback on the items which served as a systematic review of the items. The type of feedback which was sought from translators related to the ocean science content, clarity of the wording, and potential complexities introduced by the translation process. The data analysis they performed on the survey responses included Rasch analysis, Confirmatory Factor Analysis (CFA), distractor analysis, and differential item functioning. At the time of publishing, content experts were revisiting the items to check their clarity, content alignment, and explore ways to modify the items to perform better across participating countries and languages.

2.8.6 Targeting Groups

The target group for the IOLS was 16- to 18-year-old students. The reason this age category was chosen was because the IOLS is based on the Ocean Literacy Principles which are aimed at what students should know by the end of high school. The specific age range allowed the researchers to "capture a comparable sample of youth near the end of their compulsory education across variations in science course taken both within and across countries" (Fauville et al., 2018). The target group for the study performed by Greely (2008) was 13- and 14-year-old females who were taking part in an oceanography camp for girls. The target group was a convenience sample because the researchers had access to the oceanography camp for girls. Chen and Tsai (2016) targeted university students because they are regarded as future decision makers and have a high likelihood of becoming opinion-shapers in relation to the environment. A two-stage sampling method was used to first select 20 universities in Taiwan and then decide on a sample size for the universities. The target group for the study performed by Wen and Lu (2013) was children in senior grades of primary school because they are at the stage where they are developing value systems, and they are beginning to accumulate and construct knowledge systems. Wong (2003) stratified his target population of university students according to their gender, level of study (doctoral, master, and undergraduate) and disciplines e.g. Arts, Science, and Engineering etc. The target group used in the research performed by Mogias et al. (2015) were Greek pre-service teachers.

2.9 Measurement on Specific Topics

Existing research on the measurement of the relationship between humans and the ocean/environment primarily uses surveys with questions and statements related to a number of specific environmental topics. Díaz-Siefer et al. (2015) compared the effects of human-environment system knowledge and environmental action knowledge on pro-environmental behaviour. The

knowledge questions, contained in their survey, related to a number of topics including the greenhouse effect, nitrate pollution, fossil fuels, renewable energy, water usage, and energy conservation. Michalos et al. (2017) measured tenth grade students' knowledge, attitude, and behaviour concerning sustainable development. Their survey included agreement scale statements related to approaches that are necessary for sustainable development, human-action, resource usage, and the reduction of poverty. CLAMER (2011) provides a report on what the European public knows and cares about, in relation to marine climate change risks and impacts. Their survey included questions related to the causes and impacts of climate change, respondents' opinion on the most serious problem facing the world, and how informed respondents' feel regarding issues such as ocean current changes, overfishing, effects of marine invasive species, and coastal erosion. Freeman et al. (2012) reports on relationships between public attitudes, behaviours, and preferences related to marine aquaculture. Their survey contained questions regarding employment, environment protection, health and lifestyle, tourism, and aquaculture.

2.9.1 Problems Measuring OL

The types of problems encountered when attempting to perform measurement of the human-ocean relationship, with respect to specific topics, include: (i) establishing what knowledge people are required to have to promote pro-ocean-environmental behaviour, (ii) what different knowledge is required for different actors, (iii) and what and how many questions should be used to measure that knowledge. Because the surveys, in this research, are being created on narrow topics, it is important to ensure that the questions are not too difficult for all of the respondents to answer.

2.10 Measuring the Effectiveness of OL Tools and Initiatives

Sattler and Bogner (2017) used a pre- and post-retention test approach to measure the effectiveness of an instruction zoo field trip focusing on marine ecology and conservation. Figure 2.4 shows their study design. They used a convenience sample consisting of 117 students aged 15-17 years. A paper-and-pencil questionnaire was administered to the students one week before the zoo visit, immediately after taking part in the two educational modules at the zoo, and six weeks after the zoo visit. The instructional content of the modules included species' habitats and relationships, the ecosystem's structure and characteristics, and threats to the ecosystem. The Statistical Package for Social Sciences was used to perform the statistical analysis. They calculated the knowledge scores for the questionnaires and applied an Analysis of Variance (ANOVA) test to compare the knowledge scores from all three tests. ANOVA is a collection of statistical models and their associated estimation procedures used to analyse the differences among and between groups of data e.g. how much a value differs from the mean of all the values in the data group. Sattler and Bogner (2017) also applied a Wilcoxon signed-rank test to compare the pre and post scores, and a Spearman's rho correlation test to calculate any potential correlation between the knowledge levels at the three test stages. A Wilcoxon test is used to compare two paired groups of data by calculating the differences between the pairs and establishing if they are statistically different. A Spearman's rho correlation test is used to perform correlation analysis on data from an ordinal scale which is a scale where a user chooses a rating from the scale e.g. their level of concern from not concerned to extremely concerned. The results of the research, performed by Sattler and Bogner (2017), showed that the students experienced a short-term knowledge gain after participating in the zoo visit.

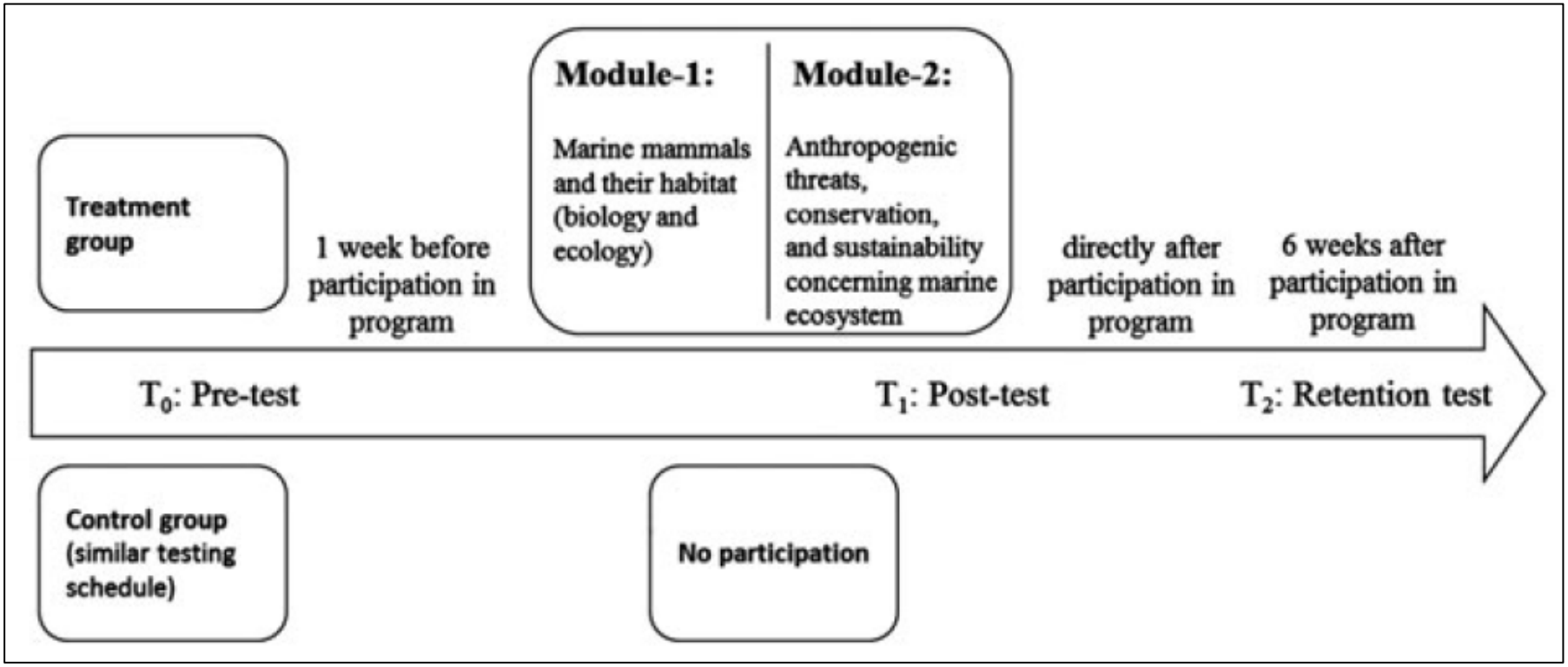

Figure 2.4: Study design (Sattler and Bogner, 2017)

In order to measure the effectiveness of a three-lesson science-based environmental education module on the use of fossil fuels and alternative energy sources, Schumm and Bogner (2016a) administered a knowledge questionnaire at three stages related to involvement in the module. The questionnaire was administered to the students one week before the module, directly after participation in the module, and six weeks later. The Two Major Environmental Values (2-MEV) scale and the General Ecological Behaviour (GEB) scale were also administered to the participants. Pearson correlation analysis was used to examine the relationships between the 2-MEV scale, the GEB scale and the results of the knowledge questions. The results of the principal component factor analysis confirmed the two-factor structure of the 2-MEV scale. The results of the post-tests showed that a correlation existed for attitude and knowledge, and behaviour and knowledge.

Scott and Sulsberger (2019) used pre- and post-surveys to measure the contribution of ocean-themed activities and empathy exercises to pre-service teachers' perceived confidence and preparedness as future classroom-based, environmental educators. The pre- and post-surveys contained Likert scale questions related to confidence, knowledge, and willingness to be environmental educators. The surveys also included a question on how informal science institutions can support teachers' science teaching and learning. The post-survey included questions on which parts of the workshop were most useful and inspiring. T-tests and Wilcoxon signed ranked tests were used to compare the mean scores before and after the workshop. A t-test is a statistical test that is used to compare the means of two groups. Their results show that statistically significant differences existed in the pre-test and post-test scores for all measures except willingness. The results also showed an increase in confidence in integrating ocean/environmental science into teaching and fostering a conservation ethic in students.

2.11 Existing Data Analysis Approaches

The data generated by responses to questionnaires and surveys needs to be analysed to generate useful information. Data analysis can be performed to generate information related to the respondents and the questions used in the questionnaires and surveys. The types of data analysis which can be used to generate information on both respondents and questions are descriptive analysis, correlation analysis, Rasch analysis and partial t-tests. The types of data analysis which relate solely to the questions include reliability analysis, confirmatory factor analysis, and distractor analysis. The collection of respondent information helps to identify groups in the respondents to surveys. Examples of groups which can be identified are those based on respondent location, level of income, gender, and level of education.

2.11.1 Descriptive Analysis

Descriptive analysis describes the data e.g. the percentage of questions a respondent got correct, the mean percentage of correct answers and their standard deviation. Hawkins et al. (2016) used descriptive statistics to measure the change in the proportion of people who considered the UK marine environment to be in good health in surveys taken in 2005, 2010 and 2015. They used histograms to graphically display the changes over time.

2.11.2 Rasch Analysis

Rasch analysis allows researchers to use the responses to surveys to position the respondents and questions on a linear scale which indicates the performance of each of the respondents and the difficulty of the survey questions (see section 3.6 Rasch Analysis). The scores calculated by Díaz-Siefer et al. (2015) were an indication of how much a person knows about the environment and how much they do in relation to the environment. They

expressed the difficulties of each questionnaire item in logits, the basic units of Rasch scales. Fauville et al. (2018) transformed the responses to each of their items into scored data, assigning incorrect responses a score of 0 and correct responses a score of 1. The data was then analysed using the Rasch model to examine the measurement quality of their OL scale. Based on the assumption of the Rasch model, they checked that the items measured an underlying unidimensional trait, ocean literacy. As part of their Rasch analysis they examined the Item Characteristic Curve (ICC), the item characteristics which included the item difficulty, and fit assessments at both model and item levels.

In research to measure the effectiveness of two learning approaches aimed at acquiring environmental knowledge, Schönfelder and Bogner (2017) used Rasch analysis to analyse the quality of the knowledge items used in their scale. They used the scale in a pre- and post-test to measure the level of the participant's retention. One of the learning approaches consisted of encountering animals at a beehive and the other consisted of observing bees using digital tools.

2.11.3 Reliability Analysis

Reliability analysis is used to check how well a set of questions measure what they are intended to measure (see section 3.8 Reliability Analysis). Michalos et al. (2017) used the Cronbach's alpha approach to measure the internal correlations among the sentences in their survey which measured knowledge, attitude, and behaviour in relation to sustainable development. Boubonari et al. (2013) performed research to measure the knowledge, attitudes, and self-reported behaviour of Greek pre-service primary teachers towards marine pollution issues. As part of their data analysis approach, they used Cronbach's alpha to assess the reliability of the knowledge, attitude, and behaviour scales.

In research to measure the effectiveness of a three-lesson module on the topic of renewable energies, Schumm and Bogner (2016b) used Cronbach's alpha

to test the reliability of a knowledge scale which was administered three times over the course of their research. The participants completed the knowledge scale one week before their participation in the lessons, immediately after their participation, and six weeks after their participation in the lessons.

Fauville et al. (2018) did not use Cronbach's alpha to determine reliability because their underlying data was not in the form of continuous variables. To account for the non-continuous nature of their data they used the polychoric matrix to perform the reliability analysis. Polychoric correlation can be used to measure the internal reliability of a group of items measuring a dimension when the variables are dichotomous (categorical variables that can only have two values 1 and 0 i.e. binary variables).

2.11.4 Distractor Analysis

Distractor analysis is used to measure the usefulness of the answer options provided to the respondent when they are answering multiple choice questions. It involves calculating the number of times an item's distractor options are chosen by the respondent with the expectation that the number of times each option is chosen should be similar (Rust, 1999). According to Fauville et al. (2018), desirable item options should not be chosen more often than the correct answer and they should attract unsure respondents to choose them. Fauville et al. (2018) flagged distractors that were chosen less than 5% of the time for follow up discussion and potential revision. Answer options which are not chosen, or are chosen less than 5% of the time, are not useful in distracting respondents who are unsure about the correct answer to the multiple-choice question.

2.11.5 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a statistical procedure used to test how well the measured variables (survey questions) represent the number of constructs e.g. attitude towards micro-plastics in the ocean (see section 3.9 Confirmatory Factor Analysis). In research related to modelling environmental literacy, Maurer and Bogner (2020) used CFA to examine factor structures of knowledge, values, and behaviour in relation to the environment. They were interested in how connected the factors were and their causal relationship with different sub-scales.

Both Fauville et al. (2018) and Jacobs et al. (2015) used CFA as part of their data analysis procedure. Fauville et al. (2018) used CFA to test their assumption that their measurement was unidimensional and Jacobs et al. (2015) performed a CFA on a pooled sample to check if Concern, Perceived Consumer Effectiveness (PCE) general, and PCE through seafood choice could be considered latent variables with two statements related to selection of seafood products for consumption and the refusal to eat seafood products that harm the marine environment. They performed a multiple group CFA for the construct "Concern" using the variable "Country" as the grouping variable. Multiple group analysis is a way of estimating a Structural Equation Model in several groups at the same time and to examine the degree to which the models are equivalent across groups (Blunch, 2008).

Structural Equation Modelling (SEM) consists of a number of methods used by researchers in both experimental and observational research to represent, estimate, and test the network of relationships between variables. One of the techniques used in SEM is factor analysis. In research to investigate the linkages between science motivation and environmental perception, Schönfelder and Bogner (2020) analysed data from 429 Irish secondary school students. They used CFA to reconfirm existing scales and investigated potential relations using SEM. CFA was used to assess the construct validity of the applied instruments and SEM was used to investigate the relationship between science motivation and environmental attitudes, with their first step testing the predictive ability of science motivation on environmental values.

2.11.6 Correlation Analysis

Correlation analysis is used to check for a relationship between two variables. Yoon Fah and Sirisena (2014) used Pearson's product momentum correlation (see section 3.7 Correlation Analysis) to identify possible significant linear relationships among knowledge, attitudes, and behaviour related to environmental literacy. They also used stepwise multiple regression analysis to investigate the contribution of environmental knowledge and attitudes to environmental behaviour. Regression analysis is used to evaluate the relationship of one or more independent variables (X1, X2… Xk) to a single, continuous dependent variable Y (Kleinbaum, 1998). The sample correlation coefficient r can be calculated using a formula, the resulting value of r is in the range from -1 to 1, and its value gives an indication of the association between the two variables. Díaz-Siefer et al. (2015) validated their scale by performing simple regressions between environmental knowledge and (1) Educational level, (2) Income, and (3) Pro-environmental behaviour. They calculated each person's score for environmental knowledge and pro-environmental behaviour using the Maximum Likelihood Estimated (MLE) model. The maximum likelihood method is a way of obtaining estimators of population parameters (Kleinbaum, 1998). The MLE method determines the values for parameters in a model. The parameter values are calculated such that they maximise the likelihood that the process described by the model produced the data that was actually observed.

Díaz-Siefer et al. (2015) calculated Pearson correlation coefficients and used them to demonstrate a positive correlation between: overall environmental knowledge and educational level; income and environmental knowledge; and environmental knowledge and pro-environmental behaviour. They piloted an effectiveness knowledge questionnaire, but due to poor reliability results and the difficulty of the questions they decided to exclude the questionnaire and focus on human-environment system knowledge and environmental action knowledge. The research performed by Yoon Fah and Sirisena (2014) found that there was a low to moderate, positive correlation between the 3 dimensions of environmental knowledge, attitudes, and behaviour.

Both Kyriazi and Mavrikaki (2013) and Michalos et al. (2017) used the 3 dimensions of Knowledge, Affect/Attitude and Behaviour to take measurements related to environmental literacy and sustainable development, respectively. Kyriazi and Mavrikaki (2013) created an instrument to evaluate the environmental literacy of post-secondary Greek students and the Affect dimension included questions related to concern about environmental problems, attitude towards regulation, eagerness to learn, and willingness to act. They found a significant correlation between the Affect and Behaviour dimensions. Michalos et al. (2017) measurement approach focused on tenth grade students in Manitoba and their findings indicate that a correlation was beginning to be seen between knowledge related to sustainability and choices favourable to sustainability.

2.11.7 Paired T-tests

A paired t-test is used to compare the means of two samples of related data from a pre- and post-test. It provides a measure of the significance of the difference between the two data groups (see section 3.10 Paired T-test Analysis). In research to examine the contribution of higher education institutions to their student's environmental literacy, Arnon et al. (2015) measured the environmental knowledge possessed by students at an Israeli college which consisted of two faculties: a faculty of science and technology and a faculty of humanities and social sciences. They used t-tests to measure the difference between the environmental knowledge possessed by the students in the two faculties. They found a significant difference between the two faculties in the areas of green self-identity, objective knowledge, and subjective knowledge. Green self-identity refers to the perceived identification of an individual with the typical green consumer. Objective knowledge is what the individual knows about a topic and subjective knowledge is how much the individual thinks they know about a topic.

In a study to examine the potential impacts of an environmental education workshop on a group of pre-service schoolteachers, Scott and Sulsberger (2019) used t-tests to compare the mean scores before and after the teachers' participation in the workshop. They found statistically significant differences for the majority of their measures including confidence in integrating ocean/environmental science into their teaching and knowledge of problems facing the ocean and marine life, but no significant difference existed for the teachers' willingness to teach about the ocean/nature.

Manoli et al. (2019) used the Two Major Environmental Values (2-MEV) model and the New Ecological Paradigm scale as an instrument to measure the change in students' attitude and values after their participation in a program called Earthkeepers. The Earthkeepers program consisted of a three-day experience at an environmental centre and activities at the students' school and at home. Students completed the instrument two weeks before visiting the centre and one month after their visit. The instrument was divided into four quadrants based on the combination of high and low scores related to the two sections of the 2-MEV model. T-tests were used to analyse the relationships between the quadrants and a statistically significant difference was found for two of the quadrants while no difference was found for the remaining two quadrants.

2.12 Chapter Summary

This chapter has provided a literature review of the areas relevant to the measurement of the effectiveness of ocean literacy tools and initiatives. The main areas covered are ocean literacy including environmental literacy models and ocean literacy dimensions, the DPSIR framework, system thinking, causal mapping in the learning environment, the ocean literacy framework, the measurement of OL, and relevant data analysis procedures. The data analysis procedures included in the literature review are procedures which are used on the results of pre- and post-surveys to measure the effectiveness of OL tools and initiatives.

Chapter 3

Research Methodology

3.1 Introduction

In this chapter, I discuss the methods and tools used to perform this research. The chapter begins with a discussion of research methods and the research process. This is followed by descriptions of the literature review process and data gathering which are related to research objectives (i) and (iii). Research objective (i) is to investigate environmental and ocean literacy dimensions and research objective (iii) is to find what approaches are taken to measure environmental and ocean literacy dimensions, and the data analysis procedures that can be used to generate useful information from responses to questionnaires and surveys. Then there is a section on the causal mapping and knowledge capture tool which is related to research objective (ii) and (iv). Research objective (ii) is to create a framework and an online causal mapping tool which can be used to identify knowledge and assist with the creation of topic specific surveys. Research objective (iv) is to use the online causal mapping tool to create DAPSIWR causal models of specific OL topics. This is followed by descriptions of the data analysis procedures used in this research. The data analysis procedures are Rasch analysis, correlation analysis, reliability analysis, confirmatory factor analysis, and paired t-test analysis. The data analysis sections are related to research objectives (v) and (vi). Research objective (v) is to use the models to create and administer surveys for use as pre- and post-surveys for OL tools and initiatives. Research objective (vi) is to use the survey response data to explore the difficulties involved in measuring the effectiveness of ocean literacy tools and interventions, especially where they relate to quite narrow and specific topics such as micro-plastics and coastal tourism. Also, use the survey response data to identify weaknesses in the questions with respect to the survey goals

3.2 Research Methods

The first step when deciding on the research topic is to search and review the published and unpublished 'grey' literature (Bowling, 2014). The literature review involves the researcher reading what other people have written about the area of interest (McNeill et al., 2005). It consists of a systematic search through library catalogues and online journals. The purposes of performing a literature review include to get ideas about research design, key issues and methods of data collection; identify problems in the research proposal and ensure the researcher does not repeat other researchers' mistakes; and it is part of the process of increasing human knowledge. Searching the literature is facilitated by the use of electronic databases (Bowling, 2014). Examples of electronic databases are Scopus, IEEE Xplore, and Web of science.

The research hypothesis is an informed decision on what the researcher thinks may be happening, and it is based on previous reading, research, and observation (McNeill et al., 2005). The hypothesis will be broken down and turned into questions which collect evidence that may support or challenge the hypothesis. The creation of research questions, based on the research hypothesis, is a way of developing a common understanding of the research agenda and is desirable in that it gives a clearer understanding of the type of information required to perform the research (Bickman and Rog, 2009).

According to Bowling (2014), when choosing a research method, the question to be addressed should not be quantitative versus qualitative methodology, but how to identify innovative strategies to combine different perspectives and quantitative and qualitative methodologies in a single study. Both methods can complement each other and are valid if applied to appropriate research questions. Qualitative techniques are appropriate for exploring new topics and obtaining insightful and rich data on complex issues while quantitative techniques are appropriate if the issue is known about, relatively unambiguous, and amenable to valid and reliable measurement.

The concept of research rigour is relevant to the reliability and validity of the research data (Bowling, 2014). The essential features of research rigour

include a systematic approach to designing the research; awareness of the importance of interpretation and not perception or assumption; and the thorough collection, analysis, and interpretation of data.

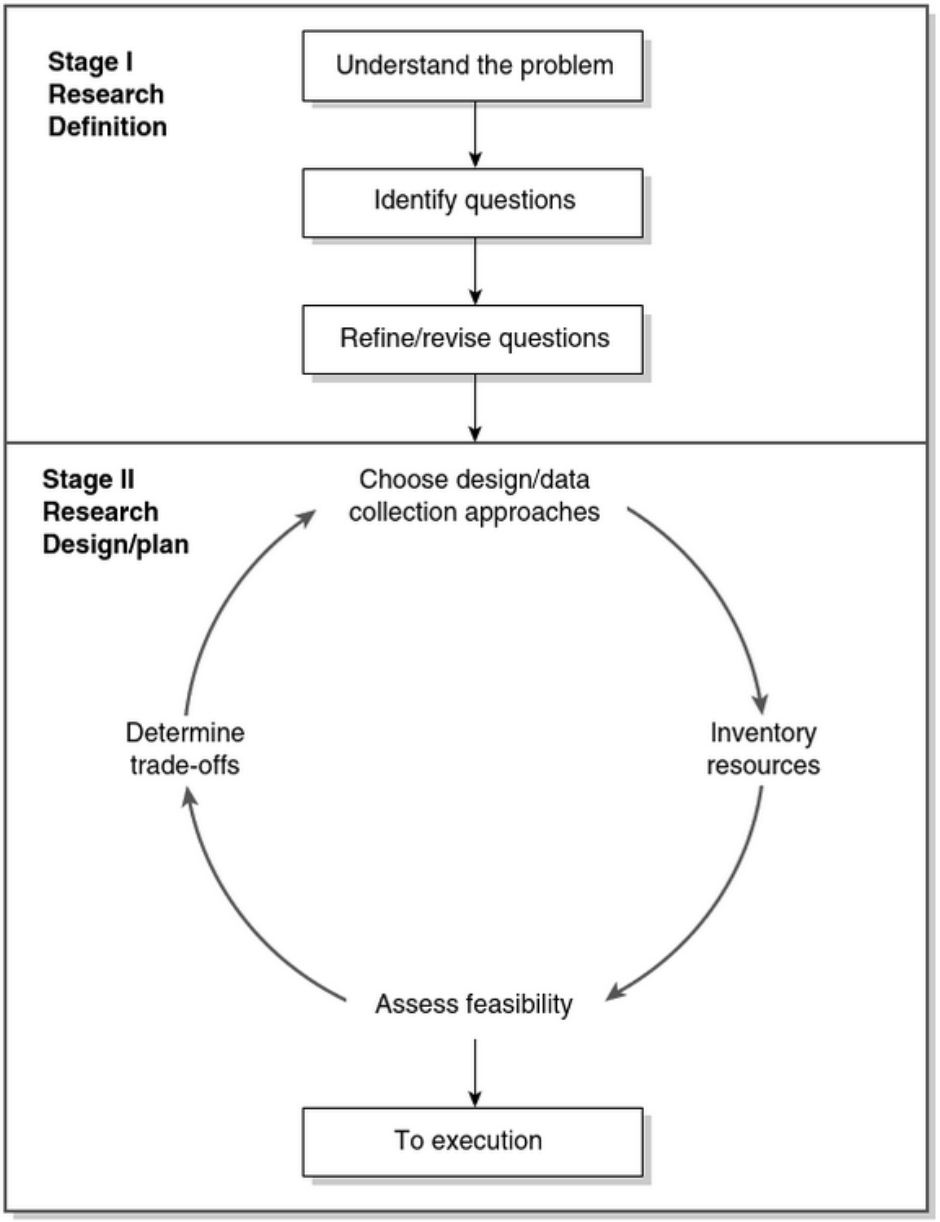

Figure 3.1: The research planning phase (Bickman and Rog, 2009)

The first phase of applied research is the planning phase, and it consists of the research definition stage and the research design/plan stage (Bickman and Rog, 2009). Figure 3.1 has an illustration of the research planning phase. The research definition stage involves working with stakeholders to refine and

revise study questions. It is important to ensure that the questions can provide useful information and that they can be addressed with the research project's timeframe, resources, and context. The activities related to the research design/plan stage are performed simultaneously until the research plan is developed (Bickman and Rog, 2009). At this stage the researcher may find it necessary to revisit decisions made at the research definition stage. The researcher should review and correct any discrepancies in the research planning phase before moving on to the research implementation phase.

3.3 Research Process

Figure 3.2 provides a diagram of the research methodology process for this research and shows how each part of the research methodology is linked to the research objectives. The literature review process involved the use of the research databases Scopus, IEEE Xplore, and Web of Science. The data gathering part of this research was performed using Google Forms and Amazon Mechanical Turk (MTurk, 2019). The data analysis was performed using the Winsteps Rasch analysis tool, the Statistical Package for Social Sciences and Microsoft Excel.

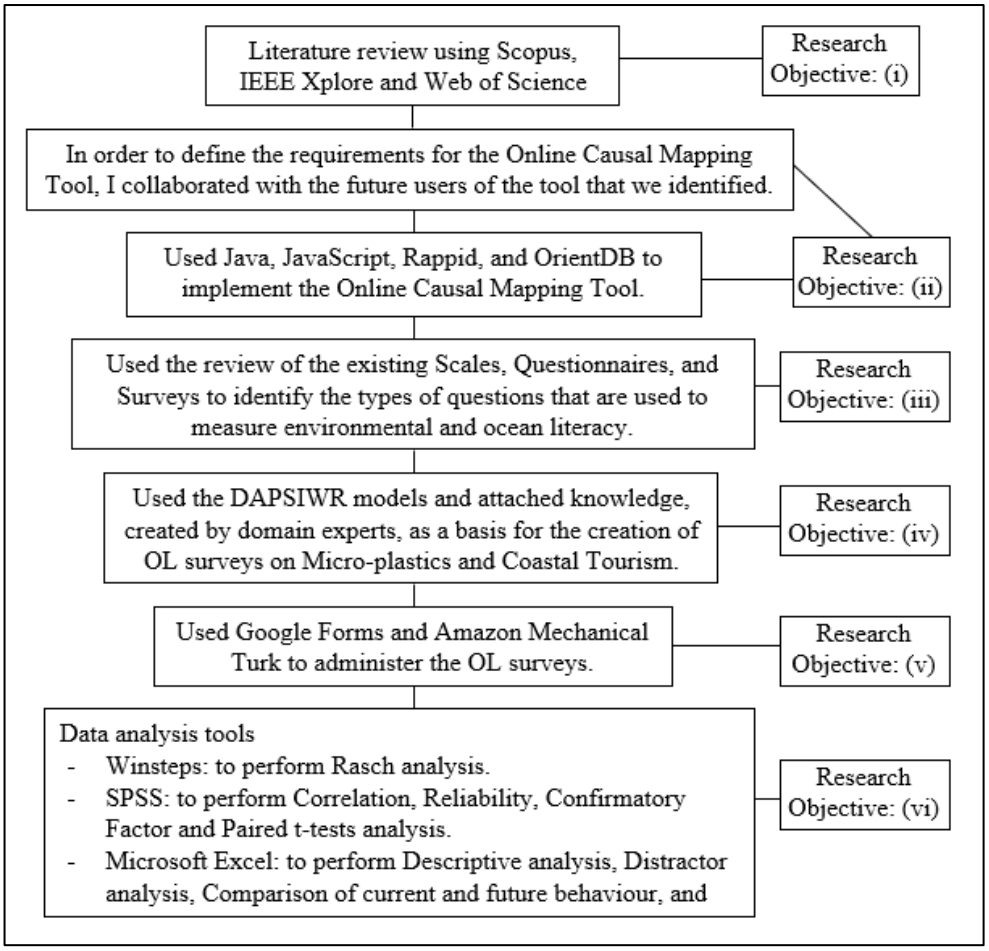

Figure 3.2: Research Methodology Process

3.4 Literature Review

Scopus is an abstract and citation database containing peer reviewed literature including scientific journals, books, and conference proceedings (Scopus, 2021). To perform a search the user can use a combination of keywords to search the information in the literature. Figure 3.3 shows a combination of search strings used in this research to find literature related to the use of surveys to perform measurement related to the ocean or the environment. The search being performed in figure 3.3 is searching for article titles which contain the text string “Environment*” or “Ocean” and the text string “Measurement”. The search also includes the text string “Survey” which is being searched for in the article title, abstract, and keywords. A wildcard (*)

is used with the text string “Environment*” to include any text string containing those characters e.g. Environmental. The search shown in figure 3.3 revealed 457 results which were then sorted to display the most recent first, and the titles and abstracts were reviewed to identify research relevant to the use of surveys related to the ocean and environment.

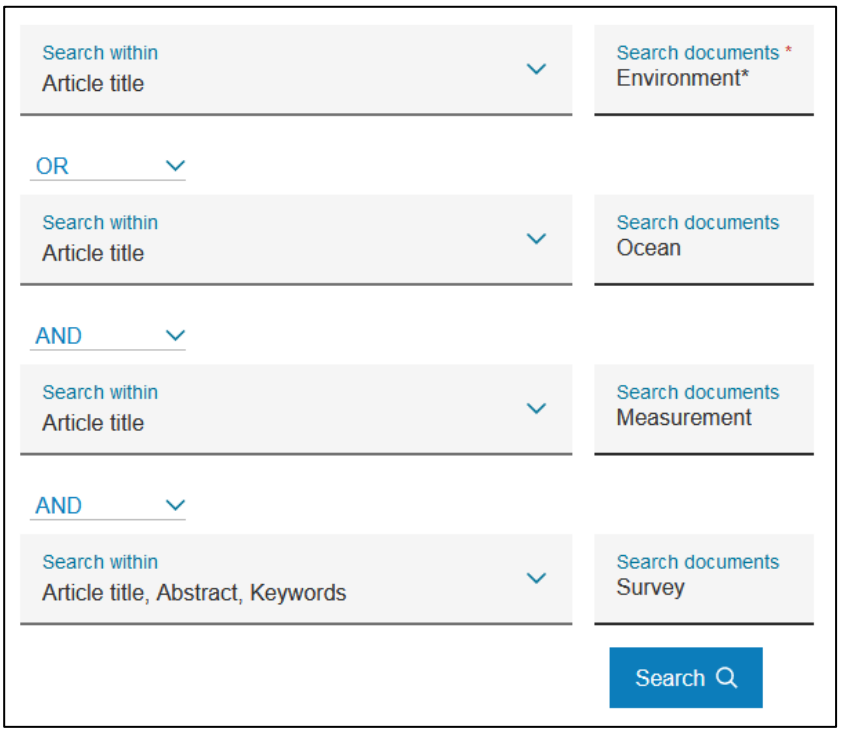

Figure 3.3: Scopus search string

IEEE Xplore (IEEE Xplore, 2021) and Web of Science (Web of Knowledge, 2021) also provide the user with features to use text strings to search the literature e.g. journals, conferences, standards, eBooks, and educational conferences. IEEE Xplore is linked with the Institute of Electrical and Electronic Engineers which is the largest technical professional organisation for the advancement of technology. Web of Science provides access to multiple databases that provide citation data for different academic disciplines.

3.5 Data Gathering

Google Forms provides the features to create, edit, format, and administer online surveys (Google Forms, 2018). Figure 3.4 shows part of the Google Form's survey creation area. The survey question which has been created is "What size are micro-plastics?" and the user is provided with three answer options. The survey creator can choose to create various types of questions including short text answer, multiple choice, checkboxes, and linear scale. Descriptions, images, and videos can also be added to the questions. When the survey is created, the survey respondent is sent a link to the online survey. When the respondent has completed the survey, the survey creator receives their response in the survey creation area.

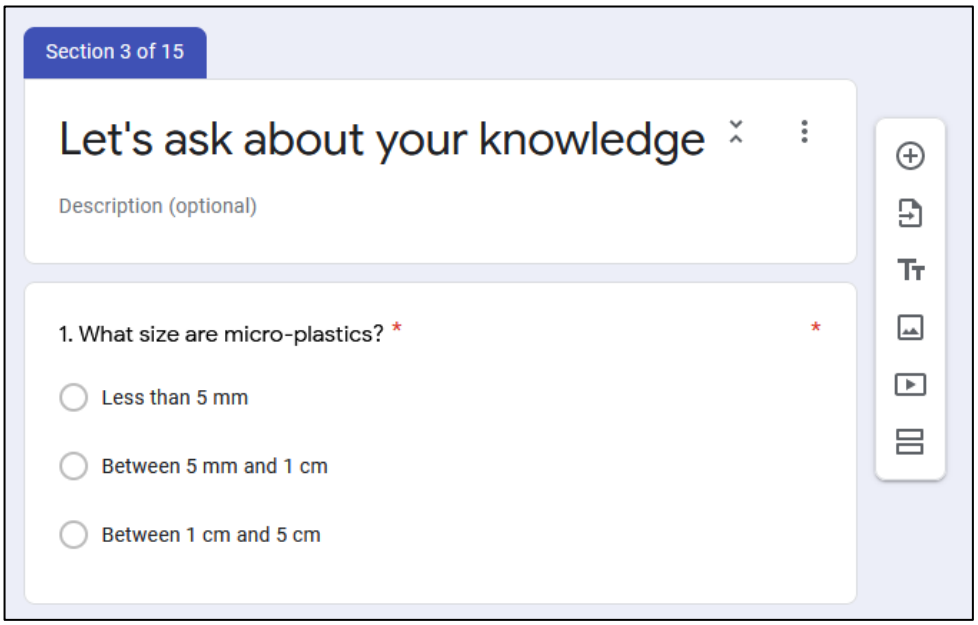

Figure 3.4: Google Form's survey creation area

3.6 The Online Causal Mapping Tool

The causal mapping tool I created was used to create DAPSIWR models of specific ocean literacy topics e.g. micro-plastics and coastal tourism. The domain experts creating the models attached knowledge to the elements of the DAPSIWR models which I used to develop pre- and post-surveys for measuring the effectiveness of OL tools. I also used the knowledge to create a micro-plastics OL tool which I administered to respondents. The micro-plastics survey which I developed was used as a pre- and post-survey to measure the effectiveness of the micro-plastics OL tool.

3.7 Rasch Analysis

The Rasch model is based on the idea that useful measurement involves examination of only one human attribute at a time and it provides a mathematical framework against which test developers can compare their data (Bond and Fox, 2007). It provides a framework where survey responses can be compared to give an indication of the extent to which each question is measuring the trait which the survey was designed to measure.

The measurement takes the form of a hierarchical “more than/less than” line of inquiry. Rasch analysis is an approach used to calculate a person’s knowledge (called here “person ability”), item difficulties, error values, and fit values from responses to a set of questions. Person ability is a measurement related to how well a person performed when answering the questions in a questionnaire. Item difficulty is a measurement related to how many times a question (item) was answered correctly by the questionnaire respondents. The error value is an indication of the accuracy of the Rasch measure for a person ability or item difficulty and the error values are related to how many items or persons are positioned in the same area on the Rasch logit scale. The fit value for items is an indication of the extent to which a question appears to be measuring the unidimensional topic and the fit for a person can give an

indication of unusual sequences of responses e.g. a person guessing the answers to questions. One of the types of fit reported by Rasch analysis is "Outfit", which can indicate if a person's responses are unexpected with respect to that person's ability (Fauville et al., 2018). The level of error and fit associated with each question can be used to identify questions which can be improved.

Logit values are person ability and item difficulty estimates which have been subjected to a log transformation and can be displayed along a logit (log odds unit) scale. Person abilities are calculated by performing a log odds (logit) transformation on the percentage of questions a respondent has answered correctly (Bond and Fox, 2007). For example, to calculate the logit value for a percentage correct score of 64% for a question, we calculate the odds of 64 to 36 by dividing 64/36, and then get the natural log of the result, which is +0.58 logits. This means that the Rasch estimate for the question is 0.58 logits. The item difficulties are calculated similarly and are based on the percentage of times a question is answered correctly.

The Rasch person-item map provides a visual representation of the positioning of person abilities and item difficulties in relation to each other along a vertical logit scale (Bond and Fox, 2007). Rasch analysis positions the questions on the vertical logit scale which indicates which questions are the least difficult, which questions are the most difficult, and it also provides insights into where gaps may exist in the questions scale. The zero-logit point on the logit scale is the mean point of the item difficulty estimates (Bond and Fox, 2007).

The Rasch Item Characteristic Curve (ICC) is a plot of the probability that a test item is answered correctly against the examinee's underlying ability on the trait being measured. Figure 3.5 shows an example of an ICC where the smooth curve is the Rasch expected item performance and the jagged line is the actual performance of the respondents on the item. Each item in a test has its own ICC. The extent to which the examinees plotted on the ICC fit the expected line gives an indication of how well the item is performing.

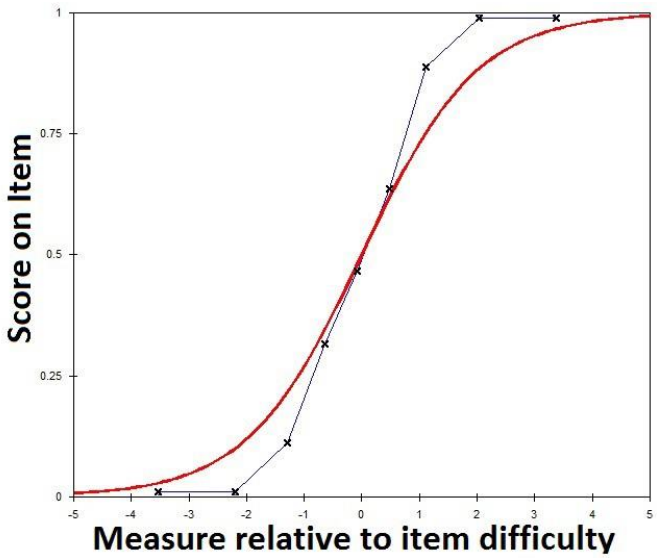

Figure 3.5: Rasch item characteristic curve example

3.8 Correlation Analysis

The strength of the relationship between two variables can be measured using correlation coefficients. The most popular coefficient is Pearson's correlation coefficient, also known as Pearson's R (Pearson's R, 2021). The formula used to calculate Pearson's correlation coefficient calculates a value for r which is a value between -1 and 1. An r value of 1 indicates a strong positive relationship i.e. for every positive increase in one variable, there is a positive increase of a fixed proportion in the other. An r value of -1 indicates a strong negative correlation i.e. for every positive increase in one variable there is a negative decrease of a fixed proportion in the other. A value of 0 for r indicates that no relationship exists between the variables i.e. the variables are not related. Figure 3.6 shows example scatter plots for a positive correlation, negative correlation, and no correlation.

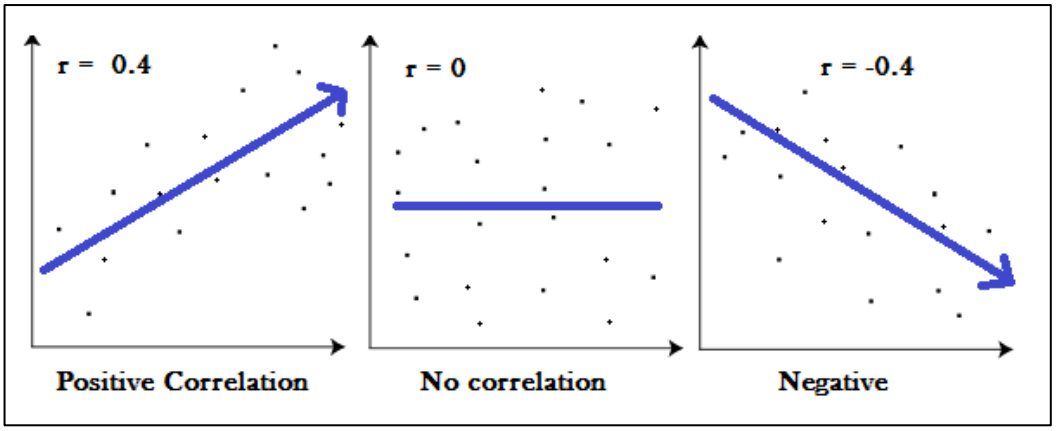

Figure 3.6: Scatter plots of positive, zero, and negative correlations (Pearson's R, 2021)

The value of r gives an indication of the strength of the relationship i.e. the larger the number the stronger the relationship. The formula used to calculate the Pearson correlation coefficient is:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[\, n\sum x^2 - (\sum x)^2 \,][\, n\sum y^2 - (\sum y)^2 \,]}}$$

Where:

r = Pearson correlation coefficient

n = number of pairs of the data

x and y are the data pairs

$\sum xy$ = sum of the products of the paired data

$\sum x$ = sum of the x data scores

$\sum y$ = sum of the y data scores

$\sum x^2$ = sum of the squared x data values

$\sum y^2$ = sum of the squared y data values

3.9 Reliability Analysis

A popular approach to analyse reliability is Cronbach's alpha. It uses the variance and covariance values of items to calculate a value alpha (α) which is an indication of the internal consistency of the items. The value of alpha indicates how closely related a set of questions are as a group. Analysis of variance can be used to assess whether means obtained from experimental conditions are significantly different from each other and, also, the analysis of variance can give one or more statistical values whose significance can be determined from look-up tables (Roberts, 1999). Covariance is calculated by removing the mean from individuals' scores on two variables, multiplying each individual's adjusted score on the first variable by the adjusted score on the second variable, sum those scores, and then divide by the number of individuals. Covariance gives an indication of the strength of the association between two measures and their variability for any given sample (Maruyama, 1997). The value of alpha ranges from 0 to 1 and higher values indicate better internal consistency. As a rule of thumb, values of 0.5 or less are unacceptable, values between 0.5 and 0.6 are poor, between 0.6 and 0.7 are questionable, between 0.7 and 0.8 are acceptable, between 0.8 and 0.9 are good, and values above 0.9 are excellent (Cronbach's Alpha, 2018).

The variance of a data set is related to how far the data is spread out and it is mathematically defined as the average of the squared differences from the mean (Variance, 2021). The variance of a set of data is calculated by:

- **Step 1:** Calculating the mean value of the set of data values
- **Step 2:** Subtracting the mean value from each value in the data set and squaring the result
- **Step 3:** Calculating the average of the squared differences

The results are squared to convert any negative values to positive and the average of the squared differences is the variance of the data set.

Covariance is similar to variance, but variance calculates how a single variable varies, while covariance is related to how two variables vary together (Covariance, 2021). The formula for calculating the variance between two variables is:

$$cov_{x,y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{N - 1}$$

Where:

- $cov_{x,y}$ = the variance between variable x and y
- x_i = data value of x
- y_i = data value of y
- $\dot{x}$ = the mean of the x values
- $\dot{y}$ = the mean of the y values
- N = the number of data values

The formula to calculate the Cronbach's alpha (α) uses the variance and covariance, and is:

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N - 1)\bar{c}}$$

Where:

- α = the Cronbach's alpha value
- N = the number of data items
- $\hat{c}$ = the average of the covariance among the items
- $\tilde{v}$ = the average of the variance

3.10 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is used to analyse the relationship between observed variables and latent variables. Latent variables are constructs or factors that are not directly observable or measured but can be inferred from a set of variables which are measured using tests and surveys (Schumacker, 2004). To use CFA, the researcher must have expectations regarding (a) the number of factors, (b) which variables reflect given factors and (c) whether the factors are correlated (Thompson, 2004). The number of factors relates to the number of constructs being measured. An example of a three-factor structure is where knowledge, attitude, and behaviour are being measured. The variables that reflect the given factor are the results of the questions associated with measuring the individual constructs e.g. the knowledge questions related to micro-plastics in the ocean. Correlation analysis is used to check if the factors are correlated.

Factor analysis is used to reduce a large number of variables into a fewer number of factors (Factor analysis, 2021). It extracts the maximum common variance from all the variables and puts them into a common score. Principal component analysis (PCA) is the most commonly used method of performing factor analysis. It is a dimensionality-reduction method that reduces the dimensionality of large data sets, by transforming a large set of variables into a smaller one while still maintaining most of the information from the large data set (PCA, 2021). PCA is performed by standardising the data to transform the data to comparable scales to ensure that data measured on larger scale ranges does not dominate data measured on smaller scale ranges. A matrix is created containing the covariances of the data and statistical techniques are used to select the principal components from the covariance matrix. CFA provides a factor loading value which is an indication of the variance explained by the variable on that particular factor. Factor analysis is one of the techniques used in Structural Equation Modelling (SEM).

SEM is a statistical analysis technique used to analyse the structure of relationships and it is a combination of factor analysis and multiple regression

analysis. It is used by researchers to understand the complex patterns of interrelationships among variables, and they need to start from a conceptually derived model specifying the relationships among a set of variables (Maruyama, 1997). A conceptually derived model relates to the expectations the researcher possesses in relation to which items in a questionnaire are measuring the various dimensions being measured by the questionnaire e.g. items measuring attitude towards micro-plastics in the ocean. SEM path diagrams are used to show the factor loadings of each variable on the factor and the correlation values between the factors.

3.11 Paired T-test Analysis

A paired t-test is a statistical procedure that is used to determine if the mean difference between two data sets is zero i.e. that there is no difference between the data sets (Paired t-test, 2021a). In a paired t-test the subjects are measured twice which results in pairs of observations. Paired t-tests are commonly used to measure the difference between scores from before and after tests. The statistical significance of a paired t-test is determined by the p-value which is related to the probability of observing no difference between the two data sets. The lower the p-value, the lower the probability is that the two data sets are the same. Usually, a value of 0.05 is chosen as the cut-off point for the p-value which means that any p-value under 0.05 indicates that a difference exists between the two data sets. The procedure for carrying out a paired t-test is as follows (Paired t-test, 2021b):

Step 1: Calculate the difference between each of the data pairs

Step 2: Calculate the mean of the differences

Step 3: Calculate the standard deviation of the differences

Step 4: Calculate the standard error of the mean difference using the formula:

$$SE(\bar{d}) = \frac{s_d}{\sqrt{n}}$$

Where:

- SE($\bar{d}$) = the standard error of the mean difference
- S_d = the standard deviation of the differences
- n = the number of data pairs

Step 5: Calculate the t-statistic using the formula:

$$T = \frac{\bar{d}}{SE(\bar{d})}$$

Where:

- T = the t-statistic
- $\bar{d}$ = the mean of the differences
- SE($\bar{d}$) = the standard error of the mean difference

Step 6: Then use the t-distribution tables to lookup the p-value for the t-statistic (T) obtained in step 5. If the p-value is less than 0.05 then a difference exists between the two data sets.

3.12 Chapter Summary

This chapter describes the methods and tools used to answer the research questions. It consists of a description of how the literature review was performed, how the data was gathered, and the online causal mapping tool. This is followed by sections on the data analysis procedures which were used in this research. The data analysis procedures are Rasch analysis, correlation analysis, reliability analysis, confirmatory factor analysis, and paired t-test analysis.

Chapter 4

Causal Mapping and Knowledge Capture Tool

4.1 Introduction

This chapter opens with a description of the online causal mapping and knowledge capture tool and is followed by information on the DAPSIWR classification which is provided to the user in the left section of the causal mapping tool. The process I used to create the functional requirements for the tool is then discussed. The architecture of the tool and the technologies used to implement the tool are then described. The chapter closes with sections on the tool design, implementation and testing, and a discussion of the DAPSIWR based causal maps created by the domain experts using the tool.

4.2 The Online Causal Mapping Tool

The online Causal Mapping tool was created to provide domain experts with the ability to create domain specific DAPSIWR causal maps online, store relevant information for each of the elements of the model, attach knowledge to the nodes and links in the model, and attach actors to the relevant areas of the model. I used the DAPSIWR modelling framework because it allows the origins and consequences of environmental problems to be described and an understanding to be developed of the dynamics associated with the links between the DAPSIWR elements. Figure 4.1 shows an image of the DAPSIWR framework with descriptions of each of the DAPSIWR elements. Allowing knowledge and actors to be attached to the elements of the DAPSIWR model provides a complete picture of the topic being modelled including the exiting knowledge related to the topic and the stakeholders linked to the elements of the model.

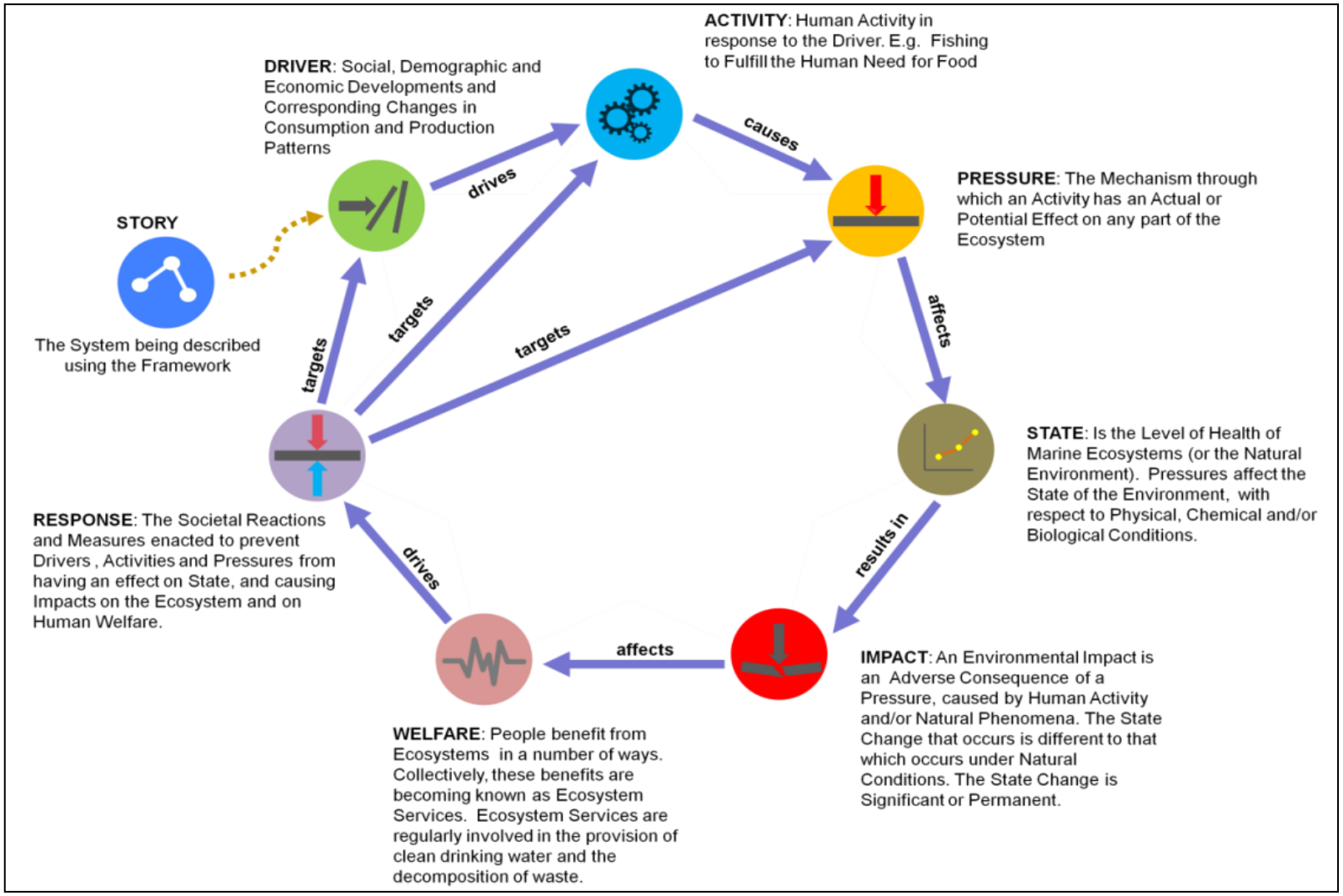

Figure 4.1: The DAPSIWR Framework

The tool provides a classification of DAPSIWR element types which the user can choose from to create DAPSIWR elements on the canvas. It is intended to be used to create visual representations of ocean-environmental topics based on the DAPSIWR framework and by changing the classification, it can be used to create causal maps related to domains other than the ocean. The tool allows users to log in and create, view, and update the model and they can use a drag-and-drop approach to create the elements to the model.

The approach used to create the online Causal Mapping tool involved reviewing the literature on existing causal mapping tools, investigating the available technologies which would be suitable to implement the tool, working with the future users of the tool to define the requirements for the tool, implementing the tool in a JavaScript environment and deploying the tool on a Glassfish application server. After deployment, I worked with the users of the tool to resolve any issues they had with the use of the tool, and I also provided instruction on the use of the tool using documentation and webinars.

4.3 The DAPSIWR Classification

The classification is a hierarchy of DAPSIWR element types, media types, and actor types. The approach used to develop the classification comprised of six dimensions of communicative interaction: How (Form), Who (Participants), When (Time), Where (Place), What (Content), and Why (Purpose). For example, the How dimension relates to the form of the OL material and is categorised in three directions: Media Degree, Media type, and Communicative practice. Media degree relates to the means of enabling communication (e.g. face-to-face communication), media type relates to the type of medium used (e.g. book or journal article), and communicative practice relates to how the material is communicated (e.g. emails or speeches).

The development of the classification consisted of the classification of knowledge sources and ocean literacy sources. The use of the DAPSIWR framework to perform the classification of the content was an integral part of the development of the classification. The classification is divided into three main sections: the DAPSIWR element types, actor types, and knowledge types. The DAPSIWR section of the classification contains element types related to drivers, activities, pressures etc. An example of a driver classification type is “Socio-political Drivers” and the driver types contained in its sub-classification are “Globalisation”, “Societal interactions”, “Well-being”, and “Regulations”. An example of a pressure classification type is “Introduction of Physical Pressure” and the pressure types contained in its sub-classification are “Smothering”, “Sealing”, “Changes in siltation”, “Abrasion”, and “Selective extraction”.

The actor section of the classification contains the sub-classifications “General Public”, “Individual”, “Professional”, “Regulatory” and “Social”. One of the sub-classifications of “Individual” is the actor type “Learner” and its sub-classifications are “Lifelong Learner”, “School Pupil”, “University Student”, and “Vocational School Student”. The knowledge section of the classification is divided into “First Degree Media”, “Second Degree Media”, and “Third Degree Media”. The media degree refers to the means of enabling the communication and the “First Degree Media” classification is defined as the human body enabling communication face-to-face. The sub-classifications of “First Degree Media” are “Education Public Events”, “Performative Arts” and “Visual Arts”. “Second Degree Media” encompasses all kinds of technically reproduced information carriers e.g. recorded theatre plays, books, magazines, and TV shows. The sub-classifications of “Second Degree Media” are “Audio Video Recording”, “Film”, “Print Media”, “Radio”, and “TV”. “Third Degree Media” is related to digital technologies facilitating networked interactions e.g. websites and online videos. The online digital media sub-classifications include blogs, chat forums, newsletters, and podcasts.

4.4 Functional Requirements

The development of the functionality provided by the Causal Mapping tool was based on a proposal to develop a knowledge base related to the ocean. The proposal was to create a publicly accessible and structured knowledge base capturing the main human-ocean relationships. The knowledge base was required to provide access to existing knowledge that has been produced in recent years, building in particular on the ecosystem service framework. It was also required to integrate knowledge on the organisation of the market economy/value chain and of the knowledge system – as basis to the development of communication material and products that are targeted and likely to be cost-effective.

Defining the requirements for the online Causal Mapping tool included researching the technologies available for creating diagrams or models online and performing research to understand how the tool could be implemented to best suit the users' needs. Two of the online diagramming technologies I researched were D3 and JointJS. D3 stands for data driven documents and it is a JavaScript library which can be used to create custom interactive data visualisations in a web browser. JointJS is a JavaScript diagramming library which can be used to create static diagrams and fully interactive diagramming tools.

The main requirements for the Causal Mapping tool were:

- A tool which could be accessed online and allow the user to create a causal map based on the DAPSIWR framework
- All information entered by the user and all knowledge attached to the DAPSIWR elements were required to be stored in an online knowledge base
- To display an interactive classification to the user to provide the functionality to create elements in the DAPSIWR model
- Provide features to the user which allows them to enter information relevant to the DASPSIWR element being created
- A facility to allow users to attach Actor elements to the appropriate elements of the model
- A bulk-upload feature to allow knowledge elements to be uploaded to the system in bulk
- The facility to create causal links between the elements of the DAPSIWR model and provide an intermediate node on the link which can be used to attach knowledge and actor elements to the links between the DAPSIWR elements
- To display a list of all the causal models already created on the Causal Mapping tool
- To restrict causal model Edit access to the model only for users with permissions to edit the model
- And allow causal model Read access to all users logged in to the online causal mapping tool

4.5 Architecture and Technologies

The online Causal Mapping tool consists of HTML web pages, Java code, JavaScript code, the Rappid diagramming framework, the Backbone JavaScript library, Scalable Vector Graphics (SVG) drawing areas, JQuery code, the JointJS JavaScript library, the EasyTree JavaScript library, and an OrientDB graph database. The Causal Mapping tool is deployed on a Glassfish web application server which allows the online Causal Mapping tool to be accessed by the users' web browser e.g. Chrome or Firefox. Figure 4.2 shows the architecture of the online Causal Mapping tool.

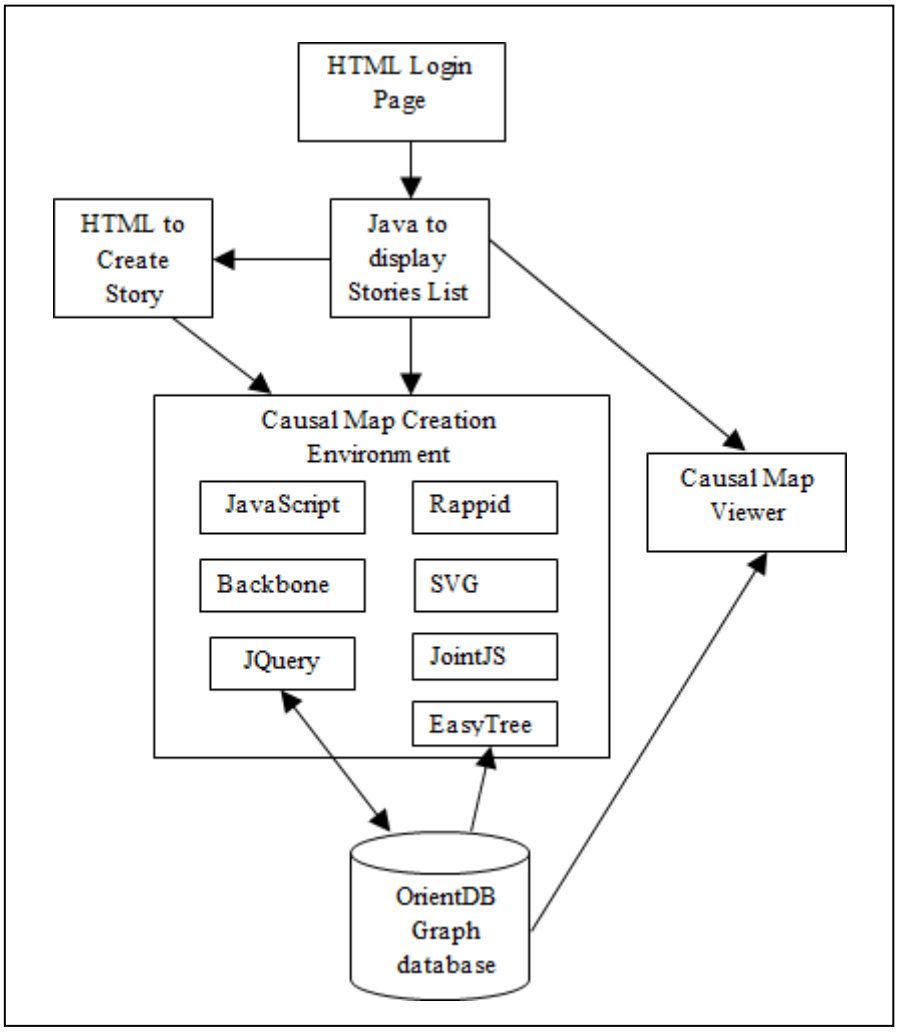

Figure 4.2: Architecture of the online Causal Mapping tool

HTML is used to implement the tool's static web pages. HTML stands for Hyper Text Markup Language and is a scripting language used by web browsers to render web pages. The HTML login page requires the user to enter their username and password to log into the online Causal Mapping tool and the HTML create story page requires the user to enter information related to the causal map they are about to create.

Java is used to create the dynamic web pages in the causal mapping tool. Java is a programming language and computing platform for creating web applications. After the user logs in, they are presented with a page which uses Java code to display a list of the existing causal maps which have already been created. The user can choose to create a new causal map, edit an existing causal map, or view a causal map. Users can only edit causal maps which they have created or causal maps which they have been given Edit privileges to. The causal map viewer area is provided to users who do not have Edit permission for a specific causal map.

JavaScript is a computer programming language that is used to create interactive effects within web pages. JQuery is a library of JavaScript functionality which makes it easier for the programmer to use JavaScript functionality. An example of where JavaScript and JQuery are used in the causal mapping tool is in the case where the user moves away from a text box after the contents of the text box have been edited. In this case, the JavaScript code detects the event and the JQuery code makes an AJAX call to the OrientDB database to update the change in the database.

The main causal map creation page implementation is based on an academic licenced version of the Rappid online diagramming tool which provides users with the features to create diagrams on a Scalable Vector Graphics (SVG) drawing area (canvas). Using Rappid, the user can create diagrams by dragging items and dropping them in a central drawing area. SVG allows graphics to be drawn on the canvas and also provides features for user interaction with the graphics.

JointJS is used in the Rappid tool to render the elements on the SVG drawing area, provide functionality to link the elements, and provide an event driven environment. An example of the functionality it provides is where it provides a menu to the user when an element is clicked on. This menu can then be used to drag a line to another element in the causal map to create a link between the two elements. An example of an event handled by the JointJS code is when the user releases their mouse key on the SVG drawing area and the JointJS code draws the element on the SVG canvas.

EasyTree is used to implement a collapsible tree representation of the classification of DAPSIWR element types from which the user can choose from to create the elements in their causal map. EasyTree is a JavaScript menu system for rendering lists and their subcategories in a tree structure. It displays the contents of the classification as a list in the left section of the causal map creation area. The user can expand and collapse the subcategories by clicking on the items in the list. When the user has selected the element type, they can drag it from the list and drop it on the SVG canvas area where an element of that type is then created.

The Backbone JavaScript library provides a key-value pair approach to store data related to the specific elements in a JavaScript environment. As the user adds information to the elements of the causal map the data is stored in the Backbone model as well as being stored in the database. This ensures that each time the user views the properties associated with an element, they can be displayed from the Backbone model which eliminates the need to make a call to the database.

OrientDB is the graph database used to store the causal maps, the information added by the user for each of the elements of the causal map, and the knowledge the user has attached to the elements of the causal map. When the causal map creation area is loaded into the web browser, a JQuery AJAX call is made to the OrientDB database. The database returns the classification schema which is then used to populate the list items and the branches of the collapsible tree. AJAX stands for Asynchronous JavaScript And XML and it

is a set of web development techniques on the client-side used to create asynchronous web applications. AJAX can send and receive data to and from a server without interfering with the display or behaviour of the web page. An AJAX call is also used to retrieve the data related to the causal map which is stored in the database. The data is then used in conjunction with the JointJS code to draw the causal map on the SVG drawing area.

4.6 Tool Design

The Causal Mapping tool has a Java-based front end which users can use to log into the system; administer the users of the system; view a list of the existing causal maps; and create, read, edit and delete the causal maps. The main area for creating causal maps is a JavaScript-based environment and it displays a collapsible tree which is an implementation of the DAPSIWR classification. The user can expand and collapse the branches of the collapsible tree to find the DAPSIWR element type they are looking for and then use a drag and drop approach to create an element of that type on the canvas. The causal maps created by the users and the information entered by the users are stored in an OrientDB database. Figure 4.3 shows a functional diagram for the online Causal Mapping tool.

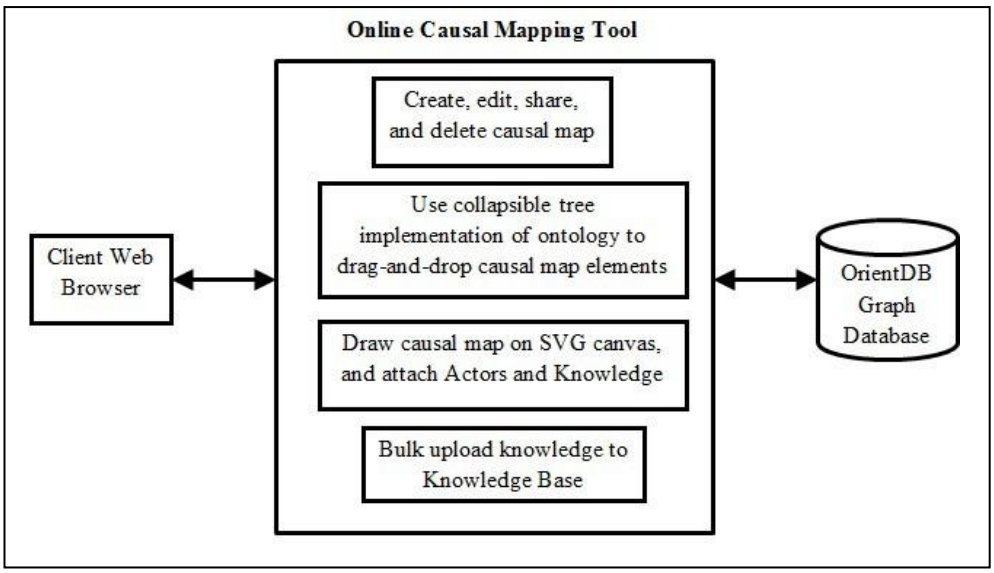

Figure 4.3: Functional diagram of online Causal Mapping tool

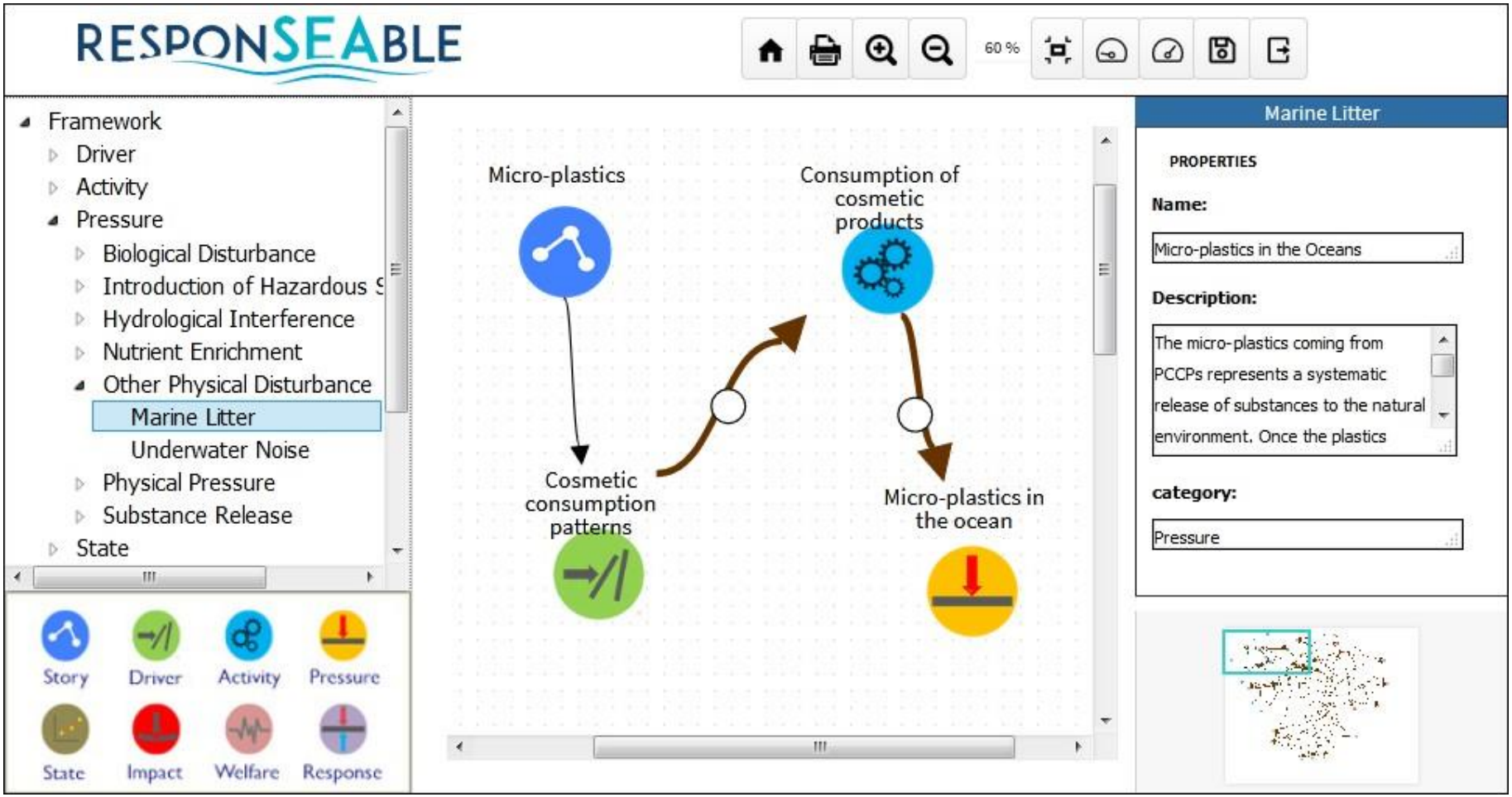

Figure 4.4: Main causal map creation screen

Figure 4.4 shows a typical view of the main causal map creation screen where the user creates their causal map. The left section contains the collapsible tree implementation of the classification from which the user can drag DAPSIWR element types and drop on the canvas in the centre section, to create the model element. The canvas is a Scalable Vector Graphics (SVG) drawing area, and it is where the user creates the DAPSIWR based causal map. On the SVG drawing area, the user can create DAPSIWR elements, Knowledge elements, Actor elements, and the links between the elements. In figure 4.4, we can see that the user has created a Story called Micro-plastics and a Driver, Activity, and a Pressure element.

In the left section of figure 4.4, the DAPSIWR element type "Marine Litter" is highlighted to show that it is this element type that was used to create the "Micro-plastics in the ocean" element. After the user had dropped the "Marine Litter" element type on the drawing area they went to the element's properties section and renamed it to "Micro-plastics in the ocean" which is a Pressure element of the causal model. The right section shows the properties entered by the user for the Pressure element which include the Name, Description, and Category of the DAPSIWR element. The bottom right section provides a navigator widget which displays a smaller view into the larger causal map. The navigator allows users to navigate quickly around the causal map using the viewer window.

The classification types are used to classify each of the nodes in the causal model being created. An example of a classification which can be used is "Consumption Patterns" which is classified in the "Indirect drivers – Economic Drivers" section of the classification. A driver related to micro-plastics which could be classified using the "Consumption Patterns" classification is "Cosmetic Consumption Patterns". The classification is primarily related to the ocean, but it could be modified to be used to create causal models in other areas.

4.7 Implementation and Testing

The individual nodes which can be used to create the causal maps are Story, Driver, Activity, Pressure, State, Impact, Welfare, and Response nodes. The images which are used to display the nodes on the canvas are shown in figure 4.5. Also, each of the causal links has an intermediary node which allows Knowledge and Actor nodes to be attached to the causal links.

Figure 4.5: Causal mapping tool node images

The user can expand and collapse the branches of the classification tree in order to find the classification element type they require for the element they intend to drag- and-drop onto the canvas. The classification is a hierarchy of DAPSIWR element types, actor types, and knowledge types. An example of the DAPSIWR part of the classification, displayed in the left section of the online Causal Mapping tool, is shown in figure 4.6. It shows the driver types which are sub-categories of the driver type “Economic Driver”. The “Economic Driver” classification is a sub-category of “Indirect Driver” which is in turn a sub-category of “Driver”. The “Economic Driver” types available for selection in figure 4.6 are Consumption Patterns, Economic Distribution, Economic Growth, Economic Productivity, Economic Structure, Energy Availability, and Material Availability.

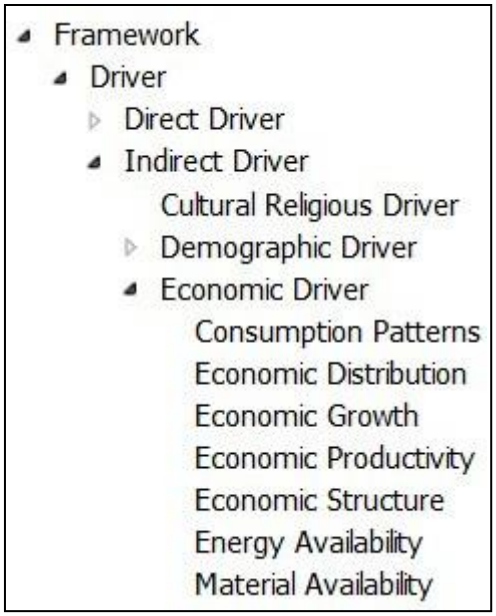

Figure 4.6: An expanded view of the Driver part of the classification

Figure 4.7 shows an expanded view of the "Actor" part of the classification. It shows the Actor types classified as being part of the "Primary Sector" which is a sub-classification of "Professional". The primary sector actor types shown in figure 4.7 are Animal Producers, Crop Producers, Fish Farmers, Fishermen, Foresters, Miners, and Quarrying Companies.

Figure 4.7: An expanded view of the Actor part of the classification

Figure 4.8 shows an expanded view of the knowledge classification. It shows types of “Education Public Events” which is a sub-classification of “First Degree Media”. The types of “Education Public Events” knowledge available for selection are Class at school, Collective action event, Conference, Public gathering, Public speech, and Workshop. The tool also provides a feature which allows for the bulk upload of knowledge. Users can use a template file for the knowledge they wish to upload, and the knowledge being uploaded is validated before it is stored in the knowledge base.

Figure 4.8: An expanded view of the Knowledge part of the classification

Figure 4.9 shows the Causal Mapping tool being used to create an activity on the SVG drawing area while creating a causal map related to the problem of micro-plastics in the ocean. The user has expanded the activity branch in the classification on the left of the screen and they have chosen the “Consumption and Household” element type. They have dragged and dropped the element type onto the SVG drawing area. Then they have clicked on the element to select it so that they can add its properties. They have named the new activity element “Consumption of cosmetic products” and entered a description and category for the element.

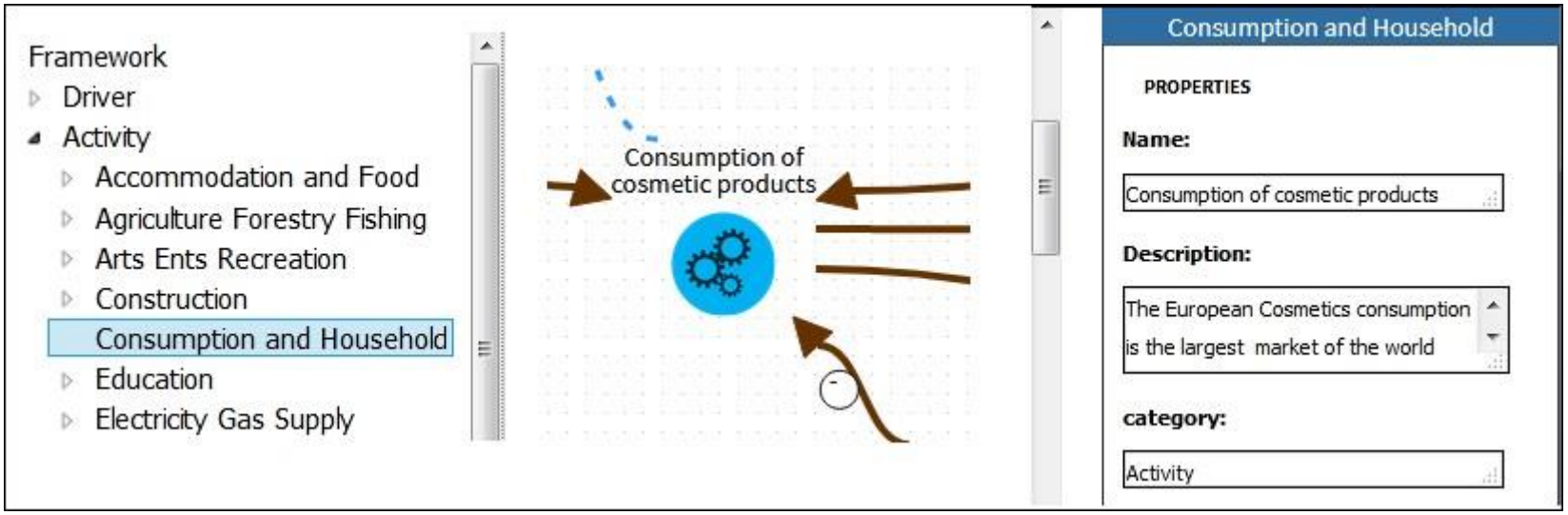

Figure 4.9: Activity element being created on the SVG drawing area

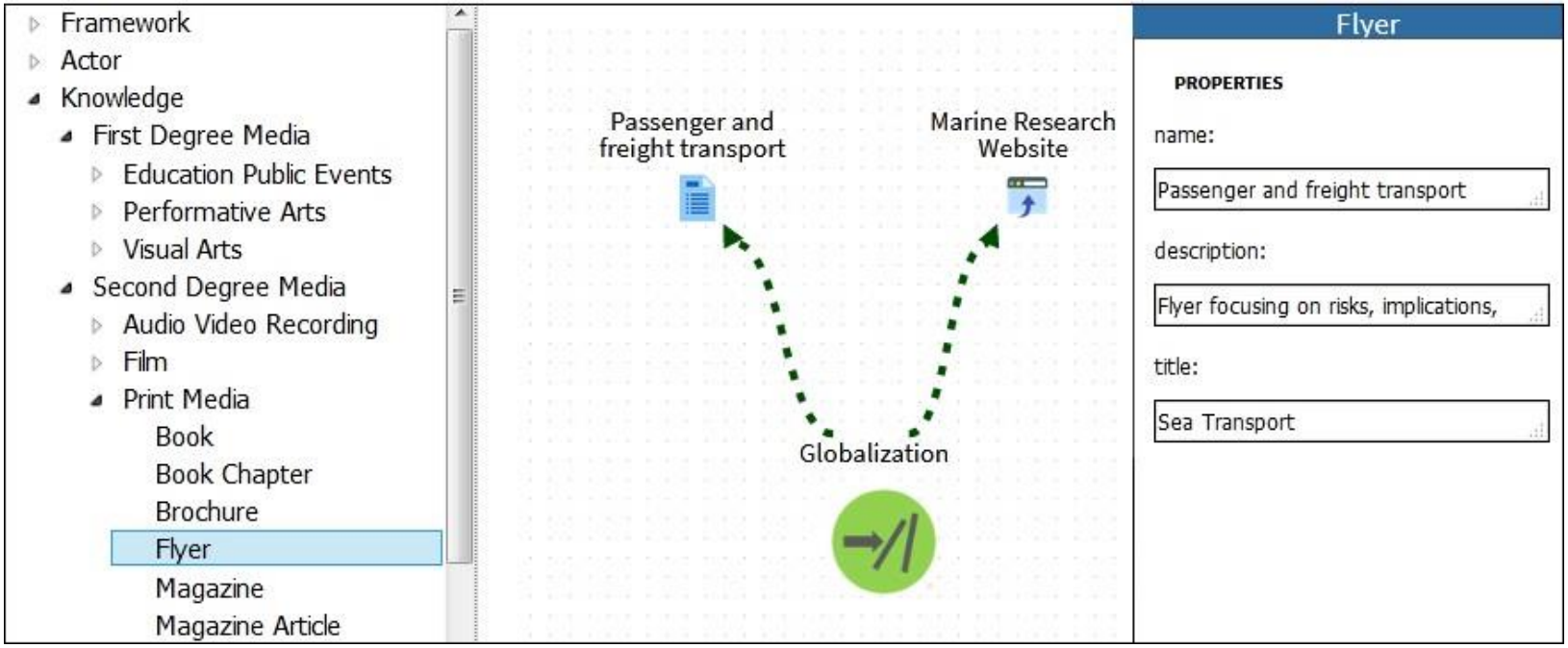

Figure 4.10: Knowledge element being created on the SVG drawing area

The creation of a knowledge element is shown in figure 4.10. The user is adding a flyer to the causal map they are creating related to the problem of invasive alien species. They have expanded the knowledge branch of the classification and selected the element type “Flyer” which is a sub-classification of “Print Media”. They have dragged and dropped the element type onto the SVG drawing area to create the flyer named “Passenger and freight transport”. They have then added a description and title to the properties of the element and attached the flyer to the driver “Globalisation”.

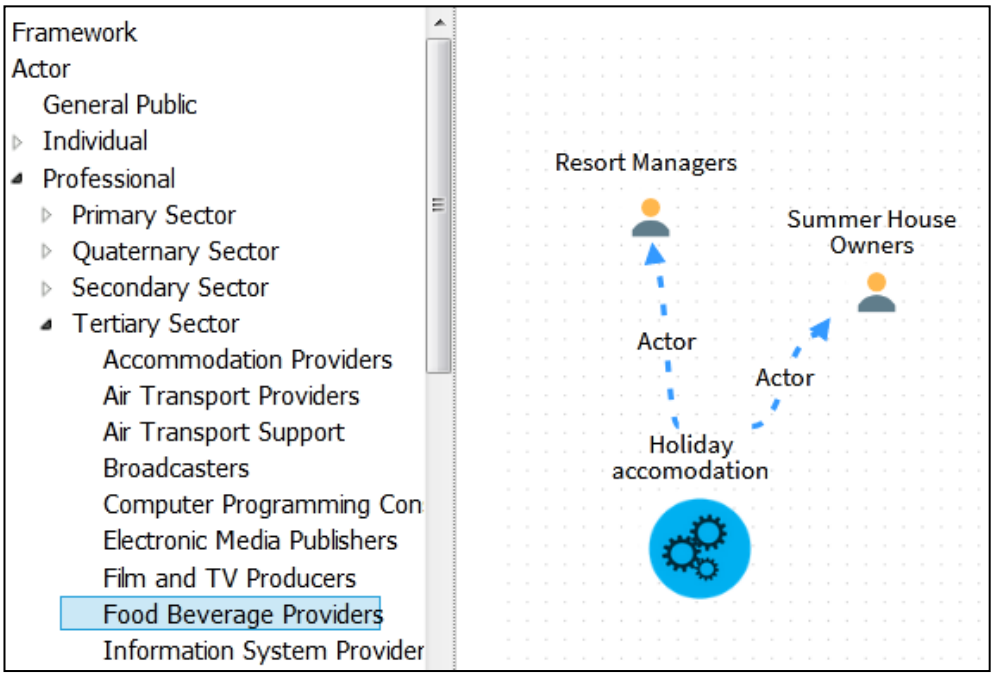

Figure 4.11: Actor element being created on the SVG drawing area

In figure 4.11, the user is creating an actor in the coastal tourism causal map. They have expanded the actor branch of the classification and they have selected “Food Beverages Providers” element type. They have dragged and dropped the element type onto the SVG drawing area and named the actor “Resort Managers”. They have then attached the actor to the activity of providing holiday accommodation, which also has the actor “Summer House Owners” attached to it.

During the development of the online Causal Mapping tool, the tool was periodically deployed to the live site to allow the project stakeholders and

intended users to access the tool. Before deployment, all new features were tested by the software development team. Webinars were provided to the users to inform them about the existing features of the tool and instruct them on how to use the tool. The users who tested the tool were invited to provide feedback related to how well the tool was functioning and any suggestions they might have on how the tool could be improved. The feedback was reviewed by the software development team and the enhancements were made to the tool.

4.8 DAPSIWR Based Causal Maps

The purposes of the causal maps created by the users of the online tool are to provide a graphical representation of the DAPSIWR elements of ocean literacy topics, to show the interconnections between the elements, and to input and attach relevant knowledge for the elements of the causal maps. The causal map topics were based on ocean related topics and included the topics Coastal Tourism, Sustainable Fisheries, Invasive Alien Species, Marine Renewable Energy, Micro-plastics and Cosmetics in the EU, and Eutrophication and Agriculture in the Baltic Sea.

Figure 4.12 shows a path through the coastal tourism causal map. It shows the driver: “Economic growth” which leads to the activity of “Coastal development” which in turn creates the pressure of “Soil sealing”. “Soil sealing” has an impact on human welfare in the form of “Decreased flood protection capacity” and a response to this impact are “Laws on setback Zones”. The “Laws on setback zones” then have an effect on “Coastal development”.

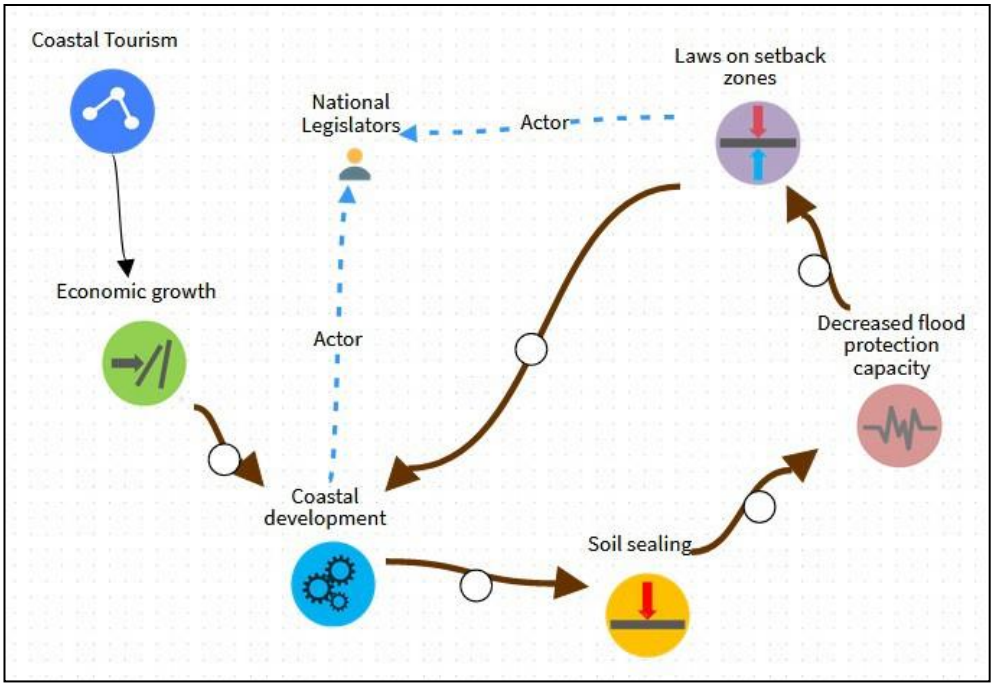

Figure 4.12: A path through the coastal tourism causal map

Part of the "Invasive alien species" causal map created by the users of the online Causal Mapping tool is shown in figure 4.13. It shows the activity of "Hull scrubbing and wiping" leading to the pressure of the "Release of non-indigenous species through bio fouling" which affects the state of "Benthic components". Benthic components are organisms that live on, in, or near the seabed. One of the impacts related to the state of the "Benthic components" is the impact "Habitat changes and loss" which has a socio-economic impact on human welfare. One of the responses in this case is "International environmental regulation".

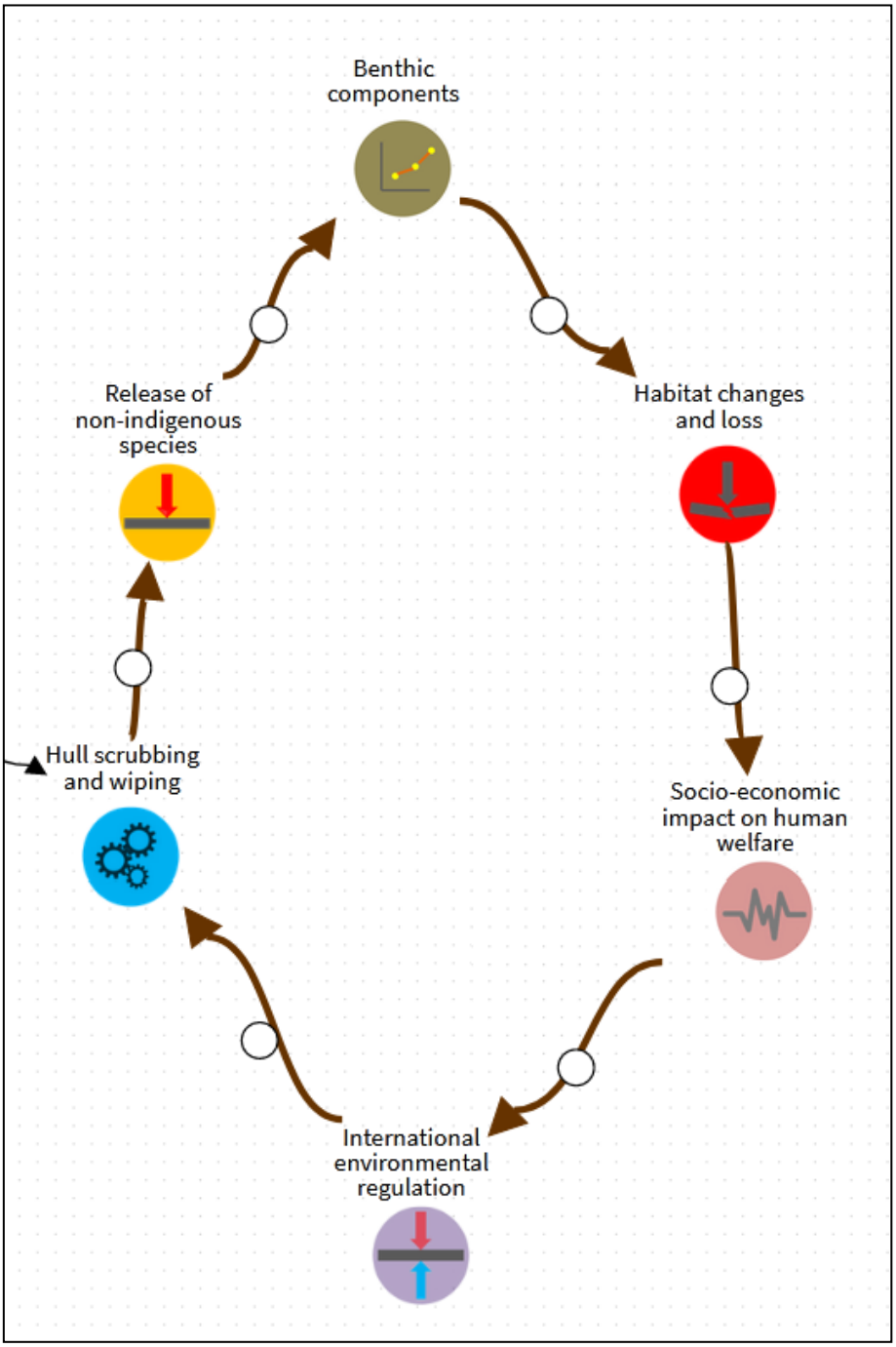

Figure 4.13: A path through the invasive alien species causal map

The image shown in figure 4.14 is part of the “Marine renewable energy” causal map created by the users of the Causal Mapping tool. It shows the story node “Marine renewable energy” with the two drivers “Economic growth” and “Marine science and tech development” connected to it. Both drivers are linked to the activity of “Electricity and gas supply” and the pressures caused

by the activity are “Physical pressure” and “Biological disturbance”. The information available in the properties section of the activity “physical pressure” relates to the addition of physical structures related to marine renewable energy e.g. wind farms. The information in the properties section for the pressure “Biological disturbance” is related to changes in the movement of water and its effects on the species that exist there.

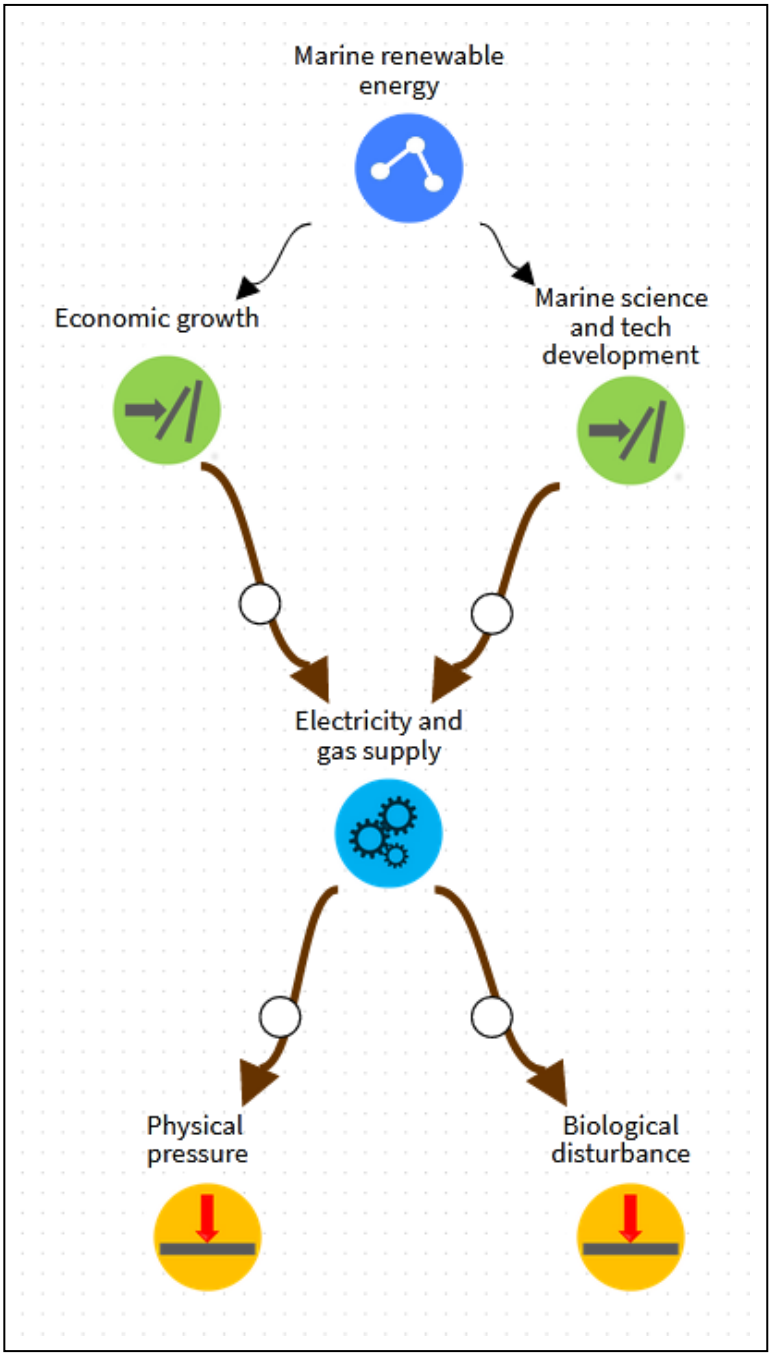

Figure 4.14: Part of the marine renewable energy causal map

4.9 Chapter Summary

The comparison of our online Causal Mapping tool with existing approaches and tools shows that it is a useful tool which allows domain experts to create DAPSIWR based causal maps of specific topics related to the ocean. It provides a DAPSIWR classification to the domain expert and allows the causal map elements to be linked with relevant knowledge stored in an online knowledge base. My Causal Mapping tool is a useful tool to create causal maps which visualise the Drivers, Activities, Pressures, States, Impacts, Welfares, and Responses related to ocean-environmental topics. The tool allows users to create DAPSIWR based causal maps online, store information related to the individual elements of the model and attach actors and knowledge elements to relevant elements in the model and the links between the elements.

Chapter 5

Surveys to Test Data Analysis Techniques

5.1 Introduction

This chapter contains a description of the approach I used to perform an experiment in surveying and the use of relevant data analysis techniques to gain insights from the survey responses. This involved gathering data related to knowledge, attitude, and behaviour on the three ocean related topics micro-plastics, coastal tourism, and sustainable fisheries. The chapter begins with a description of the approach I used and the knowledge, attitude, and behaviour questions. This is followed by a section on the results of the data analysis procedures consisting of descriptive analysis, correlation analysis, reliability analysis, Rasch analysis, current and future behaviour comparison, and distractor analysis. The chapter closes with a discussion of the results of the data analysis on the survey responses.

In order to perform an experiment in surveying and as a way of trying out the relevant data analysis approaches that I identified during the literature review, I created three OL surveys based on the three OL topics Micro-plastics (2018), Coastal Tourism (2018), and Sustainable Fisheries (2018). The surveys can be used as pre- and post-surveys to measure the effectiveness of OL tools and initiatives. These are important topics in relation to the ocean and the surveys can be used to give an indication of the level of OL possessed by respondents. Reliable surveys can be used as pre- and post-surveys to measure the effectiveness of OL tools and initiatives. Each of the surveys contain the following 5 sections: (i) general respondent information e.g. country, city, age range, (ii) questions related to the knowledge possessed by the respondent regarding the OL topic, (iii) questions on the attitude of the respondent towards the topic, (iv) questions on the current behaviour of the respondent in relation to the topic, and (v) the future intended behaviour of the respondent in relation to the topic.

5.2 Knowledge Questions

The knowledge questions, contained in the OL surveys, are based on knowledge questions created as part of the ResponSEAble project, and information contained in key story documents. The questions were single or multiple-choice questions and some of them had images associated with them. The sub-topics contained in the surveys were chosen by the domain experts and the sub-topics covered by the micro-plastics knowledge questions included possible ways for plastics to enter the ocean, micro-plastic face wash ingredients, and percentage of rubbish from single-use plastic. The sub- topics covered by the coastal tourism survey included the function of an artificial rock barrier, countries which receive the largest number of visitors each year, and the main effects of coastal development. The sub-topics covered by the sustainable fisheries survey included the types of fishing, percentage of fish which comes from fishing versus aquaculture, the self- sufficiency of the EU in seafood, and the identity of fish species.

5.3 Attitude and Behaviour Questions

The 3 attitude questions in each of the surveys require the respondent to rate their level of agreement or concern on a 10-point scale. The surveys had a general attitude question which required the respondent to rate their level of agreement with a statement related to how worried they were about damage to the natural environment and 2 attitude questions related to the survey topic. The surveys each contained 5 current behaviour questions which gathered information related to the current behaviour of the respondent in relation to the OL survey topic. Respondents were asked to rate the level of their behaviour, on a 10-point behaviour scale, in relation to the survey topics. The surveys each contained 5 future behaviour questions which are future versions of the current behaviour question. They asked the respondent about what they will do in the future in relation to the OL survey topics. An example of a statement used in one of the current behaviour questions is “I look for

products that use recycled and recyclable packaging" and the future behaviour version of that question is "I will look for products that use recycled and recyclable packaging". Appendix 2 contains the questions from the three surveys.

The surveys were created and administered online using Google Forms (2018). Google forms provide a way of creating and administering online surveys and receiving and analysing the responses to the surveys. Bitly (2018) links were used to provide access to the surveys and all of the respondents to the surveys were undergraduate university students. The students surveyed were not involved in the ResponSEAble project and had not used any of the OL tools created as part of the project.

5.4 Data Analysis and Results

The responses received from the survey participants were analysed using descriptive data analysis, Rasch analysis, correlation analysis and reliability analysis. The descriptive analysis of the data gathered reveals the numbers of questions answered in relation to the 3 topics, the percentages of correct answers to the knowledge questions, the percentage of respondents who viewed the correct answers, and information on the levels of attitude and behaviour in relation to the survey topics. The Rasch analysis of the knowledge questions provides information on:

- the relationship between the respondents' answers and the questions
- the level at which each question measures the respondents' knowledge on the topic
- how well each question fits with the unidimensional topic being measured
- the error associated with the Rasch measurements.

The correlation analysis of the responses provides information on:

- the extent to which a respondent's knowledge, attitude, and behaviour correlate.

The reliability analysis provides information on:

- the internal consistency of questions in the survey that measure similar dimensions.

5.4.1 Descriptive Analysis

Table 5.1 shows the descriptive statistics for the survey responses. The respondents to the surveys were mainly from Ireland, their age range was mainly between 18 and 24 years, and there was a total of 184 responses to the surveys. The 18- to 24-year-old cohort was chosen because they are seen as future opinion shapers and decision makers.

Survey Topic	Number of Responses	Mean Value for Correct Answers	Standard Deviation
Micro-plastics	70	48.93%	20.49
Coastal Tourism	69	39.71%	19.85
Sustainable Fisheries	45	51.85%	17.73

Table 5.1: Descriptive statistics for survey responses

5.4.2 Correlation Analysis

The Statistical Package for the Social Sciences (SPSS, 2018) was used to perform the correlation analysis on the responses to the surveys. The correlation analysis of the relationship between attitude and behaviour in relation to the surveys shows that a correlation does exist. The Pearson correlation r-value for the correlation between attitude and behaviour for the micro-plastics responses was found to be 0.495 with the correlation significant at the 0.01 level (2-tailed). The r-value for the correlation between attitude and behaviour for the coastal tourism responses was found to be 0.442 with the correlation significant at the 0.01 level (2-tailed). The r- value for the correlation between attitude and behaviour for the sustainable fisheries responses was found to be 0.296 with the correlation significant at the 0.05 level (2-tailed). No statistically significant correlation was found between knowledge and attitude or knowledge and behaviour for each of the 3 OL surveys.

The internal consistency of the questions used to measure the attitudes and behaviour of respondents was measured by performing correlations between each of the questions measuring attitude and each of the questions measuring behaviour. A statistically significant correlation was found for all of the pairings except for the pairing between micro-plastics behaviour questions 15 and 16, and the pairing between sustainable fisheries attitude questions 11 and 12.

5.4.3 Reliability Analysis

The Cronbach's alpha statistical test was used to check the internal consistency of the attitude and behaviour questions. The resulting Cronbach's alpha value for the attitude questions in the survey on micro- plastics was acceptable at 0.783, coastal tourism was good at 0.8, and sustainable fisheries was questionable at 0.604. The Cronbach's alpha value for the behaviour questions in all the surveys was good. The value for micro-plastics was 0.808,

coastal tourism was 0.869, and the value for sustainable fisheries was 0.873. The reliability analysis results tables are shown in appendix 3. The tables show the question text, mean, standard deviation, and the "Cronbach's alpha if item deleted" for each of the attitude and behaviour questions in the 3 OL surveys.

5.4.4 Rasch Analysis

The Rasch analysis of the knowledge questions in the surveys was performed using Winsteps (2018). The Winsteps software package allows Rasch person ability, item difficulty, error, and fit information to be calculated from responses to a set of questions. The Rasch estimates tables for the knowledge questions contained in the surveys are shown in appendix 3. The results of the Rasch analysis consisted of the "Total Score", "Measure", "Standard Error", and "Outfit Zstd". The "Total Score" relates to the number of respondents who answered the questions correctly. The "Measure" is related to the logit value which gives an indication of the difficulty of the question. The "Standard Error" shows the error related to the Rasch measurement and the "Outfit Zstd" is the level of fit associated with each question. The "Outfit Zstd" values are standardized fit statistics which are the result of t-tests of the hypothesis "Does the data fit the model (perfectly)?" (Outfit, 2018).

5.4.5 Current and Future Behaviour

Figure 5.1 shows a double line graph based on the responses to the micro-plastics current behaviour and future behaviour questions. The horizontal axis contains numbers related to each of the respondents and the vertical axis is the score related to the respondents' current and future behaviour. The light grey line is a plot of the respondent scores for current behaviour and the dark grey line is a plot of their scores for future behaviour. The line for future behaviour is generally above the line for current behaviour which shows that in general the respondents intend to improve their behaviour in the future.

This general trend is also reflected in the current and future behaviour responses in the coastal tourism and sustainable fisheries OL surveys.

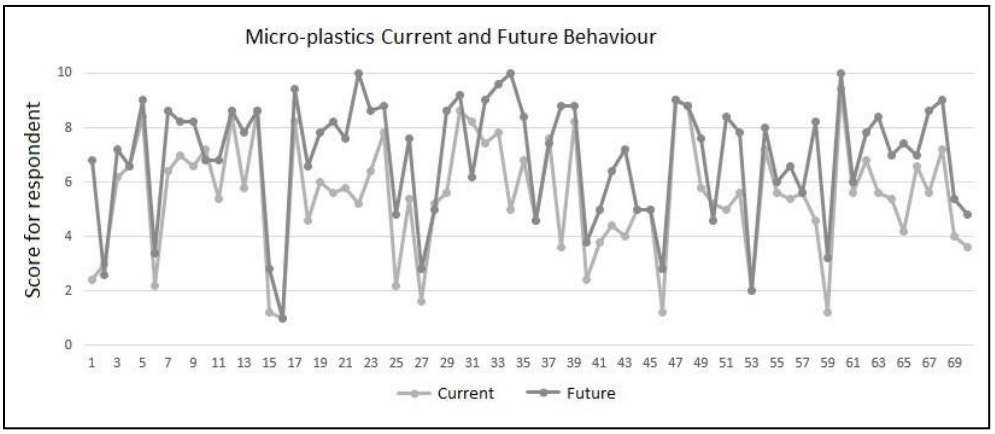

Figure 5.1: Relationship between current and future behaviour for micro-plastics survey

5.4.6 Distractor Analysis

The distractor analysis on the responses to the surveys was performed by identifying the knowledge questions in the surveys that required the respondent to choose a single answer from a list of options, calculating how many times each option was chosen, and checking if the resultant values indicated that the option was chosen more times than the correct answer or less than 5% of the time. 4 of the knowledge questions in the micro-plastics survey, 2 of the coastal tourism knowledge questions and all 9 of the sustainable fisheries questions had their distractors analysed.

5.5 Discussion

The result of the descriptive analysis shows that the OL survey respondents have a slightly higher level of knowledge about sustainable fisheries (mean 51.85%) when compared to knowledge of micro-plastics (mean 48.93%). The

level of knowledge possessed by the respondents with regard to coastal tourism was the lowest at 39.71%. The respondents to the sustainable fisheries survey had the highest percentage (28.9%) for viewing the correct answers to the knowledge questions, followed by the percentage (24.3%) of respondents who viewed the correct answers to the micro-plastics knowledge questions, and the percentage who viewed the correct answers to the coastal tourism knowledge questions is the lowest at 13%.

The mean scores for the responses to the attitude questions in the 3 OL surveys are similar with the attitude score for micro-plastics the highest at 8.29, followed by sustainable fisheries at 8, and coastal tourism with the lowest at 7.53. The mean scores for the current behaviour responses were highest for micro-plastics (5.49), followed by coastal tourism (4.46), and sustainable fisheries had the lowest mean score (3.67). The mean scores for future behaviour are all higher than the scores for current behaviour, with the score for micro-plastics (6.9) the overall highest and similar mean scores for sustainable fisheries and coastal tourism at 5.78 and 5.71, respectively.

5.5.1 Correlations

A medium correlation was found between attitude and behaviour for the responses to the surveys. The Pearson correlation r-value of 0.224 found by Yoon Fah and Sirisena (2014) for the relationship between environmental attitudes and environmental behaviours is slightly lower than the r-value of 0.296 found in this research for the relationship between attitude and behaviour with regard to sustainable fisheries. The r-values for attitude and behaviour for the micro-plastics and coastal tourism surveys are higher at 0.495 and 0.442, respectively. Michalos et al. (2017) found an r-value of 0.35 for attitudes and behaviour towards sustainable development which is slightly higher than the r-value found in this research for the same relationship related to sustainable fisheries. One of the behaviour questions in our sustainable fisheries OL survey relates to supporting campaigns that tell people to eat seafood that is sustainably sourced. Adding a related attitude

question asking people what their attitude is towards such campaigns could improve the overall measurement of the attitude and behaviour questions in the sustainable fisheries OL survey.

The reason why no significant correlation was found between knowledge and attitude, or knowledge and behaviour could be related to the quality of the questions. If the knowledge questions were more aligned with measuring knowledge related to the specific topics being measured in the attitude and behaviour questions, a significant correlation may exist. One of the coastal tourism attitude questions measures how worried respondents are about the effects of coastal tourism activities on the marine environment. Adding a knowledge question to the survey which tests a respondent's knowledge related to coastal tourism activities may help us to identify the knowledge which relates to a high level of pro-ocean-environmental concern in relation to coastal tourism activities. An example of such a question would be "How does the activity of cleaning seaweed from a beach impact the coastal environment?" Care should be taken to ensure that aligning the knowledge questions with the attitude and behaviour questions will not constrain the measurement too much and will not create questions that are too difficult for the respondents to answer correctly. Appendix 4 contains examples of improved questions for the surveys.

5.5.2 Reliability

The Cronbach's alpha values for the attitude and behaviour questions in the surveys shows an acceptable to good reliability except for the attitude questions in the sustainable fisheries OL survey. The Cronbach's alpha value for the attitude questions in the sustainable fisheries OL survey was 0.604. This value could be increased to 0.744 if attitude question 12 was removed from the survey. Question 12 in the sustainable fisheries OL survey is related to both the benefit to the marine environment and the fishing industry of buying and eating seafood that is labelled sustainable. This question could be improved by dividing it into 2 questions, one which relates to the benefit to the marine environment and another which relates to the fishing industry.

5.5.3 Rasch Estimates

The Rasch analysis of the knowledge questions in the micro- plastics OL survey shows that the most difficult question was question 5 “Select products which might have contained micro-beads in the past” and the least difficult question was question 7 “Where does the majority of our plastic waste end up?”. The respondents and questions are grouped towards the centre of the logit scale in the Rasch person-item map which indicates that the questions are not measuring the upper and lower respondent abilities. The error associated with each of the questions is low due to the fact that there are a lot of respondents grouped at the same logit level as the questions.

The Oufit Zstd value for question 2 is 4.0 which is well outside the acceptable range of -2 to 2. This means that question 2 does not fit with the unidimensionality of the micro-plastics OL survey. Question 2 is “Which of the face wash ingredients shown might be micro-plastics? An image and a list of options to choose from are provided to the respondent. The correct answer to the question is a single option but the format of the question allowed the respondent to choose multiple options. This may explain why question 2 had poor fit in the Rasch analysis. To improve the fit of this question the format of the question could be changed to only allow the respondent to choose one option. The rest of the knowledge questions in the micro-plastics OL survey have Oufit Zstd values which are within the acceptable range. Improving the set of micro-plastic knowledge questions, with a view to making them a more effective scale to measure the levels of OL possessed by respondents, would involve creating more knowledge questions that are more difficult and less difficult. These new questions could be combined with the existing questions, the survey could then be administered to another cohort, and Rasch analysis could be used to check the improvement of the questions as a scale to measure OL in relation to micro-plastics knowledge.

The Rasch analysis of the coastal tourism knowledge questions shows that the most difficult question is question 3 “Please choose the main effects of coastal development from the list below” and the least difficult question is question

1 “The picture below shows a paradise beach in the middle of summer. There is an artificial rock barrier in front of the beach. What is the function of the artificial rock barrier?” The person-item map shows that the questions are spread out along the logit scale with questions 2, 5, and 1 measuring ability below the zero-logit point and questions 3 and 4 measuring abilities above the zero-logit point.

The error associated with the Rasch measure for each of the respondents is larger than the error associated with the items which is due to the fact that there are only 5 coastal tourism knowledge questions, and they are spread out along the logit scale. To increase the effectiveness of the coastal tourism knowledge questions, more knowledge questions could be created to measure the levels of knowledge in between the existing knowledge questions. As well as being the least difficult question, question 1 is also the question with an Outfit Zstd value of 2.9 which is outside the acceptable range of -2 to 2. The reason question 2 does not appear to fit with the measurement of respondents’ knowledge related to coastal tourism may be due to the fact that question 2 is a question more related to coastal erosion rather than coastal tourism. To improve the fit of this question, it would need to be changed to focus more on coastal tourism.

The Rasch analysis of the sustainable fisheries knowledge questions shows that the most difficult question is question 1 “What is the kind of fishing shown in the image below?” and the least difficult question is question 5 “The picture below shows a Cod (Gadus morhua) fish. Where does the Cod species live?” The person-item map for the sustainable fisheries knowledge questions shows that most of the questions are grouped below the zero-logit point which means that the survey is providing measurements of respondents with medium to low knowledge levels. Questions 1 and 8 are the only questions above the zero-logit point. Improving the set of sustainable fisheries knowledge questions as a scale to measure OL knowledge related to sustainable fisheries would involve creating more knowledge questions to measure those respondents with medium to high knowledge related to sustainable fisheries.

The positioning of the respondents with medium to high knowledge of sustainable fisheries has a larger error than the positioning of those with medium to low knowledge. This is due to the fact that there are less questions in the medium to high knowledge section. The "Outfit Zstd" value for question 9 is 2.1 which is just outside the acceptable range for fit. Question 9 relates to the percentage of the global population that depends on the ocean for food. A way of attempting to improve this question could involve adding more specific information to the wording of the question.

5.5.4 Question Distractors

The distractor analysis of the micro-plastics knowledge questions indicated that questions 4 and 7 could be improved. Question 4 is "Sunlight can degrade plastics in the ocean: true or false?" More respondents chose the incorrect (false) answer than the correct answer. This question could be improved by adding a third option to allow the respondent to indicate if they are unsure about the answer. Question 7 is "Where does the majority of our plastic waste end up?" and less than 5% of respondents chose the options "Burned for energy" and "Recycled". This question could be improved by removing these answer options and possibly adding in an option which would more successfully attract respondents who are unsure about the correct answer. Similarly, 2 of the coastal tourism knowledge questions and 6 of the sustainable fisheries knowledge questions had distractors which were chosen less than 5% of the time. Each of these questions would benefit from a review of their distractors with a view to removing options which do not sufficiently distract unsure respondents.

5.6 Chapter Summary

The types of analysis I performed on the responses to the survey questions were descriptive analysis, correlation analysis, reliability analysis, Rasch analysis, and distractor analysis. The descriptive analysis provides an overview of the responses to the surveys and gives an indication of the levels of knowledge, attitude and behaviour that exists in relation to the survey topic. The correlation analysis measures the strength of the relationship between the knowledge, attitude, and behaviour questions. A strong correlation is important when the surveys are being used as pre- and post-surveys to measure the effectiveness of OL tools because it indicates that those who score well on the knowledge questions also have a high level of attitude and behaviour. Reliability, Rasch and distractor analysis provide information on how the surveys can be improved which makes the surveys more effective as pre- and post-surveys.

Chapter 6

Evaluation of the Effectiveness of OL Tools

6.1 Introduction

This chapter begins with a description of the micro-plastics and coastal tourism OL tools which were created in the ResponSEAble project. This is followed by sections on the micro-plastics and coastal tourism DAPSIWR models, and the knowledge attached to each of the elements of the models, by the domain experts. The micro-plastic survey, which I created, is then discussed and this is followed by a description of the micro-plastics OL tool which I also created. The micro-plastics OL tool was created based on the knowledge attached to the micro-plastics DAPSIWR model. The following results section contains the results of the data analysis applied to the responses of the microplastics survey and its use as a pre- and post-survey to measure the effectiveness of the microplastics OL tool. The chapter then closes with a discussion of the results of the data analysis.

6.2 Micro-plastics Ocean Literacy Tools

The micro-plastics OL tools which were developed as part of the ResponSEAble project were an interactive and educational map, a video on rethinking plastic in the Atlantic, a cartoon on micro- and nano-plastics, and three posters related to the problem of micro-plastics. The interactive map leads the user through the main aspects of the micro-plastics story while allowing them to delve into individual topics as they wish. Figures 6.1 and 6.2 shows an example of what the user sees while viewing the interactive map. Information is provided to the user on the impacts of micro-plastics in the ocean and they are shown an interactive image related to the impacts (figure 6.2). The user can click on each of the elements in the interactive

image to learn more about the impact of micro-plastics on fish, the water in the ocean and the seabed. Some examples of the topics covered by the interactive map are micro-plastics in seafood (potential), plastic marine debris, awareness raising campaigns, market response to the phase out of microbeads, cosmetic production, and the transport of plastic pellets and polymers.

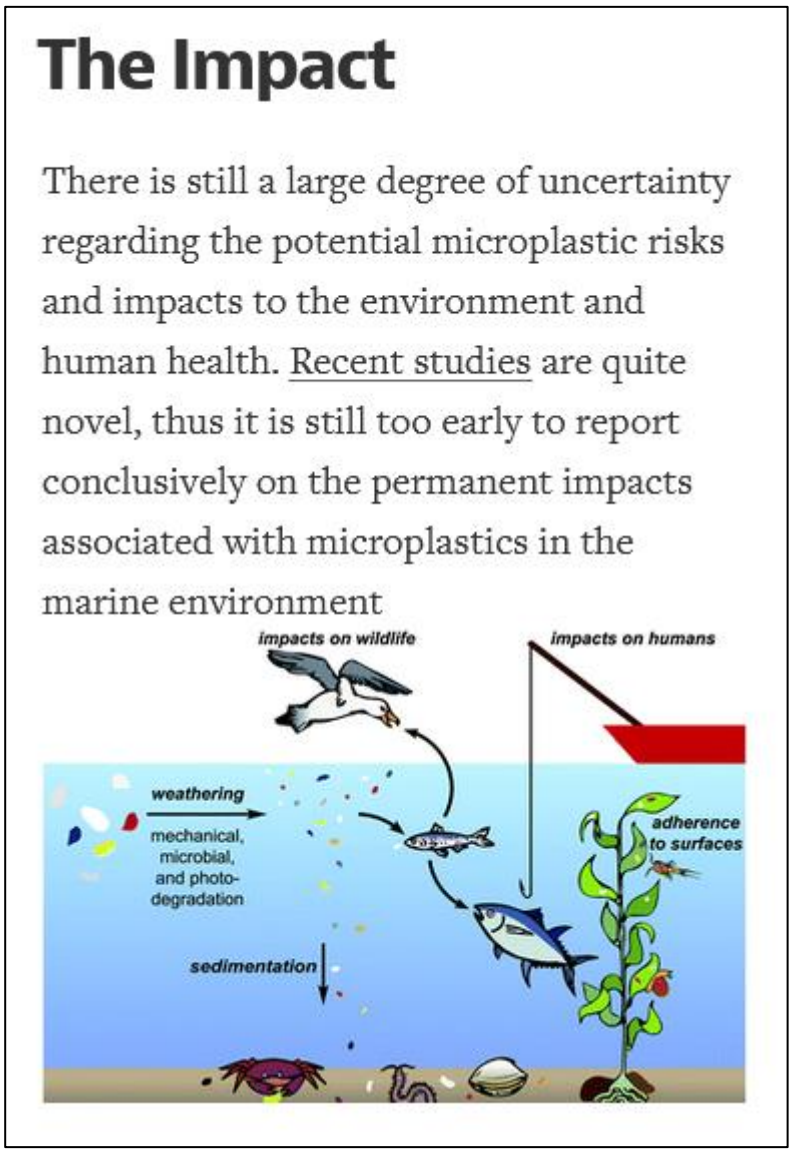

Figure 6.1: Example of interactive map (left section)

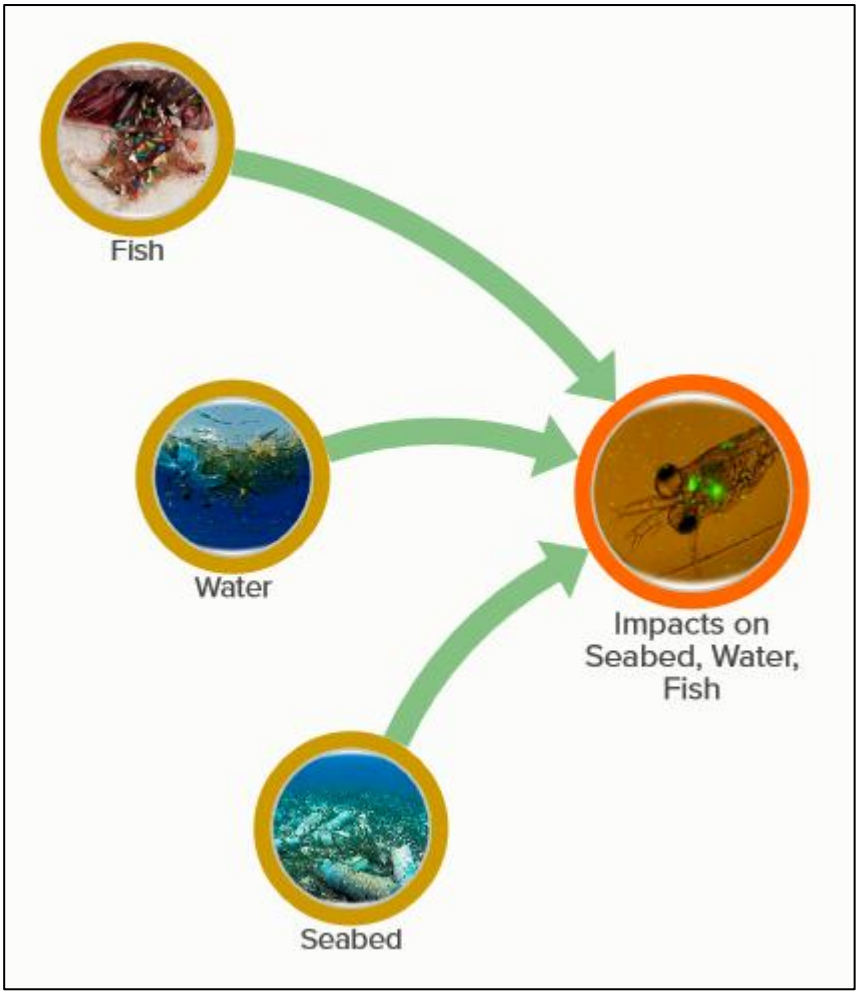

Figure 6.2: Example of interactive map (right section)

The video on rethinking plastic in the Atlantic consists of experts providing information to the viewer on topics including the dispersion of micro-plastics in the ocean, the amount of plastic waste produced in Europe, information on the attributes of micro-plastics, where micro-plastics come from, and the effects of the ingestion of micro-plastics on marine life. The cartoon on micro- and nano-plastics takes the user through the aspects of the problem of micro-plastics from the point of view of drivers, activities, pressures, states, impacts, welfare, responses, and management. The activity section of the cartoon tackles where plastics products come from and where they go. It starts with shipping, then shows the product being transported to the supermarket, the purchase of the product by the consumer, the use of cosmetic products by the consumer, and the treatment of wastewater containing micro-plastics.

The three posters provide information related to turning the tide on plastic in the ocean, a scientific view of micro-plastics, and selling products without plastic packaging. Figure 6.3 shows a section of the posters which displays a cycle related to micro-plastics. It starts with the attributes of plastic as a material and its widespread availability, moving to how plastic enters the waste stream, then to the effects of plastic on marine life, and finishes with information related to the responses to the problem of micro-plastics from government organisations and the consumer.

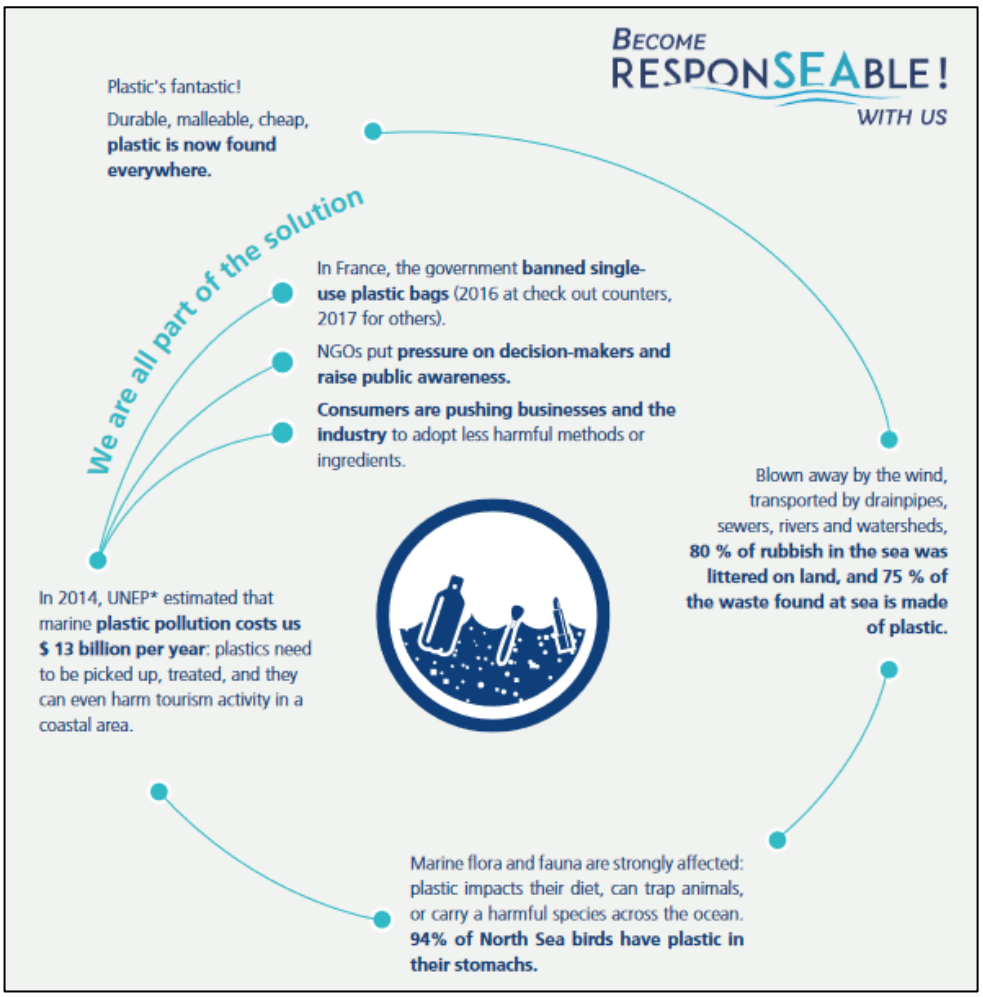

Figure 6.3: Section of micro-plastics poster

6.3 Coastal Tourism Ocean Literacy Tools

The ResponSEAble coastal tourism OL tools included a web story, a cartoon, a video, and a systems thinking tool. The coastal tourism web story is presented as a web document which allows users to view the main information related to coastal tourism. It provides information on the development of coastal tourism, the increase in the number of tourists over the years, and the changes to the coastline brought about by coastal development. The user can view and interact with images which show how a location once discovered can become a popular tourist destination, and the tool also shows a comparison between tourist destinations before and after they become popular. Figures 6.4 and 6.5 show images of Lloret de Mar, Spain in the 1900s and the present day. The images are used in the web story to show the effects of tourism on coastal areas. The web story also provides cause and effect information, and information related to sustainable tourism.

Figure 6.4: Lloret de Mar, Spain in the 1900s

Figure 6.5: Present day Lloret de Mar, Spain

The coastal tourism cartoon takes the user through a sequence which begins with an unspoiled beach, followed by peoples' need for holidays by the sea, the building of hotels to meet demand, the reduction of the beach due to development, and the damage to the seabed. The cartoon characters take a boat trip and notice how the building of a marina has altered currents and affected the movement of sand. They also see the effects of anchors dragging on the sea floor, the effects of development on marine life breeding sites, and buildings built too close to the shore. Towards the end of the cartoon the user is provided with information on how improvements can be made to minimise the negative effects of costal tourism which include minimum distance regulations for building near the shoreline and using some of the proceeds from coastal tourism to restore habitats.

The video "Making Tourism Sustainable – The Mediterranean" visits one of Italy's main coastal resorts (Rimini) and provides information on the new sustainable approach that is being taken to reduce the negative impact of tourism on the ocean environment. The measures implemented include the construction of cycle lanes to reduce car traffic, increased facilities for recycling waste, and the restoration of an environmentally degraded area by planting trees and creating a sand dune to protect the coast. Towards the end

of the video the user is provided with information on a beach facility which was developed to reduce the negative effects on the environment. The facility contains small waste recycling points, solar panels, geothermal heat pumps, and a wastewater recycling system for showers.

The “Systems Thinking for Sustainable Tourism” tool demonstrates the usefulness of using Systems Thinking approaches to develop a better understanding of the mechanisms at play in relation to the problems caused by coastal tourism. It provides information on why mass coastal tourism is a problem, systems and ocean literacy concepts, the effects of mass tourism on the coastal environment, countering the effects of mass tourism, a case study on a coastal resort, uncontrolled growth, systems thinking for sustainable tourism, and how investing in the environment can change the dynamics of coastal tourism. As the user proceeds through the tool, they can adjust dials related to the regeneration and degeneration rates to see how they affect the environmental quality over a 20-year period, and also see the effect of the increase in tourist numbers on the quality of the environment. Figure 6.6 contains examples of images used in the systems thinking tool which are related to countering the effects of mass tourism on the coastal environment. The images provide information related to wastewater treatment, recycling facilities, beach erosion barriers, and beach nourishment. Beach nourishment is related to the use of coastal defence schemes to regularly replace beach sand which has been lost through drift and erosion.

Figure 6.6: Example images from systems thinking tool

6.4 The Micro-plastics DAPSIWR Model

The micro-plastics model created by the domain experts, using the online Causal Mapping tool, is based on marine science literature related to the problem of micro-plastics in the ocean. Figure 6.7 shows a section of the micro-plastics DAPSIWR model which includes the Driver: Material availability of plastic, the Activity: Micro- plastics added to cosmetics, and the Pressure: Micro-plastics in the ocean. The image shows that due to the material availability of plastics, micro-plastics are added to cosmetic products which in turn cause the existence of micro-plastics in the ocean. The relevant actors for the activity of adding micro-plastics to cosmetics products are Cosmetic manufacturers. The relevant actors related to the link between micro-plastics added to cosmetics and the existence of micro-plastics in the ocean is Wastewater treatment managers.

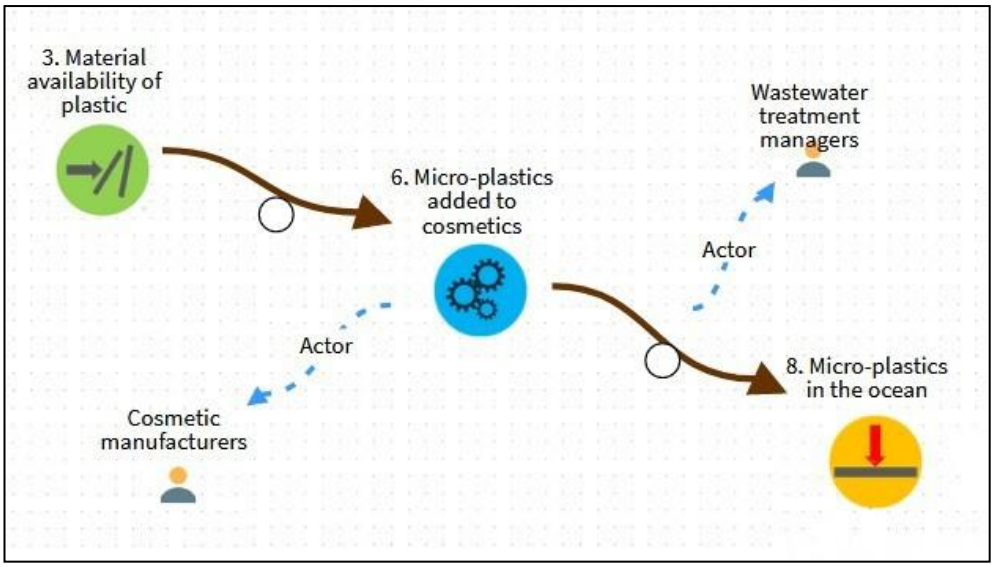

Figure 6.7: Driver-activity-pressure in the micro-plastics DAPSIWR model

Figure 6.8 shows the section containing the Impact: "Increase of micro-plastics in the ocean", Welfare: "Micro-plastics in seafood (potential)" and the Response: "Checking for micro-plastics in cosmetic products". The image shows that the increase of micro-plastics in the ocean has the potential to introduce micro-plastics into seafood and a response to this issue could be for cosmetics consumers (actors) to check if their cosmetic purchases contain micro-plastics. The relevant actors affected by the existence of micro-plastics in seafood are the general public. Responses close the loop on the story creation process, for example, the Response "Checking for micro-plastics in cosmetics purchases" will have a bearing on the Activity of adding micro-plastics to cosmetic products.

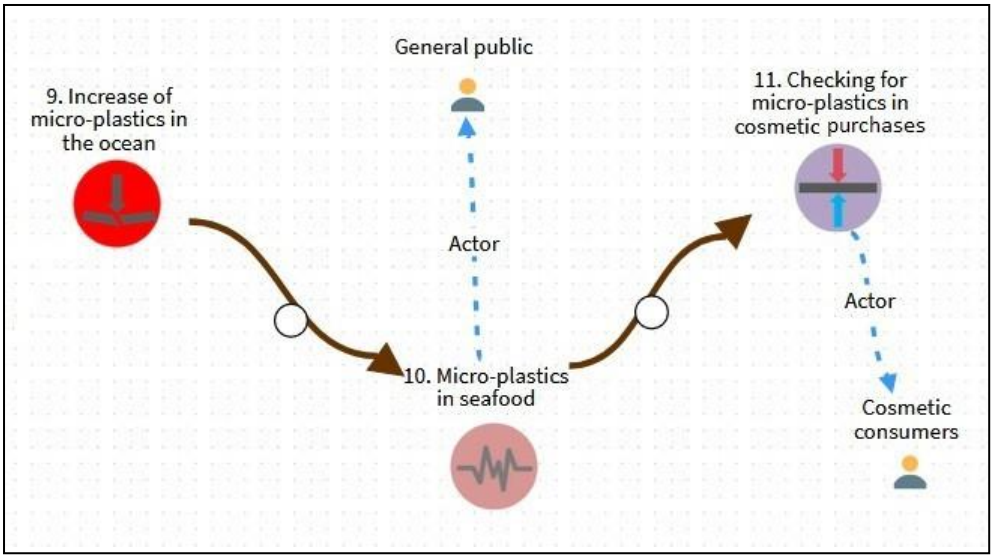

Figure 6.8: Impact-welfare-response in micro-plastics DAPSIWR model

6.5 The Coastal Tourism DAPSIWR Model

The online Causal Mapping tool was used by subject matter experts to create a DAPSIWR model of the ocean-environmental problems related to coastal tourism. An example of a path through the coastal tourism model contains the Driver "Interest in sun, sea, and sand holidays", Activity "Construction of structures on the coastline", Pressure "Coastal Erosion", Welfare (impact) "Reduction of beach and damage to infrastructures", and Response "Laws on setback zones". The actors attached to this path through the Coastal Tourism model are "Tourists", "Construction companies", and "Hotel owners".

Figure 6.9 shows a section of the coastal tourism model containing the Driver "Economic benefits of tourism" which leads to the Activity "Food and beverage services" which causes the Pressure of "Marine litter". The Actors "Hotel owners" and "Restaurant owners" benefit economically from tourism, and "Restaurant owners" perform the activity of providing "Food and beverages services.

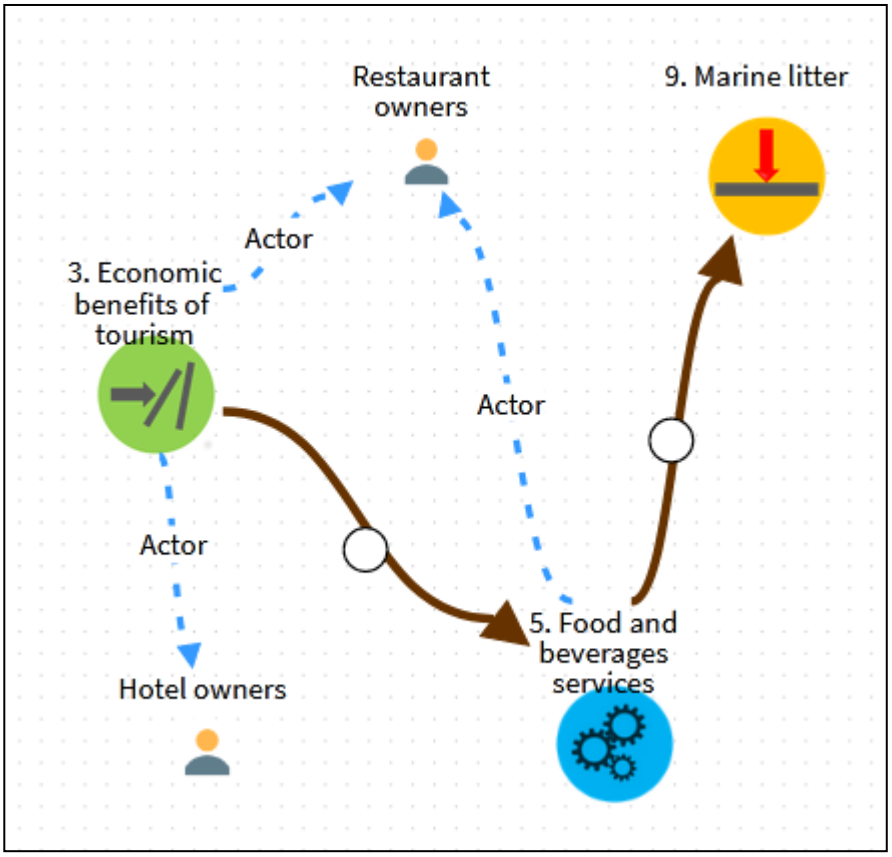

Figure 6.9: Driver, activity, and pressure in coastal tourism model

The part of the DAPSIWR model for coastal tourism shown in figure 6.10 contains the Activity “Construction of structures on the coastline”, Pressure “Habitat fragmentation and deterioration”, Impact “Disturbance of nesting and breeding sites”, Welfare (impact) “Reduction in species numbers”, and Response “Sustainable development goals”. This part of the coastal tourism model shows that the activity of construction of structures on the coastline leads to the pressure of habitat fragmentation and deterioration which has the impact of disturbing nesting and breeding sites. The disturbance of nesting and breeding sites causes a reduction in species numbers, which has an impact on human welfare, and a response to this situation is the implementation of sustainable development goals. Figure 6.10 represents a feedback loop where the response of implementing sustainable development goals has an effect on the construction of structures on the coastline.

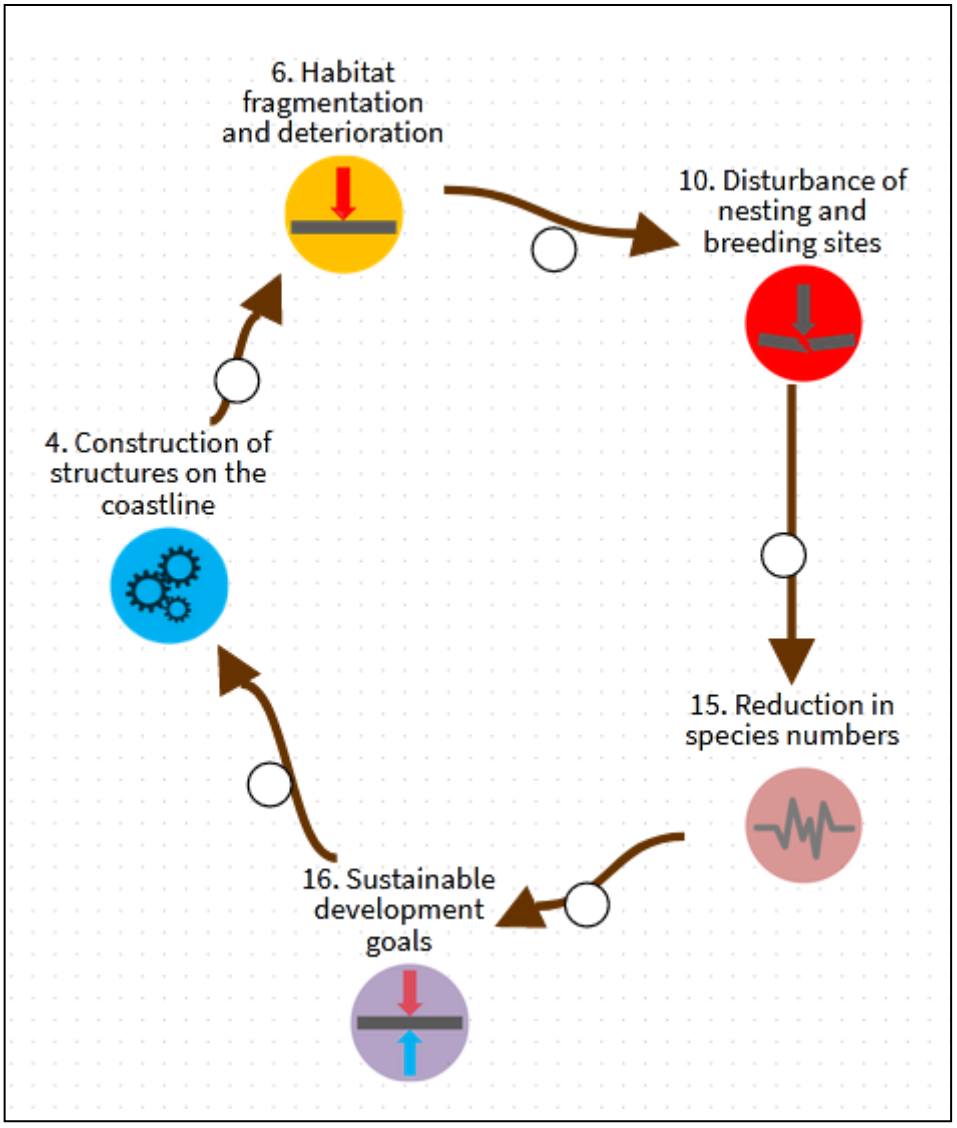

Figure 6.10: Activity, pressure, impact etc. in coastal tourism model

6.6 Relevant Micro-plastics Knowledge

The knowledge relevant to the problem of micro-plastics in the ocean was identified and attached to the causal model elements by the domain experts. An example of the knowledge associated with the link between the Driver: "Cosmetic consumption patterns" and the Activity: "Production of cosmetic products" (figure 6.11) is "In 2015, European cosmetics consumption was the largest market in the world at €72 billion, far ahead of the United-States at €37.8 billion, and Japan at €29.3 billion". An example of the knowledge associated with the link between the Activity: "Micro-plastics added to

cosmetics" and the Pressure: "Micro- plastics in the ocean" (figure 6.7) relates to the fact that only a portion of micro-plastics are removed from the water in wastewater treatment systems.

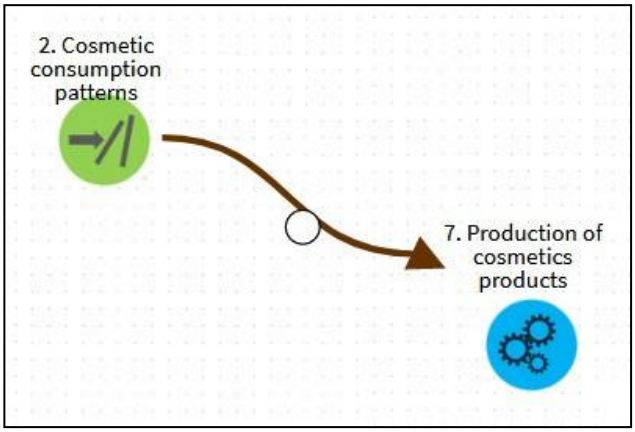

Figure 6.11: Driver-activity in micro-plastics DAPSIWR model

Figure 6.12 shows part of the micro-plastics causal map which contains the Driver: "Need for product packaging", Activity: "Production of plastic packaging" and Pressure "Micro-plastics in the ocean". An example of knowledge associated with the Driver: "Need for product packaging" is "There are several sources of macro-plastic, such as equipment for fisheries, aquaculture and recreational users. These larger pieces of plastics are fragmented into smaller pieces (micro-plastics) by weathering". An example of knowledge associated with the Activity: "Production of plastic packaging" is "In 2012, Plastics Europe reported that annual plastic production had increased from 1.5 million tonnes in the 1950s to approximately 280 million tonnes in 2011". An example of knowledge associated with the Pressure "Micro-plastics in the ocean" is "The durability of plastic presents major threats to the marine environment; it affects habitats, living organisms, and ecosystems. Concentrations of micro-plastics are especially high in the Mediterranean Sea".

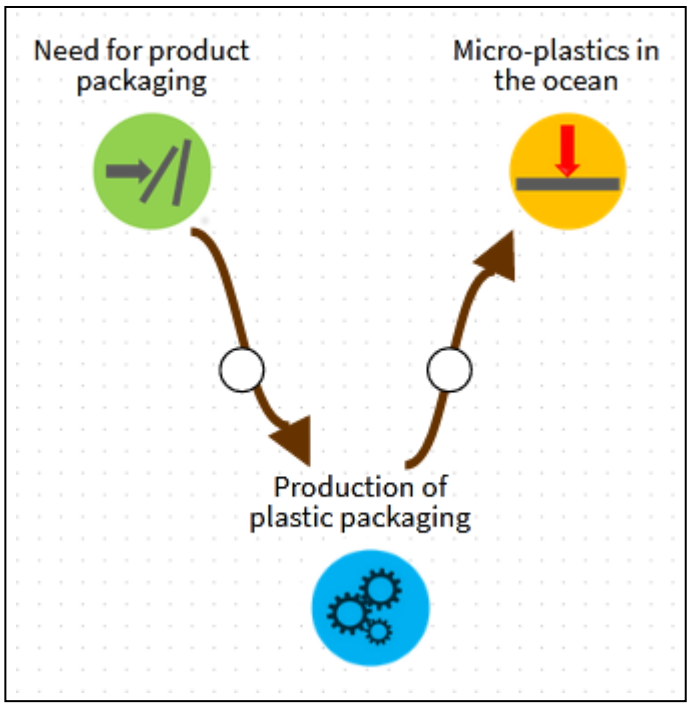

Figure 6.12: Driver-activity-pressure in micro-plastics DAPSIWR model

6.7 Relevant Coastal Tourism Knowledge

The subject matter experts identified the relevant knowledge for the coastal tourism causal model and attached the knowledge to the DAPSIWR elements of the coastal tourism model using the Causal Mapping and Knowledge Capture tool. An example of the identified knowledge is “Over the decades, in particular from the 1960s up to the 1980s, the need for accommodating growing numbers of tourists has led to the massive urbanization of portions of the Mediterranean coast, often in a rapid and uncontrolled manner”. This knowledge is associated with the link between the Driver “Interest in sun, sea, and sand holidays” and the Activity “Construction of structures on the coastline”. An example of the knowledge associated with the Driver “Economic benefits of tourism” is “Tourism accounts for 10% of global GDP making it a very important sector in the world”. An example of knowledge associated with the link between the Activity “Construction of structures on the coastline” and the Pressure of “Soil sealing” (figure 6.13) is “Coastal development causes a high rate of soil sealing, which results in a large amount

of water reaching the urban drainage system –which is then discharged into the sea".

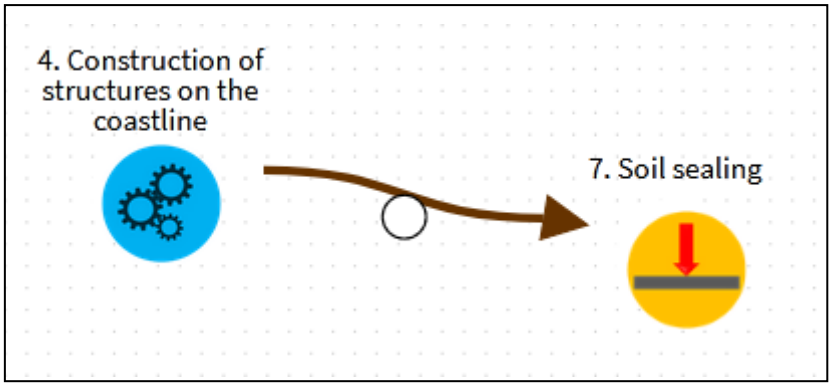

Figure 6.13: Activity and pressure in coastal tourism model

Figure 6.14 shows part of the coastal tourism DAPSIWR model which contains the Pressure "Coastal erosion", Welfare (impact) "Reduction of beach and damage to infrastructures", and Response "Laws on setback zones". An example of the knowledge associated with the Pressure "Coastal erosion" is "A typical response to erosion is building erosion barriers (parallel or perpendicular to the beach) and the artificial nourishment of eroded beaches". An example of knowledge related to the Welfare (impact) "Reduction of beach and damage to infrastructures" is "The construction of recreational ports and marinas implies digging activities and the modification of the seabed. The combination of these two phenomena ultimately alters sediment dynamics and marine currents, which in turn contribute to erosion issues". An example of knowledge associated with the Response "Laws on setback zones" is "Law 1337/1983 'Urban development and relative provisions. This Law (which constitutes the basic legal framework for urban planning in Greece) is intended to control haphazard urban and ex-urban development, and thus required master plans for all urban areas".

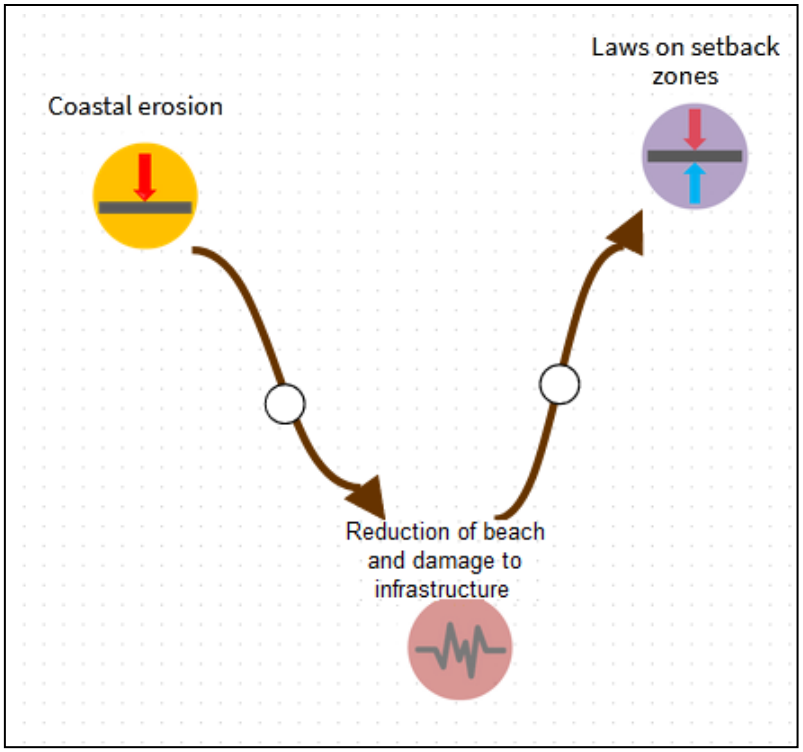

Figure 6.14: Pressure, welfare (impact), and response in coastal tourism model

6.8 The Micro-plastics Survey

I created the micro-plastics survey using the causal map created by the domain experts and the knowledge they attached to the map. The difference between this survey and the survey described in section 5.1 of this thesis is that this survey was created from the domain expert's causal map and attached knowledge, while the previous micro-plastics survey was a combination of questions that were available from the ResponSEAble project work. Table 6.1 shows a summary of the surveys performed in this research.

Survey Topic	Survey Participants	Description	No. of Responses	Purpose of Survey
3 surveys on: Micro-plastics (MP), Coastal Tourism (CT), and Sustainable Fisheries (SF)	University students, aged 18 to 24 years	Survey content based on existing questions created in the ResponSEAble project	MP: 70 CT: 69 SF: 45	An experiment in surveying and data analysis
2 surveys on: Micro-plastics and Coastal Tourism	Respondents aged between 18 and 25 holding a US bachelor's degree	Survey content based on domain expert knowledge attached to DAPSIWR model elements	MP: 80 CT: 76	Development of surveys suitable for use as pre- and post-surveys to measure the effectiveness of OL tools
Pre- and post-survey on Micro-plastics	Respondents aged between 18 and 25 holding a US bachelor's degree	The survey contained the 12 most difficult questions from the previous micro-plastics survey	34 responses to both the pre- and post-survey	To measure the effectiveness of the micro-plastics OL tool

Table 6.1: Summary of surveys performed

Appendix 5 shows the contents of the micro-plastics survey. The survey contains 5 sections: (i) Respondent information e.g. Amazon Mechanical Turk worker Id, city, education level, (ii) Knowledge questions on the micro-plastics topic, (iii) Questions related to the respondent's attitude towards micro- plastics in the ocean, (iv) Current behaviour questions in relation to micro- plastics, and (v) Questions related to the intended future behaviour of the respondent in relation to micro-plastics.

The survey questions were created by analysing the knowledge associated with each of the elements of the micro-plastics model and choosing knowledge which could be converted into relevant questions to ask the respondents to the survey. An example of a piece of knowledge and its associated survey question was the knowledge "Once the plastic reaches the ocean, its greatest strength – its durability – also provides a key cause for concern as it accumulates in the ocean" and its associated question was "Which one of the following characteristics of plastic causes the greatest concern when it reaches the ocean? Flexibility, durability, texture, or colour". The knowledge questions in the survey were multiple choice questions and each was associated with an element or link in the micro-plastics model. An example of a knowledge question which was associated with the link between the Driver: "Cosmetic consumption patterns" and the Activity: "Production of cosmetic products" is "Please choose the area with the highest global cosmetics consumption: United States, Europe, or Japan?"

The attitude questions in the survey focus on the most important issues related to the existence of micro-plastics in the ocean from the point of view of the interaction between humans and the ocean environment. They measure respondents' attitude towards damage to the natural environment, the use of micro-plastics in cosmetics, a ban on the use of micro-plastics in cosmetics, the problems micro-plastics in the ocean might cause, and the type of effect on the ocean if people stop using products containing micro- plastics. The current and future behaviour questions focus on the level to which respondents perform pro-ocean-environmental actions in relation to micro-plastics in the ocean. They measure behaviour related to plastic recycling;

looking for products which do not contain micro-plastics; looking for products that use recycled packaging, recyclable packaging, or no packaging; supporting brands that don't sell products containing micro-plastics; and supporting campaigns to ban the sale or use of micro-plastics in products.

The approach used to create the coastal tourism survey was similar to the approach I used to create the micro-plastics survey. Appendix 6 contains a description of the coastal tourism survey, the results and analysis of the responses to the survey, and a discussion of the insights I gained from the use of the survey.

6.9 The Micro-plastics OL Tool

After the Rasch analysis was performed on the responses to the micro-plastics survey, I identified the top twelve most difficult questions which provided me with insights into the areas of the micro-plastics topic which the respondents had the least knowledge on. I created a pre- and post-survey which contained the top 12 most difficult questions, and an OL tool which provided the information required to answer the 12 most difficult questions. The content of the OL tool was based on the micro-plastics causal map and its attached knowledge. The micro-plastics OL tool is shown in appendix 7. The pre-survey, OL tool, and post-survey were administered in Google forms and respondents were asked to (1) Take the pre- survey, (2) View the OL tool, and (3) Take the post-survey. This approach was used to obtain a measure of respondents' knowledge before they used the tool and then a measure of their knowledge after they used the tool. A paired t-test was then used to measure the difference between the pre- and post-scores to provide a measurement of the effectiveness of the OL tool. The 12 most difficult questions were questions numbered 3, 10, 8, 7, 19, 4, 6, 9, 22, 18, 11, and 17.

6.10 Results

The total number of responses to the micro-plastics survey was 80, which included 32 males and 48 females. The respondents were between the ages of 18 and 25, located in the US, and have a Bachelor's degree. The respondents' city locations were from across the US and included Denver, Boston, Houston, and Seattle. There were a range of main subjects studied by the respondents' which included Biochemistry, Engineering, and Finance. The average score achieved by the respondents to the survey on knowledge related to micro-plastics in the ocean was 67.10%. The average score for attitude was 8.33 out of 10, the average score for current behaviour was 6.5, and the average score for future behaviour was 7.66.

6.10.1 Correlation Analysis

The correlation analysis of the responses to the micro-plastics survey shows that there is a significant positive correlation between knowledge, attitude, and behaviour. The Pearson correlation r-value for the correlation between knowledge and attitude is 0.388 with the correlation significant at the 0.01 level (2-tailed). The r-value for the correlation between knowledge and current behaviour is 0.246 with the correlation significant at the 0.05 level (2-tailed). The r-value for the correlation between knowledge and future behaviour is 0.323 with the correlation significant at the 0.01 level (2- tailed). The r-value for the correlation between attitude and current behaviour is 0.591 with the correlation significant at the 0.01 level (2- tailed). The r-value for the correlation between attitude and future behaviour is 0.759 with the correlation significant at the 0.01 level (2-tailed).

6.10.2 Reliability Analysis

The Cronbach's alpha values for the attitude, current behaviour, and future behaviour questions in the micro-plastics survey are 0.902, 0.890, and 0.939, respectively. Tables 6.2, 6.3, and 6.4 show the question text, mean, standard deviation, and the "Cronbach's alpha if item deleted" for the attitude, current behaviour, and future behaviour questions.

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Q23: How do you feel about damage to the natural environment?	8.50	2.13	0.854
Q24: How do you feel about the use of micro-plastics in cosmetic products?	8.00	2.38	0.868
Q25: To what extent do you agree that the use of micro-plastics in cosmetics should be banned?	8.69	1.95	0.885
Q26: How do you feel about the problems micro-plastics in the ocean might cause?	8.46	2.30	0.862
Q27: What type of effect do you feel there will be on the ocean if people stop using products containing micro-plastics?	8.01	2.22	0.928

Table 6.2: Mean, standard deviation, and "Cronbach's alpha if item deleted" for the micro-plastics attitude questions

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Which of the following options to reduce the effects of micro-plastics on the marine environment do you do?			
Q28: I separate plastics for recycling.	7.28	2.78	0.917
Q29: I look for products that do not contain micro-plastics (such as some cosmetic products).	5.30	3.38	0.868
Q30: I look for products that use recycled packaging or recyclable packaging.	6.88	2.71	0.867
Q31: I look for products that do not use any packaging.	6.05	2.86	0.858
Q32: I support brands that don't sell products containing micro-plastics.	6.63	2.88	0.855
Q33: I support campaigns to ban the sale or use of micro-plastics in products.	6.88	3.09	0.850

Table 6.3: Mean, standard deviation, and "Cronbach's alpha if item deleted" for the micro-plastics current behaviour questions

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Which of the following options to reduce the effects of micro-plastics on the marine environment will you do in the future?			
Q34: I will separate plastics for recycling.	7.98	2.45	0.956
Q35: I will look for products that use recycled packaging or recyclable packaging.	7.58	2.34	0.924
Q36: I will look for products that do not use any packaging.	7.24	2.39	0.926
Q37: I will look for products that do not contain micro-plastics (such as some cosmetic products).	7.58	2.61	0.918
Q38: I will support brands that don't sell products containing micro-plastics.	7.81	2.55	0.921
Q39: I will support campaigns to ban the sale or use of micro-plastics in products.	7.78	2.63	0.917

Table 6.4: Mean, standard deviation, and "Cronbach's alpha if item deleted" for the micro-plastics future behaviour questions

6.10.3 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a way of analysing the relationship between the responses to survey items and the trait they are measuring (e.g. attitude towards micro-plastics in the ocean) and structural equation modelling is used to understand the patterns of relationships between the survey items and the trait being measured. Factor analysis is one of the methods used in structural equation modelling. Figure 6.15 shows the structural equation modelling path diagram for the micro-plastics survey. The CFA results show that both the attitude and behaviour survey items load together tightly and are measuring the trait they were intended to measure.

Figure 6.15 shows the factor loadings for the attitude and behaviour questions in the survey and the Pearson correlation r-values for the interrelations between knowledge, attitude, and behaviour. For interpretation purposes, the closer the factor loading is to 1 or -1 indicates how strongly the survey item influences the trait being measured. In figure 6.15, the range of factor loadings for the attitude questions is 0.735 to 0.836 and the range for behaviour is from 0.468 to 0.884. The factor loadings obtained by Schneiderhan-Opel and Bogner (2021) ranged from 0.38 to 0.61 for the utilisation dimension and from 0.32 to 0.48 for the preservation dimension of the 2-MEV scale. As an example, the factor loading for the 2-MEV utilisation item related to building more roads so people can travel to the countryside was 0.61 and, in this research, I obtained a factor loading of 0.735 for an attitude question related to the use of micro-plastics in cosmetic products. The range of factor loadings, for the New Environmental Paradigm (NEP) scale, obtained by Baierl et al. (2021), was from 0.21 to 0.80, and, as an example, a factor loading of 0.66 was obtained for the NEP item related to the fact that if things don't change, we will soon have a big disaster in the environment.

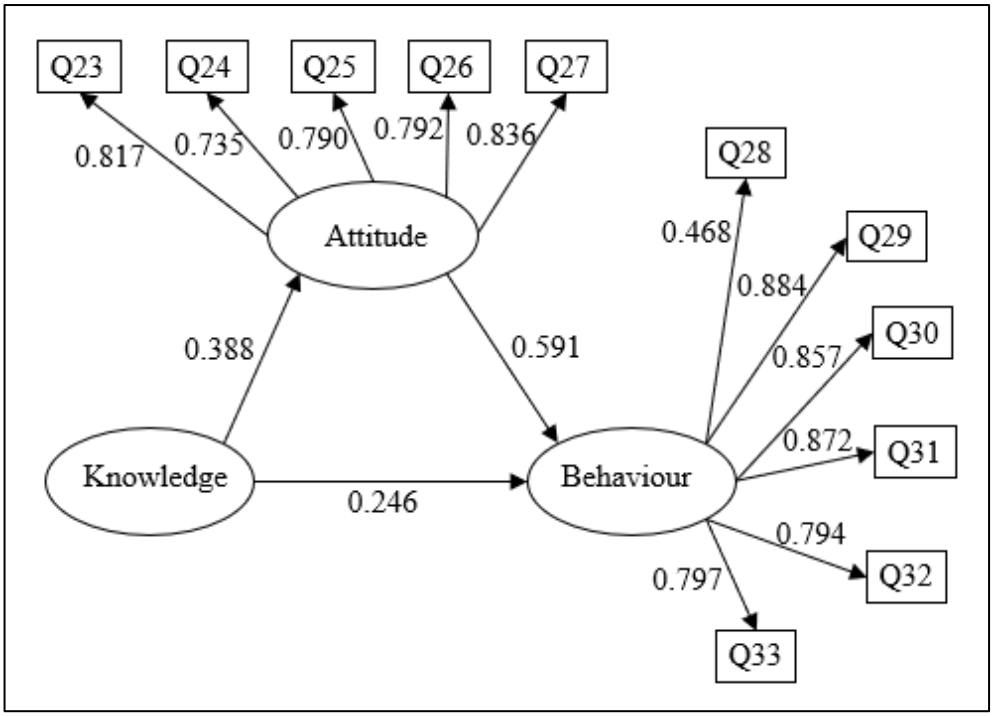

Figure 6.15: Structural equation modelling path diagram for the micro-plastics survey

6.10.4 Rasch Analysis

Rasch analysis is focused on the examination of a single attribute at a time (unidimensional) (Bond and Fox, 2007) and the attribute focused on in this section is respondents' knowledge of the problem of micro-plastics in the ocean. The results of the Rasch analysis of the responses to the micro-plastics survey are shown in table 6.5. The table contains information on the question number used in the survey, the total score (number of respondents who answered the question correctly), the Rasch measure of the question difficulty, the error associated with the Rasch measure, and the fit value for the question.

Question number	Total score	Measure	Standard Error	Outfit Zstd
Q3	14	2.64	0.30	1.4
Q10	17	2.39	0.28	-0.8
Q8	31	1.45	0.24	1.5
Q7	40	0.94	0.24	-1.9
Q19	44	0.71	0.24	0.5
Q4	46	0.60	0.24	2.2
Q6	46	0.60	0.24	-0.5
Q9	50	0.37	0.24	-0.6
Q22	52	0.24	0.25	-0.7
Q18	53	0.18	0.25	2.5
Q11	56	-0.01	0.26	0.5
Q17	59	-0.22	0.27	-1.6
Q5	60	-0.29	0.27	0.8
Q14	60	-0.29	0.27	-0.5
Q15	62	-0.44	0.28	-0.4
Q16	64	-0.60	0.29	-0.1
Q1	67	-0.88	0.31	-0.1
Q2	70	-1.21	0.35	0.2
Q12	72	-1.47	0.38	-0.4
Q13	72	-1.47	0.38	-1.0
Q20	73	-1.63	0.40	-0.3
Q21	73	-1.63	0.40	-0.2

Table 6.5: Rasch estimates for the micro-plastics knowledge questions

6.10.5 Current and Future Behaviour

The double line graph contained in figure 6.16 shows a graph of the respondents' average scores for current behaviour and future behaviour for the micro-plastics survey. The numbers related to the respondents are shown on the horizontal axis and the score related to the respondents' current and future behaviour is shown on the vertical axis. The light grey line shows the respondent scores for current behaviour and the dark grey line shows their scores for future behaviour. The line for future behaviour is generally above the line for current behaviour which shows that in general the respondents intend to improve their behaviour in the future.

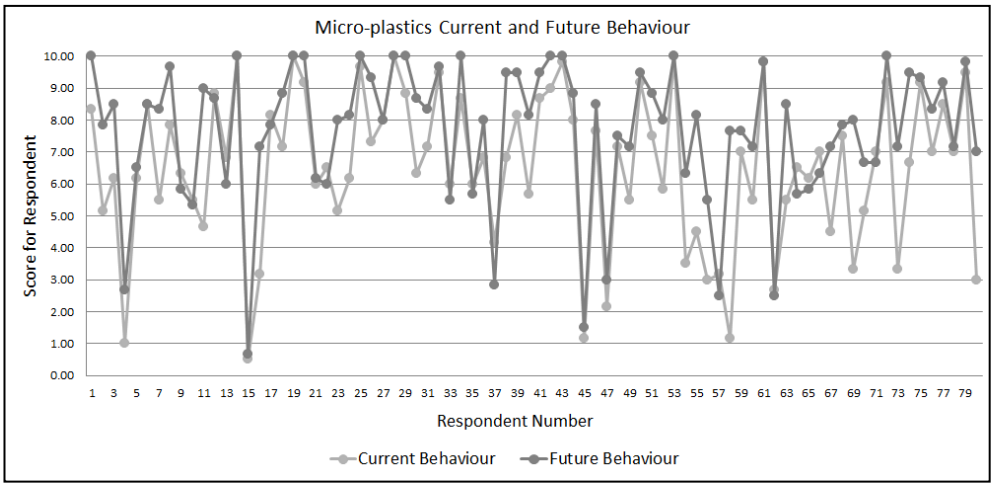

Figure 6.16: Relationship between current and future behaviour for micro-plastics survey

6.10.6 Distractor Analysis

The distractor analysis on the responses to the surveys was performed by identifying the knowledge questions in the surveys that required the respondent to choose a single answer from a list of options, calculating how many times each option was chosen, and checking if the resultant values indicated that the option was chosen more times than the correct answer or less than 5% of the time. 18 of the knowledge questions in the micro- plastics survey had their distractors analysed.

6.10.7 Micro-plastics OL Tool Results

There was a total of 34 respondents who filled out the pre-survey, viewed the OL tool, and filled out the post-survey. The percentage score of correct answers for the pre- and post-surveys achieved by the respondent was calculated. I then compared the scores using a paired t-test in order to gain insight into the effectiveness of the OL tool. The paired t-test is an analysis approach used to measure if the mean values of the responses to the pre- and post-survey scores are statistically significantly different. There are three criteria used with the results of the paired t-test to check for a significant difference. The three criteria are:

1. Is the t-value greater than a critical value that is contained in t distribution table?
2. Is the p-value less than 0.05?
3. Does the 95% confidence interval cross zero?

The result of the paired t-test has a t-value of 6.342 with 33 degrees of freedom and the corresponding value in the lookup distribution table is 2.04. The measured p-value is 0.001 and both the upper and lower 95% confidence intervals are negative, so they do not cross zero. This means that the three criteria are fulfilled which proves that the mean values of the pre- and post-survey scores are statistically significantly different.

29 of the 34 survey respondents got a higher score in the post-survey when compared with their pre-survey score. Three of the survey respondents got a lower mark in the post-survey and two respondents got the same score in both the pre- and post-surveys. A visual comparison of the achieved scores is shown in the double line graph in figure 6.17. In the double line graph, we can see that the line for the post- survey scores is, for the most part, substantially higher than the line for the pre-survey scores. This proves that the micro-plastics OL tool was successful in increasing the respondents OL in relation to micro-plastics.

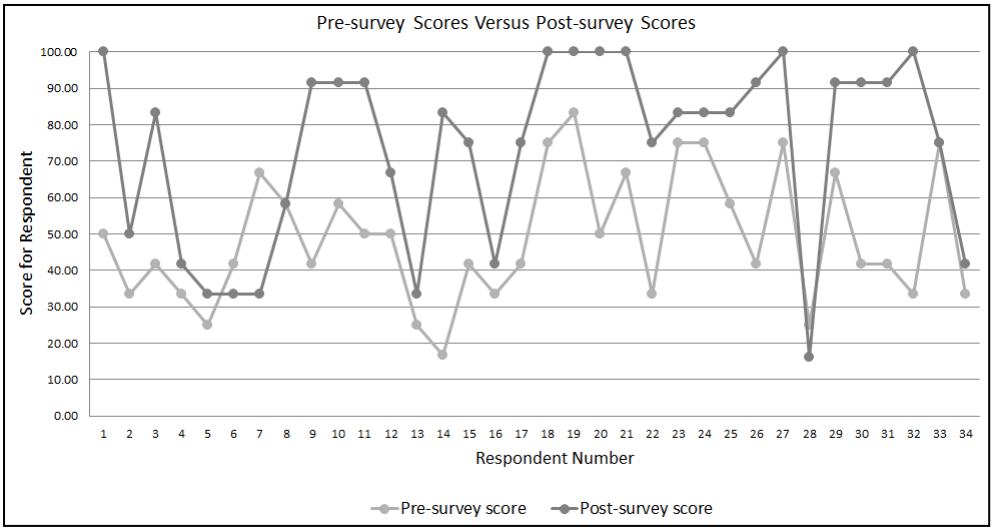

Figure 6.17: Pre- versus post-survey scores for the micro-plastics OL tool

6.11 Discussion

Using my framework, specific topics related to the ocean can be modelled by domain experts and they can attach the relevant knowledge to the elements of the model. The knowledge is then used to create OL tools and pre- and post-surveys to measure the effectiveness of the tools. The analysis of the survey responses provides insights into how the surveys can be improved and identifies gaps in the knowledge.

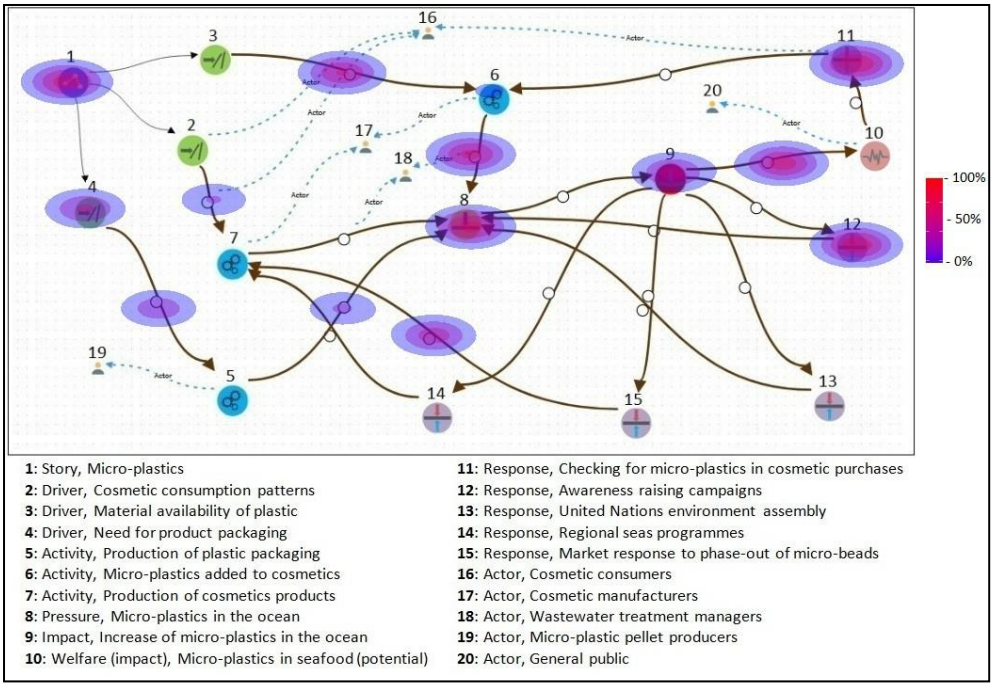

Figure 6.18: Example of how micro-plastics results can be visualised (Heat Mapper, 2019)

Linking the topic knowledge and survey questions with the individual elements of the DAPSIWR model allows us to identify the levels of knowledge possessed by respondents in relation to the individual elements of the DAPSIWR model. In this research, we are drawing a distinction between measuring OL on a broad scale, measuring OL on a specific topic, and measuring knowledge on the DAPSIWR elements of a topic. Measuring OL on a specific topic can be used to measure the effectiveness of an OL tool or initiative using pre- and post-surveys. In large scale surveys, measuring knowledge on the elements of a topic can help to identify where gaps in the knowledge of the topic exist. An example of how the results of the survey can be visualised is shown in figure 6.18. It shows a heat map approach which could be a useful visualisation tool for the results of a large-scale survey (e.g. thousands of people, surveying the full map).

The correlation analysis of the responses to the micro-plastics survey shows that a significant positive correlation exists between the pairings: knowledge and attitude, knowledge and current behaviour, knowledge and future behaviour, attitude and current behaviour, and attitude and future behaviour. The existence of a correlation between these pairings shows that the knowledge questions, created using my framework, are successful in identifying knowledge which correlates with pro-ocean-environmental attitude and behaviour. The r-value of 0.246, for the correlation between knowledge and current behaviour, found in this research is slightly lower than the r-value of 0.27 found by Díaz-Siefer et al. (2015) for the relationship between environmental knowledge and pro-environmental behaviour.

The reliability analysis of the responses to the micro-plastics survey shows that the internal consistency for the attitude (0.902) and future behaviour (0.939) questions are excellent and the internal consistency for the current behaviour (0.890) questions is slightly below the excellent range.

Table 6.5 shows the Rasch estimates for the micro-plastics knowledge questions. The table is ordered by question difficulty with the most difficult question at the top and the least difficult question at the bottom. Question 3 is the most difficult question in the survey and question 21 is the least difficult. Question 3 is "Please choose the area with the highest global cosmetics consumption" and the options provided to the respondent are United States, Europe, and Japan, with Europe being the correct answer. The distractor analysis of question 3 shows that 48 respondents chose the United States, 18 chose Japan, and 14 chose Europe. All of the respondents to the survey are located in the United States and this may be the reason why so many of the respondents chose the incorrect answer (United States) as a response to the question. Question 21 is "Which of the face wash ingredients shown might be micro-plastics?" and the options provided to the respondent were Aqua, Parfum, Lactose, Polyethylene, and Menthol.

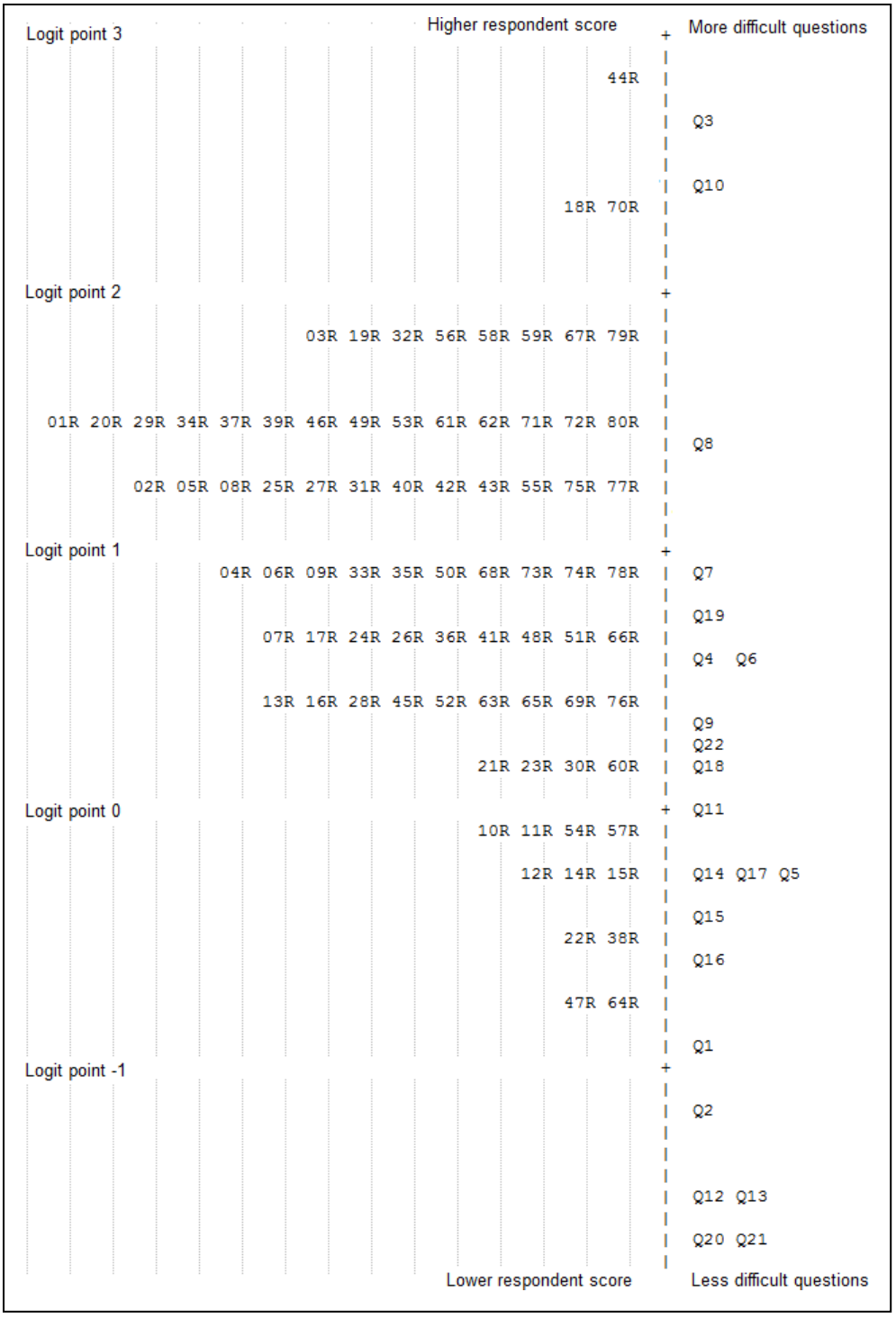

Figure 6.19: Rasch person-item map for the micro-plastics survey

The analysis of the person-item map (figure 6.19) shows a good spread in the positioning of the questions on the vertical logit scale. The number of questions positioned below the zero point is similar to the number of questions positioned above the zero point. This provides a useful measurement scale of questions to measure respondents' knowledge related to micro-plastics in the ocean. There is a gap in the question scale between the 1.5 logit and 2.5 logit area of the scale. This gap could be filed by attempting to create questions which are targeted at the 1.5 to 2.5 logit area of the scale. The error associated with the positioning of the questions is low except for the questions positioned towards the bottom of the scale. For example, questions 20 and 21 have the highest error (0.40) which is due to the fact that there are few respondents positioned towards the bottom of the scale, as shown in the bubble chart in figure 6.20. The fit values for the questions are within the acceptable range of -2 to 2 except for question 4 (2.2) and question 18 (2.5) which are slightly outside the acceptable range. Both questions could benefit from a review with a view to improving their fit as questions measuring respondents' knowledge related to the problem of micro-plastics in the ocean.

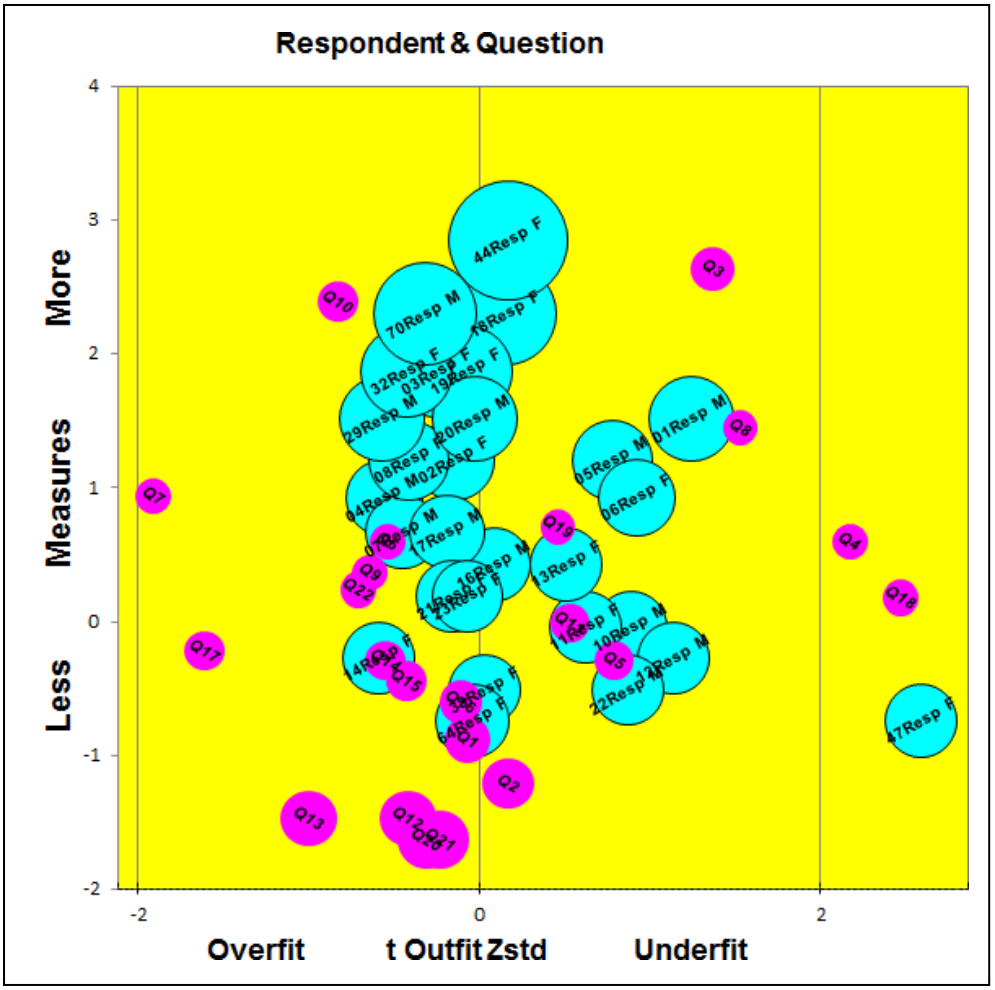

Figure 6.20: Rasch bubble chart for micro-plastics survey

The distractor analysis of the questions in the micro-plastics survey shows that some of the question distractors could be improved. Question 1 relates to the size of micro-plastics and the distractor analysis shows that the option "Between 1cm and 5cm" was not chosen by any of the survey respondents. This indicates that this option is not useful as a distractor to attract unsure respondents so it could be removed. Question 6 queries respondents' knowledge on the percentage of rubbish they think comes from single-use plastic. The options provided to the respondent are 19%, 49%, and 89%. The "19%" option was chosen less than 5% of the time which indicates that the 19% option is not a useful distractor. To improve this question's distractors the options provided to the respondent could be changed to 39%, 59%, and 89%. The distractor "Colour" was provided as an option to answer question

13 which is related to the characteristics of plastic which causes the greatest concern when it reaches the ocean. “Colour” was not chosen by any of the respondents, so this option could be removed or possibly replaced by a different characteristic of plastic.

6.12 Chapter Summary

The users of the online causal mapping and knowledge capture tool successfully created educationally beneficial causal maps which can be viewed online by people interested in learning about the ocean related topics. The knowledge relevant to the specific elements and relationships in the causal map was identified and stored in the online knowledge base. In this research, I used the knowledge attached to the micro-plastics causal map, that was created using the online causal mapping tool, to create a survey of the knowledge, attitude, and behaviour possessed by survey respondents. The causal mapping tool can also be used for other purposes including in an education setting where students can learn about system thinking through the use of the tool and learn about ocean/environmental topics by perusing causal maps already created using the tool. The causal mapping tool could also provide a query mechanism which would allow users to retrieve data specific to their topic of interest e.g. all knowledge linked to the drivers of the problem of micro-plastics in the ocean.

The correlation analysis of the relationship between knowledge, attitude, and behaviour in relation to the micro-plastics topic shows that there is a significant correlation between knowledge, attitude, and behaviour. These correlations prove that basing the survey on the DAPSIWR model and knowledge related to the elements of the DAPSIWR model, was a successful approach to the creation of a topic specific survey which measures knowledge which correlates with pro-ocean-environmental attitude and behaviour. The reliability analysis shows that the reliability of the questions ranges from just below excellent to excellent. The Rasch analysis and distractor analysis

provides insights into how the surveys as a whole can be improved and also how the individual questions can be improved. The use of the micro-plastics survey as a pre- and post-survey to measure the effectiveness of the OL tool, which I created, showed that the OL tool was effective.

Chapter 7

Conclusions

7.1 Introduction

This chapter contains concluding information on the work performed which is related to the research questions, the research objectives, and the research contribution. It also contains suggestions on future work which could be performed to build on the work carried out in this research.

7.2 Research Questions and Contributions

The overall contributions of this research were the literature review related to the ocean and environment and related measurement work; the framework to measure the effectiveness of OL tools and initiatives; the development and use of the online causal mapping tool and associated knowledge base (which did not previously exist); the process of building causal maps using the causal mapping tool; and the development of pre- and post-surveys on the topics of micro-plastics and coastal tourism, using DAPSIWR models created by domain experts. In order to achieve this, there were four research questions focused upon in this research.

RQ 1: Can we create a new integrated framework that models, and captures systems and knowledge which can be used to measure the different Ocean Literacy (OL) dimensions for specific topics?

The work performed to answer research question one involved a review of the existing literature related to defining, modelling, and measuring ocean literacy; existing OL tools and initiatives; the DAPSIWR framework; scales,

questionnaires, and surveys related to environmental and ocean literacy; tools for creating models; and relevant data analysis techniques. The review was related to the first and second research objectives of this research. I developed the online Causal Mapping and Knowledge Capture tool to provide domain experts with a tool which they used to create topic specific OL causal models using a DAPSIWR based classification of ocean related element types. The framework I have developed was used to generate questions for pre- and post-surveys from causal maps and attached knowledge developed by domain experts.

I created topic specific pre- and post-surveys based on the causal maps created by the domain experts and the knowledge they attached to the elements of the causal models. The results of these surveys showed that the level of knowledge possessed by the respondents to the micro-plastics survey was 67.10% and the level for the coastal tourism survey was 54.53%. The attitude score for micro-plastics was 8.33 and for coastal tourism the score was 8.19. The current behaviour score for micro-plastics was 6.5 and the score for coastal tourism was 6. The future behaviour scores for both micro-plastics and coastal tourism was 7.66 and 7.53, respectively. My analysis showed that the micro-plastics survey successfully measured the differences in ocean literacy before and after respondents participated in the use of the micro-plastics OL tool I created.

RQ2: What measurement mechanisms and analysis techniques are useful to use with this framework?

In order to answer this question, I reviewed the existing literature on the use of surveys to measure awareness, knowledge, attitude, behaviour, communication, and activism in relation to the environment. The use of pre- and post-surveys is a popular approach to the measurement of the effectiveness of awareness raising tools and initiatives. The data analysis techniques which are useful in the development of measurement instruments

are correlation analysis, reliability analysis, confirmatory factor analysis, Rasch analysis, paired t-test analysis, distractor analysis, and comparing current and future behaviour. Díaz-Siefer et al. (2015) expressed the difficulties of each of their questionnaire items in logits which are the basic units of Rasch scales and Fauville et al. (2018) used Rasch analysis to examine the measurement quality of their OL scale. The Cronbach's alpha approach was used by Michalos et al. (2017) to measure the internal correlations among the sentences in their survey related to sustainable development. Correlation analysis allows us to search for correlations in relationships between, for example, knowledge and attitude or between attitude and behaviour. The reliability analysis allows us to measure how closely related the questions in each of the groups are e.g. knowledge questions, attitude question etc. The Rasch analysis allows us to create a scale of questions for measurement on a topic and it also provides us with insights into how the questions and surveys can be improved. Distractor analysis provides us with insights on how useful the answer options provided with multiple choice questions are and the comparison of current and future behaviour indicates the extent to which respondents intend to improve their behaviour in the future.

RQ 3: Can we use this framework and tools to evaluate the effectiveness of ocean literacy initiatives and tools?

Based on the results of the administration of the DAPSIWR model based micro-plastics survey, I identified the 12 most difficult micro-plastics questions. A micro-plastics OL tool was then created, and I used the micro-plastics pre- and post-surveys to test the effectiveness of the tool. I found that the majority of people who used the tool achieved a substantial increase in their level of knowledge related to the problem of micro-plastics in the ocean and the paired t-test showed a significant difference between the before and after scores.

I also used my framework to develop a DAPSIWR model based coastal tourism survey which could be used to measure the effectiveness of the OL tools related to coastal tourism. The use of the framework and Causal Mapping tool to create the coastal tourism model etc. was related to research objective four. The knowledge required, by the users of the tool, to answer the coastal tourism survey questions could be incorporated into the OL tools and the survey could then be used as a pre- and a post-survey to administer to the users of the tools. The scores achieved by the tool users in the pre- and post-surveys could be compared to obtain a measurement of the effectiveness of the coastal tourism OL tool.

RQ 4: What insights can we obtain from the analysis of the survey response data to help design better OL tools and initiatives?

The results of the correlation analysis performed on the responses to the first set of 3 OL surveys, which were used as an experiment in surveying and data analysis, showed that a correlation existed between attitude and behaviour, but no correlation existed between knowledge and attitude or behaviour. The correlation analysis performed on the responses to the micro-plastics survey, I created based on the DAPSIWR models created by the domain experts, showed a significant correlation between knowledge, attitude, and behaviour. The correlation analysis of the coastal tourism responses showed that a significant correlation exists between the knowledge and attitude, and attitude and behaviour.

The insights into ways we can improve the surveys stem from the reliability analysis, Rasch analysis, and distractor analysis of the responses to the surveys. For example, the reliability analysis of the responses to the sustainable fisheries attitude questions in the first set of 3 OL surveys indicated that the survey could be improved if one of the questions (Question 12) was divided into 2 separate questions.

The Rasch analysis of the responses to the micro-plastics survey, in the first set of 3 OL surveys, showed that the survey was not measuring the upper and lower limits of respondent abilities. It showed an unacceptable fit value for question 2 in the survey. After reviewing the question, it appeared that the reason why there was a problem with the question was because the correct answer to the question was a single answer, but the user was allowed to choose multiple answers to the question. The Rasch analysis of the other surveys in the set of 3 OL topic surveys, and the micro-plastics and coastal tourism surveys based on the DAPSIWR model revealed further gaps in the measurement scale of questions and indicated questions which could be improved.

The distractor analysis of the surveys created in this research indicated a number of survey questions which would benefit from a change or update to the answer options provided to the question respondent. For example, in the case of question 6 in the DAPSIWR based micro-plastics survey, the answer option 19% was chosen less than 5% of the time which indicates that this option is not a useful answer option to attract unsure respondents. This question could be improved by modifying the answer options to better attract unsure respondents.

Using a heat map approach, for example, gives us a visual representation of the specific areas of the topics where people have higher and lower levels of knowledge. The data analysis approaches provide us with insights into how the surveys can be improved which allows us to create higher quality surveys which are better at measuring the effectiveness of OL tools and initiatives. Also, the knowledge associated with the elements of the DAPSIWR causal maps and the insights from the data analysis of the survey responses provides us with information which can be used to improve the content of OL tools related to the survey topics.

7.3 Future Work

This research has created and used a framework that models and captures systems and knowledge which can be used to assess and improve the effectiveness of OL tools and initiatives. The online Causal Mapping tool allows users to create OL topic specific models which are used to inform the creation of surveys which measure the effectiveness of ocean related interventions. The framework is a significant contribution to the efforts to increase and measure OL and it can also be applied to other areas, for example, efforts to increase and measure environmental literacy.

7.3.1 Topic Specific Surveys

In this research I successfully created and administered a DAPSIWR model-based survey on the topics of micro-plastics in the ocean and the ocean-environmental problems created by coastal tourism. In the future, it would be beneficial to create and administer DAPSIWR model-based surveys on other important ocean related topics e.g. sustainable fisheries and aquaculture, ballast water and invasive alien species, eutrophication and agriculture, and marine renewable energy. Also, it would be useful to create actor specific surveys which could be used to measure knowledge, attitude, and behaviour of trainees for ocean related professions and ocean related industry professionals e.g. fishermen and seafarers.

In future research, it would be useful to apply the results of the data analysis to a review of the contents of the surveys with a view to improving the questions, so that the knowledge which correlates with a pro-ocean-environmental attitude and behaviour can be identified. Further work could also be performed to ensure that the level of bias in the survey questions is kept to a minimum. The improved questions could then be used as a scale to measure the respondent's levels of knowledge, attitude, and behaviour in relation to the topics. The contents of the surveys could be used to inform the measurable objectives of the Theory of Change framework (ToC, 2019).

7.3.2 OL Tools Development

The knowledge required to answer the questions contained in existing and future topic specific ocean related surveys could be used to create OL tools which create awareness on the topic. The usage and effectiveness of the tools could be measured using approaches similar to the approach used in this research to measure the effectiveness of the micro-plastics OL tool. The heat map approach used in this research can be used to identify the levels of knowledge possessed by people. This can be used to inform the content of OL tools i.e. the areas with the least knowledge can have a stronger focus in the OL tool.

7.3.3 Causal Mapping Tool

The existing causal maps created by the users of the online Causal Mapping tool could be further analysed and enhanced to make them more educationally beneficial. Adding specific information to the properties of the DAPSIWR elements in the causal maps would make the causal maps more informative. Also, attaching more knowledge and evidence to the elements of the causal models and the links between the elements would enhance the usefulness of the topic specific models. The classification used in the online Causal Mapping tool is based on a classification of ocean related elements and by changing this classification the tool could be used to create causal maps related to any environmental or other domains.

7.3.4 Further Data Analysis

The data analysis procedures used in this research can be used on future surveys and OL tools in order to measure their effectiveness and provide insights into how they can be improved. For example, Structural Equation Modelling, Exploratory Factor Analysis and Confirmatory Factor Analysis could be used to identify factors which influence ocean related behaviour.

These data procedures could be used as part of the process of improving the survey questions by creating a model of which types of knowledge, attitude, and behaviour related to a topic load on the levels of ocean literacy possessed by survey respondents on specific topics. For example, a structural equation modelling approach could be used to identify if knowledge of species fishing quotas affects the choices made by seafood consumers.

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Appendix 1

Types of questions used to measure ocean / environmental awareness, knowledge, and attitude

Question / Description	Question Type	Answer Type	Reference
Obtain participants' agreement on different possible causes of contaminants in the marine environment. (11 items provided) Used to assess awareness within the frame of the study.	Awareness	7-point Likert scale ranging from "totally disagree" (1) to "totally agree" (7).	Jacobs et al. (2015)
Are you familiar with the concept of declaring parts of the sea as marine protected areas?	Awareness	Yes or no	Hawkins et al. (2016)
Have you heard of the Marine and Coastal Access Act?	Awareness	Yes or no	Hawkins et al. (2016)
What percentage of the total area of UK coastal waters would you estimate is currently declared as marine protected areas?	Awareness	Open answer	Hawkins et al. (2016)
When you think about the coastline or the sea, what are the three most important environmental matters that come to mind?	Awareness	Open answer	Gelcich et al. (2014)
Below is a list of some problems our oceans are facing, which ones do you think are a result of human activities?	Awareness	Select from list	Umuhire and Fang (2016)

Where, if at all, have you seen or heard of information about climate change impacts on coastlines or the sea?	Awareness	Select from list	CLAMER (2011)
How informed do you feel about each of the following?	Awareness/ Knowledge	5-point scale, 5 = very well informed and 1 = Not informed at all, don't know	CLAMER (2011)
How much do you know about global warming and sea level rising?	Knowledge	5-point scale from 1 (a little) to 5 (a lot)	Chen and Tsai (2016)
Ask participants to answer true or false to different concepts about the ocean environment	Knowledge	True or false	Umuhire and Fang (2016)
Do you know the following terms?	Knowledge	Yes or no	Umuhire and Fang (2016)
Which one of the following is the major source of your information about oceans?	Knowledge	Select one	Umuhire and Fang (2016)
By how much, if at all, do you think sea temperature around the coasts of [your country] has risen over the past 100 years' / 'will rise over the past 100 years?	Knowledge	Select one answer	CLAMER (2011)
Ask a knowledge question related to the topic	Knowledge	Choose correct answer	Mogias et al. (2015)

Present pieces of knowledge to the participant and ask them to choose how correct they think they are	Knowledge	5-point Likert-type scale ranging from –1 (sure incorrect) to 1 (sure correct)	Boubonari et al. (2013)
Obtain participants' opinions on statements related to how affective a single persons' actions can be	Attitude	7-point Likert scale ranging from "totally disagree" (1) to "totally agree" (7).	Jacobs et al. (2015)
Do you think that the seas around Britain are currently in:	Attitude	Answer options: Good, fair or poor health	Hawkins et al. (2016)
In the past ten years, do you think that the health of Britain's seas has:	Attitude	Improved, stayed the same, deteriorated	Hawkins et al. (2016)
Below are provisions which are currently contained within the Marine Bill. Please indicate how important each one is to you	Attitude	Very, quite or not important	Hawkins et al. (2016)
How satisfied are you with the designation of 27 marine conservation zones out of 127 recommended sites? Please give a reason for your answer (Sometimes this question can follow information that has been provided to the participant)	Attitude	Extremely or slightly satisfied, neither satisfied nor unsatisfied, slightly or extremely dissatisfied and open answer for second part	Hawkins et al. (2016)

Do you think more of Scotland's seas should be fully protected from trawling and dredging?	Attitude	Yes, no or don't know	Hawkins et al. (2016)
Use positive statements to obtain participants' attitude e.g. The present generation should ensure that the environment is maintained or enhanced for the benefit of future generations	Attitude	5-point scale was used from 1 (strongly disagree) to 5 (strongly agree)	Chen and Tsai (2016)
Use negative statements to obtain participants' attitude e.g. Humans have the right to modify the marine environment to suit their needs	Attitude	5-point scale was used from 1 (strongly disagree) to 5 (strongly agree)	Chen and Tsai (2016)
With which one of the following two statements do you agree more?	Attitude	Select one	Umuhire and Fang (2016)
When, if at all, do you think the following impacts of climate change on the coastline and seas of Europe become apparent?	Attitude	Impacts are already apparent, next 20 years, next 50 years, over 50 years, never, don't know	Gelcich et al. (2014)
If you had to decide what climate change and marine policies should be prioritized by the EU, which three would you select from the list below?	Attitude	Select 3 from list	Gelcich et al. (2014)

How effective are the following in tackling climate change impacts at the coastline or in the sea?	Attitude	Very effective, Somewhat effective, Not very effective, and Not at all effective.	Gelcich et al. (2014)
Thinking about the causes of climate change, which, if any, of the following best describes your opinion?	Attitude	Entirely natural, Mainly natural, Natural and humans, Mainly humans, Entirely humans	CLAMER (2011)
And now please indicate to what extent do you feel concerned about each of the following?	Attitude	5-point scale, 5 = very concerned and 1 = Not at all concerned, don't know	CLAMER (2011)
To what extent, if at all, do you trust each of the following types of media when providing information about climate change impacts on the coastline or the sea?	Attitude	5-point scale, 5 = Trust a lot and 1 = distrust a lot, don't know	CLAMER (2011)
Select the three most effective actions individuals should take to reduce and cope with the impacts of climate change	Attitude	Select 3 from list	CLAMER (2011)

How willing would you be to risk a reduced yield in this season if there was a good chance of a higher yield?	Attitude	Scales used: 1 = not at all willing, 2 = not very willing, 3 = neutral, 4 = somewhat willing, 5 = very willing	McCann et al. (1997)
Provide the participant with a list of environmental problems and ask them how urgent they feel each one is?	Attitude	0 = not sure, 1 = not urgent at all, 2 = not urgent, 3 = moderately urgent, 4 = urgent, and 5 very urgent	Wong (2003)
Prioritise the top 12 development issues in China for the next five years	Attitude	1st priority, 2nd priority, and last priority	Wong (2003)
"I am concerned about marine environmental problems because of the consequences for … my personal life, my health, all people, people where I live, seafood, and birds	Attitude	7-point Likert scale ranging from "totally disagree" (1) to "totally agree" (7).	Jacobs et al. (2015)
I tell my friends about marine environmental protection	Behaviour	5-point scale from 1 (never act on) to 5 (always act on).	Chen and Tsai (2016)
I purchase less-polluting or environmentally friendly seafood products when I shop, even though these products are comparatively more expensive than similar ones	Behaviour	5-point scale from 1 (never act on) to 5 (always act on).	Chen and Tsai (2016)

How often did you visit the coastal areas in the past one-year?	Behaviour	Once a month or greater than once a month, less than once a month, or never	Umuhire and Fang (2016)
Have you taken any of the following actions to reduce and cope with the impacts of climate change	Behaviour	Select from list	CLAMER (2011)

Appendix 2

Questions contained in the three OL surveys used as an experiment in surveying and data analysis

Question Text	Answer Options
Micro-plastics Survey	
1. Select all which you think are possible ways for micro-plastics to enter the oceans:	- Breakdown of larger pieces of plastic - Release of micro particles from scrubs - Accidental spillage of plastic during transport - From sewage discharge
2. Which of the face wash ingredients shown might be micro- plastics?	- Aqua - Parfum - Lactose - Polyethylene - Menthol
3. What percentage of ocean rubbish do you think comes from single-use plastic (things that were only used once and then thrown away)?	- 49% - 69% - 89% - 99%
4. Sunlight can degrade plastics in the ocean: true or false?	- True - False

5. Select products which might have contained micro-beads in the past:	- Toothpaste - Facial Scrubs - Shower Gel - Lip Gloss - Nail Polish
6. Why is plastic dangerous for marine life?	- They mistake it for food but cannot digest it - It absorbs toxins which could be harmful to anything that eats it - It's not harmful at all!
7. Where does the majority of our plastic waste end up?	- Oceans - Burned for energy - Landfills - Recycled
8. The equivalent of one rubbish truck of plastic waste is being added to the sea every...?	- Second - Minute - Hour - Day
9. To what extent do you agree with the following statement? "I am very worried about damage to the natural environment"	Agreement scale 0-10
10. How worried are you about the problems micro-plastics in the sea might cause?	Concern scale 0-10

11. To what extent do you agree with the following statement? “I believe there will be a benefit to the health of the sea and people’s health if I stop using products containing micro-plastics”	Agreement scale 0-10
Which of the following options to reduce the effects of micro-plastics on the marine environment do you do? 12. I look for products that use recycled and recyclable packaging.	Scale from Not at all – All the time, 0-10
13. I look for products that do not contain micro-plastics (such as some cosmetic products).	Scale from Not at all – All the time, 0-10
14. I support shops and brands that don’t sell products containing micro-plastics.	Scale from Not at all – All the time, 0-10
15. I support campaigns to ban the sale or use of micro-plastics in products.	Scale from Not at all – All the time, 0-10
16. I separate plastics for recycling.	Scale from Not at all – All the time, 0-10
Which of the following options to reduce the effects of micro-plastics on the marine environment will you do in the future? 17. I will look for products that use recycled and recyclable packaging.	Scale from Not at all – All the time, 0-10
18. I will look for products that do not contain micro-plastics (such as some cosmetic products).	Scale from Not at all – All the time, 0-10
19. I will support shops and brands that don’t sell products containing micro-plastics.	Scale from Not at all – All the time, 0-10

20. I will support campaigns to ban the sale or use of micro-plastics in products.	Scale from Not at all – All the time, 0-10
21. I will separate plastics for recycling.	Scale from Not at all – All the time, 0-10
Coastal Tourism Survey	
1. The picture below shows a paradise beach in the middle of summer. There is an artificial rock barrier in front of the beach. What is the function of the artificial rock barrier?	- To protect bathing water against waves - To keep the water calm for swimmers - To protect the beach against erosion - To create a sunbathing spot for tourists - To create a favourable environment for molluscs and other marine species
2. Which countries receive the largest number of visitors on a yearly basis? Please select 3	- France - Turkey - Greece - Spain - Italy - Croatia - Tunisia
3. Please choose the main effects of coastal development from the list below:	- An increase in the amount of water reaching the urban drainage system - Artificialisation of the seabed - Alteration of marine currents

4. The image below shows a beach backed by dunes. Dunes are a vital component of coastal systems. Why are dunes so important to the coastal environment?	- Protect the coast against sea and wind erosion - Provide an excellent spot for sunbathing - Provide an excellent spot for building summer houses - Constitute an important ecosystem with unique species - Provide an excellent spot for sunbathing when the wind is too strong
5. Since 1995, international tourism in the Mediterranean basin has grown by almost:	- 5% - 35% - 75% - 100%
6. To what extent do you agree with the following statement? “I am very worried about damage to the natural environment”	Agreement scale 0-10
7. How worried are you about the effects of coastal tourism activities on the marine (ocean) environment?	Concern scale 0-10
8. To what extent do you agree with the following statement? “I believe there will be a benefit to the marine environment and human health and happiness if I support sustainable tourism activities (e.g. recycling & using businesses that limit their environmental impact).”	Agreement scale 0-10
Which of the following options to reduce the negative effects of coastal tourism do you currently do? 9. When on holiday on the coast I separate litter for recycling.	Scale from Not at all – All the time, 0-10

10. When on holiday on the coast I look to use businesses that reduce their negative impact on the environment.	Scale from Not at all – All the time, 0-10
11. When planning a holiday on the coast I look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	Scale from Not at all – All the time, 0-10
12. I look for information on sustainable tourism practices that I can undertake in the areas I visit.	Scale from Not at all – All the time, 0-10
13. I support projects to restore coastal and marine habitats that have been degraded by coastal development.	Scale from Not at all – All the time, 0-10
Which of the following options to reduce the negative effects of coastal tourism will you do in the future? 14. When on holiday on the coast I will separate litter for recycling.	Scale from Not at all – All the time, 0-10
15. When on holiday on the coast I will look to use businesses that reduce their negative impact on the environment.	Scale from Not at all – All the time, 0-10
16. When planning a holiday on the coast I will look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	Scale from Not at all – All the time, 0-10
17. I will look for information on sustainable tourism practices that I can undertake in the areas I visit.	Scale from Not at all – All the time, 0-10
18. I will support projects to restore coastal and marine habitats that have been degraded by coastal development.	Scale from Not at all – All the time, 0-10

Sustainable Fisheries Survey	
What is the kind of fishing shown in the image below?	- Trawl fishing - Angling - Ghost-fishing - Electric fishing
2. What percentage of the fish consumed in the EU comes from fishing and aquaculture?	- 25 % Aquaculture and 75 % Fishing - 50 % Aquaculture and 50 % Fishing - 75 % Aquaculture and 25 % Fishing
3. Is the European Union self-sufficient in seafood?	- Yes - No
4. What type of fishing technique is shown in the image below?	- Trawling - Seine netting - Angling - Longline
5. The picture below shows a Cod (Gadus morhua) fish. Where does the Cod species live?	- North-East Atlantic - It is a river fish - Mediterranean Sea - Great Barrier Reef, Australia
6. Which species is shown in the image below?	- Salmon - Turbot - Cod - Mackerel

7. The image below shows an Albacore Tuna (Thunnus alalunga). At what age does the Albacore Tuna reproduce?	- 2 years old - 5 years old - 10 years old - 15 years old
8. Which European country eats the most fish and seafood per capita?	- Sweden - United Kingdom - France - Portugal - Romania
9. What percentage of the global population depends on oceans and seas for food?	- 0-20% - 21-40% - 41-60% - 61-80% - 81-100%
10. To what extent do you agree with the following statement? “I am very worried about damage to the natural environment”	Agreement scale 0-10
11. How worried are you about the effects of unsustainable fishing or aquaculture on the marine (ocean) environment?	Concern scale 0-10
12. To what extent do you agree with the following statement? “I believe there will be a benefit to the marine environment and the fishing industry if I buy and eat sea food that is labelled as sustainable.”	Agreement scale 0-10

Which of the following options do you currently do to reduce the negative effects fishing and aquaculture may have on fish populations and the marine environment? 13. I use sustainable sea food guides or look for information on which seafood to eat.	Scale from Not at all – All the time, 0-10
14. I ask shops where the sea food I eat has come from and if it is sustainably sourced.	Scale from Not at all – All the time, 0-10
15. I support campaigns that tell people to eat seafood that is sustainably sourced.	Scale from Not at all – All the time, 0-10
16. I look for information on the sustainability of fishing and aquaculture practices used to produce my food.	Scale from Not at all – All the time, 0-10
17. I support projects and sea food producers that provide sustainable sea food.	Scale from Not at all – All the time, 0-10
Which of the following options will you do in the future to reduce the negative effects fishing and aquaculture may have on fish populations and the marine environment? 18. I will use sustainable sea food guides or look for information on which seafood to eat.	Scale from Not at all – All the time, 0-10
19. I will ask shops where the sea food I eat has come from and if it is sustainably sourced.	Scale from Not at all – All the time, 0-10
20. I will support campaigns that tell people to eat seafood that is sustainably sourced.	Scale from Not at all – All the time, 0-10

21. I will look for information on the sustainability of fishing and aquaculture practices used to produce my food.	Scale from Not at all – All the time, 0-10
22. I will support projects and sea food producers that provide sustainable sea food.	Scale from Not at all – All the time, 0-10

Appendix 3

Reliability and Rasch analysis results for 3 OL surveys used as an experiment in surveying and data analysis

Question Text	Mean	Standard Deviation	Cronbach's Alpha if Item Deleted
9. To what extent do you agree with the following statement? "I am very worried about damage to the natural environment"	8.19	1.77	0.536
10. How worried are you about the problems micro-plastics in the sea might cause?	8.07	1.82	0.565
11. To what extent do you agree with the following statement? "I believe there will be a benefit to the health of the sea and people's health if I stop using products containing micro-plastics"	8.6	1.62	0.919
12. I look for products that use recycled and recyclable packaging.	5.63	2.74	0.741
13. I look for products that do not contain micro-plastics (such as some cosmetic products).	3.56	2.92	0.751
14. I support shops and brands that don't sell products containing micro-plastics.	4.79	3.09	0.724
15. I support campaigns to ban the sale or use of micro-plastics in products.	5.37	2.96	0.782
16. I separate plastics for recycling.	8.13	2.24	0.834

Mean, standard deviation, and Cronbach's alpha if item deleted for micro-plastics attitude and behaviour questions

Question Text	Mean	Standard Deviation	Cronbach's Alpha if Item Deleted
6. To what extent do you agree with the following statement? "I am very worried about damage to the natural environment"	7.25	2.11	0.655
7. How worried are you about the effects of coastal tourism activities on the marine (ocean) environment?	6.71	2.34	0.706
8. To what extent do you agree with the following statement? "I believe there will be a benefit to the marine environment and human health and happiness if I support sustainable tourism activities (e.g. recycling & using businesses that limit their environmental impact)."	8.64	1.79	0.800
9. When on holiday on the coast I separate litter for recycling.	7.16	2.93	0.876
10. When on holiday on the coast I look to use businesses that reduce their negative impact on the environment.	3.94	3.19	0.837
11. When planning a holiday on the coast I look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	3.07	2.92	0.821
12. I look for information on sustainable tourism practices that I can undertake in the areas I visit.	3.61	3.17	0.810
13. I support projects to restore coastal and marine habitats that have been degraded by coastal development.	4.52	3.30	0.856

Mean, standard deviation, and Cronbach's alpha if item deleted for coastal tourism attitude and behaviour questions

Question Text	Mean	Standard Deviation	Cronbach's Alpha if Item Deleted
10. To what extent do you agree with the following statement? "I am very worried about damage to the natural environment"	8.49	1.34	0.358
11. How worried are you about the effects of unsustainable fishing or aquaculture on the marine (ocean) environment?	7.78	1.99	0.427
12. To what extent do you agree with the following statement? "I believe there will be a benefit to the marine environment and the fishing industry if I buy and eat sea food that is labelled as sustainable."	7.80	2.19	0.744
13. I use sustainable sea food guides or look for information on which seafood to eat.	3.11	3.14	0.818
14. I ask shops where the sea food I eat has come from and if it is sustainably sourced.	2.49	3.27	0.849
15. I support campaigns that tell people to eat seafood that is sustainably sourced.	4.76	3.40	0.842
16. I look for information on the sustainability of fishing and aquaculture practices used to produce my food.	3.13	3.24	0.821
17. I support projects and sea food producers that provide sustainable sea food.	4.87	3.35	0.892

Mean, standard deviation, and Cronbach's alpha if item deleted for sustainable fisheries attitude and behaviour questions

Question Text	Total Score	Measure	Standard Error	Outfit Zstd
Q5. Select products which might have contained micro- beads in the past:	17	1.34	0.31	-1.0
Q4. Sunlight can degrade plastics in the ocean: true or false?	31	0.23	0.27	-0.3
Q3. What percentage of ocean rubbish do you think comes from single-use plastic (things that were only used once and then thrown away)?	32	0.15	0.27	-0.5
Q1. Select all which you think are possible ways for micro- plastics to enter the oceans:	33	0.08	0.27	-1.4
Q8. The equivalent of one rubbish truck of plastic waste is being added to the sea every...?	34	0.01	0.26	1.7
Q2. Which of the face wash ingredients shown might be micro-plastics?	37	-0.20	0.26	4.0
Q6. Why is plastic dangerous for marine life?	38	-0.27	0.27	-1.3
Q7. Where does the majority of our plastic waste end up?	52	-1.35	0.30	-0.5

Rasch estimates for micro-plastic survey knowledge questions

Question Text	Total score	Measure	Standard Error	Outfit Zstd
Q3. Please choose the main effects of coastal development from the list below:	3	3.01	0.62	-0.4
Q4. The image below shows a beach backed by dunes. Dunes are a vital component of coastal systems. Why are dunes so important to the coastal environment?	18	0.59	0.31	0.7
Q2. Which countries receive the largest number of visitors on a yearly basis? Please select 3	32	-0.60	0.28	-0.1
Q5. Since 1995, international tourism in the Mediterranean basin has grown by almost:	32	-0.60	0.28	-1.6
Q1. The picture below shows a paradise beach in the middle of summer. There is an artificial rock barrier in front of the beach. What is the function of the artificial rock barrier?	52	-2.40	0.35	2.9

Rasch estimates for coastal tourism survey knowledge questions

Question Text	Total Score	Measure	Standard Error	Outfit Zstd
Q1. What is the kind of fishing shown in the image below?	2	3.59	0.76	-0.2
Q8. Which European country eats the most fish and seafood per capita?	14	0.91	0.36	0.7
Q7. The image below shows an Albacore Tuna (Thunnus alalunga). At what age does the Albacore Tuna reproduce?	23	-0.11	0.33	1.0
Q2. What percentage of the fish consumed in the EU comes from fishing and aquaculture?	25	-0.33	0.33	-0.2
Q9. What percentage of the global population depends on oceans and seas for food?	25	-0.33	0.33	2.1
Q4. What type of fishing technique is shown in the image below?	27	-0.55	0.33	-0.6
Q6. Which species is shown in the image below?	29	-0.77	0.34	-0.7
Q3. Is the European Union self-sufficient in seafood?	31	-1.01	0.35	0.3
Q5. The picture below shows a Cod (Gadus morhua) fish. Where does the Cod species live?	34	-1.40	0.37	-0.3

Rasch estimates for sustainable fisheries survey knowledge questions

Appendix 4

Examples of improved questions for surveys

Modified Question	Reason(s) for Modification
Coastal Tourism: How does the activity of cleaning seaweed from a beach impact the coastal environment?	This is a new question which is focused on identifying the knowledge which should lead to pro-ocean-environmental behaviour.
Sustainable Fisheries, Question 12: To what extent do you agree with the following statement? “I believe there will be a benefit to the marine environment if I buy and eat sea food that is labelled as sustainable.”	The original question was related to the benefits to both the marine environment and the fishing industry which led to poor internal correlation results. To improve this question, it could be divided into 2 questions.
Sustainable Fisheries: To what extent do you agree with the following statement? “I believe there will be a benefit to the fishing industry if I buy and eat sea food that is labelled as sustainable.”	This is a new question based on the second part of the original Sustainable Fisheries question, referred to above.
Micro-plastics, Question 2: Which of the face wash ingredients shown might be micro-plastics? (with answer options changed from multiple to single)	The original question allowed the respondent to choose multiple answers which led to a Rasch Outfit value well outside the acceptable range. The question could be changed to only allow a single answer option to be chosen.
Micro-plastics, Question 10: Do you think the existence of micro- plastics in the sea is a problem? If so, how worried are you about the problems micro-plastics in the sea might cause?	The original question did not ask the respondent if they thought micro-plastics in the sea was a problem which could have indicated the type of answers the survey was looking for.

Micro-plastics, Question 11: To what extent do you agree with the following statements? “I believe there will be a benefit to the health of the sea and people’s health if I stop using each of the following products which could contain micro-plastics”. – fleece clothing, - facial scrubs, - lip gloss	The original question asked respondents to indicate their belief related to the benefit of stopping using products containing micro-plastics. The new question could list products which could contain micro-plastics and then ask the user to indicate their belief related to the benefit of stopping using each of them. The reasons for changing this question are to make the question more informative and to allow respondents to indicate their belief on specific products containing micro-plastics.
Micro-plastics, Question 12: I look for products that use recycled, recyclable packaging, or no packaging.	“No packaging” could be added to the original question which is probably the best pro-environmental behaviour.
Micro-plastics, Question 16: Add a question before the statement to ask if the respondent has recycling options available to him or her.	The reason for adding the question before the statement is to allow for the situation where the respondent may want to recycle but does not have the facilities available.

Appendix 5

DAPSIWR model based micro-plastics survey

Knowledge questions	
1. What size are micro-plastics?	• Less than 5 mm • Between 5 mm and 1 cm • Between 1 cm and 5 cm
2. Increased awareness of micro-plastics has made people more environmentally aware of the effects of micro-plastics on the ocean, true or false?	• True • False
3. Please choose the area with the highest global cosmetics consumption:	• United States • Europe • Japan
4. Cosmetic manufacturers alter their activities to reflect the growing environmental concerns of cosmetic consumers, true or false?	• True • False
5. Plastics are by-products of the oil industry, true or false?	• True • False
6. What percentage of ocean rubbish do you think comes from single-use plastic (things that were only used once and then thrown away)?	• 19% • 49% • 89%

7. Please choose the attributes that plastic packaging generally has from the list below:	Low production costs • High durability • High flexibility • High production costs
8. Sunlight can degrade plastics in the ocean: true or false?	• True • False
9. Select all which you think are possible ways for micro-plastics to enter the oceans:	• Breakdown of larger pieces of plastic • Release of micro particles from cosmetics such as facial scrubs/washes • Accidental spillage of plastic during transport • Produced by marine vegetation • From sewage discharge
10. Select products which might have contained micro-beads in the past:	• Toothpaste • Facial Scrubs • Shower Gel • Lip Gloss • Nail Polish
11. What proportion of micro-plastics are removed from the water in wastewater treatment systems?	• All micro-plastics are removed • A proportion of the micro-plastics are removed • None of the micro-plastics are removed

12. Please choose the correct statement:	• Most cosmetic products are 'rinse off' products and they end up in household wastewater systems • Most cosmetic products are not 'rinse off' products and they do not end up in household wastewater systems
13. Which one of the following characteristics of plastic causes the greatest concern when it reaches the ocean?	• Flexibility • Durability • Texture • Colour
14. Regulation adopted in the US and emerging national regulations shows that a ban on some categories of micro-plastics is very likely in the future, true or false?	• True • False
15. Several environmentally friendly alternatives to plastic microbeads already exist and are being used by the cosmetic industry, true or false?	• True • False
16. Is there any part of the ocean where plastics have not been found?	• Yes • No
17. Why is plastic dangerous for marine life?	• They mistake it for food but cannot digest it • It absorbs toxins which could be harmful to anything that eats it • It's not harmful at all!
18. Where does the majority of our plastic waste end up?	• Oceans • Burned for energy • Landfills • Recycled

19. The equivalent of one rubbish truck of plastic waste is being added to the sea every...?	• Second • Minute • Hour • Day
20. Plastics can absorb and release pollutants, and carry pathogenic microorganisms, including bacteria and viruses, true or false?	• True • False
21. Which of the face wash ingredients shown might be micro-plastics?	• Aqua • Parfum • Lactose • Polyethylene • Menthol
22. Please choose the correct statement:	• The cosmetic industry is currently reducing the amount of micro-plastics used in their products. • The cosmetic industry is currently increasing the amount of micro-plastics used in their products.
Attitude questions	
23. How do you feel about damage to the natural environment?	Concern scale 0-10
24. How do you feel about the use of micro-plastics in cosmetic products?	Concern scale 0-10
25. To what extent do you agree that the use of micro-plastics in cosmetics should be banned?	Agreement scale 0-10
26. How do you feel about the problems micro-plastics in the ocean might cause?	Concern scale 0-10

27. What type of effect do you feel there will be on the ocean if people stop using products containing micro-plastics?	Scale from Very negative – Very positive, 0-10
Current behaviour questions	
Which of the following options to reduce the effects of micro-plastics on the marine environment do you do?	
28. I separate plastics for recycling.	Scale from Not at all – All the time, 0-10
29. I look for products that do not contain micro-plastics (such as some cosmetic products).	Scale from Not at all – All the time, 0-10
30. I look for products that use recycled packaging or recyclable packaging.	Scale from Not at all – All the time, 0-10
31. I look for products that do not use any packaging.	Scale from Not at all – All the time, 0-10
32. I support brands that don't sell products containing micro-plastics.	Scale from Not at all – All the time, 0-10
33. I support campaigns to ban the sale or use of micro-plastics in products.	Scale from Not at all – All the time, 0-10
Future behaviour questions	
Which of the following options to reduce the effects of micro-plastics on the marine environment will you do in the future?	
34. I will separate plastics for recycling.	Scale from Not at all – All the time, 0-10
35. I will look for products that use recycled packaging or recyclable packaging.	Scale from Not at all – All the time, 0-10

36. I will look for products that do not use any packaging.	Scale from Not at all – All the time, 0-10
37. I will look for products that do not contain micro-plastics (such as some cosmetic products).	Scale from Not at all – All the time, 0-10
38. I will support brands that don't sell products containing micro-plastics.	Scale from Not at all – All the time, 0-10
39. I will support campaigns to ban the sale or use of micro-plastics in products.	Scale from Not at all – All the time, 0-10

Appendix 6

Coastal Tourism Survey and Data Analysis

Appendix 6.1 The Coastal Tourism Survey

The content of the coastal tourism survey was based on the relevant knowledge identified for the coastal tourism topic and the questions are linked with the individual elements of the coastal tourism DAPSIWR model. The layout of the sections of the survey was similar to the layout of the Micro-plastics survey. An example of a knowledge and survey question pairing was the knowledge "Tourism accounts for 10% of global GDP making it a very important sector in the world. As a blue growth sector, it has the potential to create well-being and jobs while contributing to the good state of coastal and marine environments" and the associated question reads "What percentage of the world's market (Gross domestic product) does tourism account for?" This question is associated with the Driver "Economic benefits of tourism". An example of a question which is associated with the link between the Pressure "Habitat fragmentation and deterioration" and the Impact "Disturbance of nesting and breeding sites" is "Please choose the environmental impacts, of land use change and construction, from the list below:". The list of options provided to the respondent, to answer the question, were Biodiversity loss, Endangered species, Improvement in water quality, Degradation of water quality, and Loss of carbon stocks.

The attitude questions in the survey measure the respondent's attitude towards issues relevant to the human-ocean relationship. The attitude section includes questions related to the construction of structures close to the beach, the effects of coastal tourism activities on the marine environment, and the possible effects of people adopting sustainable tourism activities. The current and future behaviour questions focus on the extent to which respondents take the effects of coastal tourism into account when choosing a holiday and choosing holiday accommodation; their level of support for projects to restore

coastal and marine habitats; their use of businesses that reduce their impact on the environment; their behaviour in relation to recycling when on holiday; and the extent to which they look for information on sustainable tourism practices. The following table contains the questions in the coastal tourism survey:

Knowledge questions	
1. Which of these countries receive the largest number of visitors on a yearly basis? (Please select 3 countries)	• France • Turkey • Greece • Spain • Italy • Croatia • Tunisia
2. Since 1995, international tourism in the Mediterranean has grown by almost:	• 5% • 35% • 75% • 100%
3. Mediterranean coastal tourism has been built on providing services expected by tourists and decreasing costs of accommodation, true or false?	• True • False
4. Please choose the industry sectors which have an impact on coastal development processes:	• Tourism promotion companies • Regional and national legislators • Airline pilots • Local urban planning authorities • Hotel managers and owners • Real estate companies

5. In the Mediterranean area, the number of visits are:	• Increasing and the average expenditure per night is decreasing • Decreasing and the average expenditure per night is increasing
6. What percentage of the world's market (Gross domestic product) does tourism account for?	• 1% • 10% • 50% • 80%
7. Please choose the main effects of coastal development from the list below:	• An increase in the amount of water reaching gutters and drains in built up areas • Artificialisation of the seabed • Improvement in the biodiversity of the coastal area • Alteration of marine currents
8. In the Mediterranean region, the construction of new marinas is a very profitable business, true or false?	• True • False
9. Please choose the responses to coastal erosion from the list below:	• Building erosion barriers parallel to the beach • Building houses close to the beach • Building erosion barriers perpendicular to the beach • The replenishment of sand on eroded beaches
10. The environmental quality of mass tourism destinations started to decline in the 1980s and 1990s, true or false?	• True • False
11. Coastal Tourism's success itself can threaten its own economic viability, True or False?	• True • False

12. The development of hotels, housing, services and leisure activities in coastal tourism areas leads to:	• An increase in biodiversity • A decrease in biodiversity • No change in biodiversity
13. The construction of structures on the coastline has a:	• Positive effect on nesting and breeding sites • Negative effect on nesting and breeding sites • No effect on nesting and breeding sites
14. Please choose the environmental impacts, of land use change and construction, from the list below:	• Biodiversity loss • Endangered species • Improvement in water quality • Degradation of water quality • Loss of carbon stocks
15. Buildings built close to the seaside:	• Have a negative environmental effect on the movement of sand • Have a positive environmental effect on the movement of sand • Do not affect the movement of sand
16. In the time period from 1955 to 2012 the presence of dunes on the Italian coast has:	• Increased from 1200km to over 1900km • Decreased from 1200km to less than 700km • Not changed

17. The picture below shows a paradise beach in the middle of summer. There is an artificial rock barrier in front of the beach. What is the function of the artificial rock barrier?	• To protect bathing water against waves • To keep the water calm for swimmers • To protect the beach against erosion • To create a sunbathing spot for tourists • To create a favourable environment for molluscs and other marine species
18. The image below shows a beach backed by dunes. Dunes are a vital component of coastal systems. Why are dunes so important to the coastal environment?	• Protect the coast against sea and wind erosion • Provide an excellent spot for sunbathing • Provide an excellent spot for building summer houses • Constitute an important ecosystem with unique species • Provide an excellent spot for sunbathing when the wind is too strong
19. At the beach, I am allowed to collect any type of shellfish, true or false?	• True • False

20. Please select all of the statements which you think are correct. Sustainable tourism:	• Respects the environment, heritage and local cultures • Can use natural resources that are key for tourism development without degrading biodiversity • Prioritizes economic benefit over environmental concern • Respects local culture as well as traditional values • Must ensure sustainable economic activity for everybody involved
21. There are laws in place which provides a regulatory framework for the development of the coastal zone, true or false?	• True • False
22. The 'Urban development and relative provisions" law in Greece excludes enclosures within a distance of 500m from the shoreline, true or false?	• True • False
Attitude questions	
23. How do you feel about damage to the natural environment?	Concern scale 0-10
24. How do you feel about the construction of structures close to the beach?	Concern scale 0-10
25. How do you feel about the effects of coastal tourism activities on the marine (ocean) environment?	Concern scale 0-10
26. How do you feel about the possible effects of the construction near the beach e.g. the disturbance of nesting and breeding sites?	Concern scale 0-10

27. What type of effect do you feel there will be on the ocean if people support sustainable tourism activities?	Scale from Very negative - Very positive, 0-10
Current behaviour questions	
Which of the following options to reduce the effects of coastal tourism on the marine environment do you do?	
28. When choosing my holiday destination, I take the effects of coastal tourism into consideration.	Scale from Not at all – All the time, 0-10
29. When choosing holiday accommodation near the coast, I take the effects of coastal tourism into consideration.	Scale from Not at all – All the time, 0-10
30. I support projects to restore coastal and marine habitats that have been degraded by coastal development.	Scale from Not at all – All the time, 0-10
31. When on holiday on the coast I look to use businesses that reduce their negative impact on the environment.	Scale from Not at all – All the time, 0-10
32. When on holiday on the coast I separate litter for recycling.	Scale from Not at all – All the time, 0-10
33. I look for information on sustainable tourism practices that I can undertake in the areas I visit.	Scale from Not at all – All the time, 0-10
34. When planning a holiday on the coast I look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	Scale from Not at all – All the time, 0-10

Future behaviour questions	
Which of the following options to reduce the effects of coastal tourism on the marine environment will you do in the future?	
35. When choosing my holiday destination, I will take the effects of coastal tourism into consideration.	Scale from Not at all – All the time, 0-10
36. When choosing holiday accommodation near the coast, I will take the effects of coastal tourism into consideration.	Scale from Not at all – All the time, 0-10
37. I will support projects to restore coastal and marine habitats that have been degraded by coastal development.	Scale from Not at all – All the time, 0-10
38. When on holiday on the coast I will look to use businesses that reduce their negative impact on the environment.	Scale from Not at all – All the time, 0-10
39. When on holiday on the coast I will separate litter for recycling.	Scale from Not at all – All the time, 0-10
40. I will look for information on sustainable tourism practices that I can undertake in the areas I visit.	Scale from Not at all – All the time, 0-10
41. When planning a holiday on the coast I will look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	Scale from Not at all – All the time, 0-10

Appendix 6.2 Results and Analysis

There was a total of 76 responses to the coastal tourism survey, with 52 of the respondents being female and 24 males. The respondents were aged 18 – 25 years, located in the US, and had education to the level of bachelor's degree. The respondents' city locations included Philadelphia, Los Angeles, Chicago, and Houston. The main subjects studied by the respondents included Business, Psychology, Engineering, and History. The average score for respondents' knowledge related to coastal tourism was 54.53%. The average score for attitude was 8.19 out of 10, current behaviour was 6.00, and future behaviour was 7.53.

Appendix 6.2.1 Correlation Analysis

The results of the correlation analysis of the coastal tourism survey questions show that there is a significant correlation between the knowledge and attitude questions, the attitude and current behaviour questions, and the attitude and future behaviour questions. The Pearson correlation r-value for the correlation between knowledge and attitude is 0.309 with the correlation significant at the 0.01 level (2-tailed). The r-value for the pairing attitude and current behaviour is 0.387 with the correlation significant at the 0.01 level (2-tailed). The r-value for the correlation between attitude and future behaviour is 0.510 with the correlation significant at the 0.01 level (2- tailed).

Appendix 6.2.2 Reliability Analysis

The Cronbach's alpha values for the coastal tourism attitude, current behaviour, and future behaviour questions are 0.845, 0.929, and 0.939, respectively. The information in the following tables is the question text, mean, standard deviation, and "Cronbach's alpha if item deleted" for each of the questions.

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Q23: How do you feel about damage to the natural environment?	8.64	1.70	0.789
Q24: How do you feel about the construction of structures close to the beach?	8.04	2.15	0.787
Q25: How do you feel about the effects of coastal tourism activities on the marine (ocean) environment?	8.29	1.86	0.767
Q26: How do you feel about the possible effects of the construction near the beach e.g. the disturbance of nesting and breeding sites?	8.43	1.81	0.783
Q27: What type of effect do you feel there will be on the ocean if people support sustainable tourism activities?	7.57	2.33	0.920

Table containing the mean, standard deviation, and "Cronbach's alpha if item deleted" for the coastal tourism attitude questions

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Which of the following options to reduce the effects of coastal tourism on the marine environment do you do?			
Q28: When choosing my holiday destination, I take the effects of coastal tourism into consideration.	5.09	2.96	0.912
Q29: When choosing holiday accommodation near the coast, I take the effects of coastal tourism into consideration.	5.24	3.20	0.908
Q30: I support projects to restore coastal and marine habitats that have been degraded by coastal development.	7.12	2.70	0.927
Q31: When on holiday on the coast I look to use businesses that reduce their negative impact on the environment.	6.12	3.11	0.914
Q32: When on holiday on the coast I separate litter for recycling.	7.66	2.69	0.943
Q33: I look for information on sustainable tourism practices that I can undertake in the areas I visit.	5.54	3.25	0.910
Q34: When planning a holiday on the coast I look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	5.29	3.35	0.910

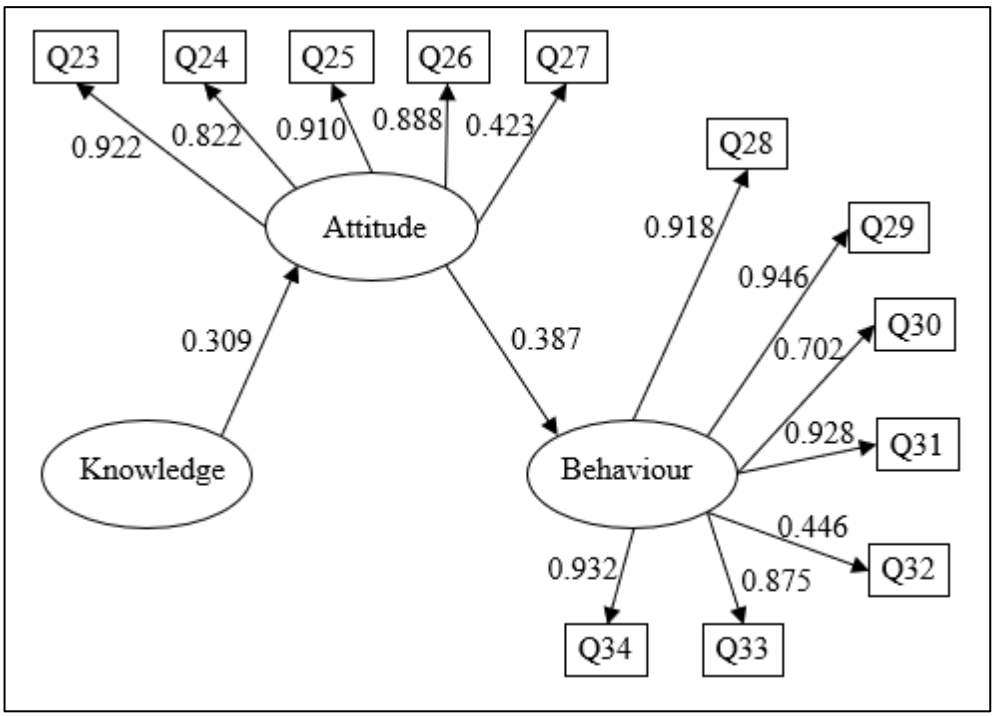
Table containing the mean, standard deviation, and "Cronbach's alpha if item deleted" for the coastal tourism current behaviour questions

Question text	Mean	Standard deviation	Cronbach's alpha if item deleted
Which of the following options to reduce the effects of coastal tourism on the marine environment will you do in the future?			
Q35: When choosing my holiday destination, I will take the effects of coastal tourism into consideration.	7.32	2.36	0.923
Q36: When choosing holiday accommodation near the coast, I will take the effects of coastal tourism into consideration.	7.33	2.37	0.920
Q37: I will support projects to restore coastal and marine habitats that have been degraded by coastal development.	7.79	2.13	0.930
Q38: When on holiday on the coast I will look to use businesses that reduce their negative impact on the environment.	7.30	2.52	0.926
Q39: When on holiday on the coast I will separate litter for recycling.	8.33	2.16	0.953
Q40: I will look for information on sustainable tourism practices that I can undertake in the areas I visit.	7.33	2.45	0.920
Q41: When planning a holiday on the coast I will look for towns or resorts where council officials have introduced schemes to reduce negative impacts from tourism.	7.32	2.46	0.926

Table containing the mean, standard deviation, and "Cronbach's alpha if item deleted" for the coastal tourism future behaviour questions

Appendix 6.2.3 Confirmatory Factor Analysis

The figure below shows the structural equation modelling path diagram for the coastal tourism survey.



Structural equation modelling path diagram for coastal tourism survey

Appendix 6.2.4 Rasch Analysis

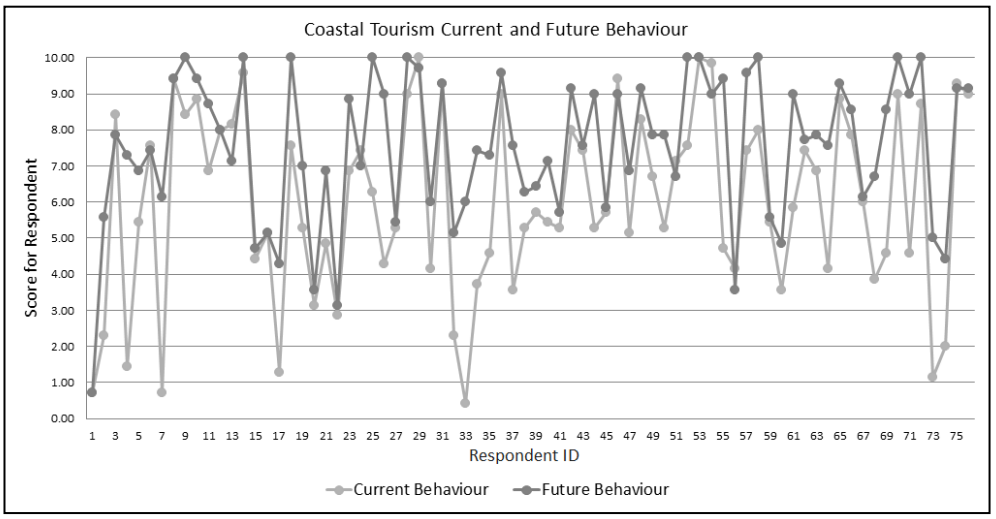
The unidimensional attribute which was the focus of the Rasch analysis in this section is the respondents' knowledge related to the ocean- environmental problems caused by coastal tourism. The results of the knowledge questions for the coastal tourism survey were coded using 1 for a correct answer and 0 for an incorrect answer. The results were then inputted into the Winsteps data file and the Rasch analysis of the knowledge responses was performed. The results of the Rasch analysis of the responses to the coastal tourism knowledge questions are shown in the table below. The information shown in the table consists of the question number used in the survey, the total number of times the question was answered correctly, the Rasch measure for the question, the standard error associated with the question, and the outfit value for the question.

Question number	Total score	Measure	Standard Error	Outfit Zstd
Q9	10	3.05	0.36	-0.5
Q7	20	2.08	0.28	-1.6
Q2	21	2.01	0.28	3.2
Q4	21	2.01	0.28	-0.9
Q20	30	1.38	0.26	-1.0
Q14	33	1.19	0.25	-0.8
Q1	36	1.00	0.25	1.6
Q17	41	0.68	0.25	-0.7
Q18	48	0.23	0.26	-0.8
Q16	54	-0.20	0.27	0.3
Q10	56	-0.35	0.28	0.8
Q6	58	-0.52	0.29	-0.4
Q22	58	-0.52	0.29	1.1
Q11	63	-0.98	0.32	-0.2
Q21	63	-0.98	0.32	1.3
Q12	65	-1.21	0.34	-1.6
Q19	65	-1.21	0.34	-1.1
Q3	66	-1.33	0.36	0.6
Q15	66	-1.33	0.36	-0.8
Q5	67	-1.46	0.37	1.4
Q8	69	-1.77	0.41	0.5
Q13	69	-1.77	0.41	-1.1

Table containing the Rasch estimates for the coastal tourism knowledge questions

Appendix 6.2.5 Current and Future Behaviour

The figure below shows a double-line graph of the relationship between the coastal tourism current behaviour responses and the responses for future behaviour. As can be seen in the figure, the respondents' average scores for future behaviour are generally higher than their scores for current behaviour which indicates that the respondents intend to improve their behaviour in relation to coastal tourism in the future. For example, the average score for respondent ID 33 for current behaviour in relation to coastal tourism was 0.43, while the score for future behaviour for the same respondent was 6.



Coastal tourism current and future behaviour

Appendix 6.3 Discussion

Comparing the correlation analysis results for the coastal tourism survey with the results from the micro-plastics survey shows that there is a slightly lower correlation between knowledge and attitude in the coastal tourism survey when compared with the correlation found in the micro-plastics survey. The micro-plastics correlation r-value was 0.388 while the r-value for coastal tourism was 0.309. The r-value for the correlation between knowledge and current behaviour for the micro-plastics survey was 0.246, but there was no significant correlation found for the relationship between knowledge and

current behaviour in the coastal tourism survey. The correlation between attitude and current behaviour in the coastal tourism survey (r-value 0.387) is lower than that found for the micro-plastics survey (r-value 0.591). Similarly, the correlation between attitude and future behaviour for the coastal tourism survey (r-value 0.510) is lower than that found for the micro-plastics survey (r-value 0.759). In general, the correlations for the comparisons between knowledge, attitude, and behaviour are better for the micro-plastics survey when compared with the coastal tourism survey.

The internal consistency analysis of the attitude, current behaviour, and future behaviour questions in the coastal tourism survey show that the attitude questions have a good internal consistency (Cronbach's alpha value 0.845). The current and future behaviour questions have an excellent internal consistency with the value for current behaviour at 0.929 and the value for future behaviour at 0.939. The Cronbach's alpha values found for the coastal tourism survey are similar to the values found for the micro- plastics survey with the value for the micro-plastics attitude questions (0.902) slightly higher than that for coastal tourism (0.845), the value for current behaviour for coastal tourism (0.929) is slightly higher than the value for the micro-plastics survey (0.890), and the value in both surveys for future behaviour is the same (0.939).

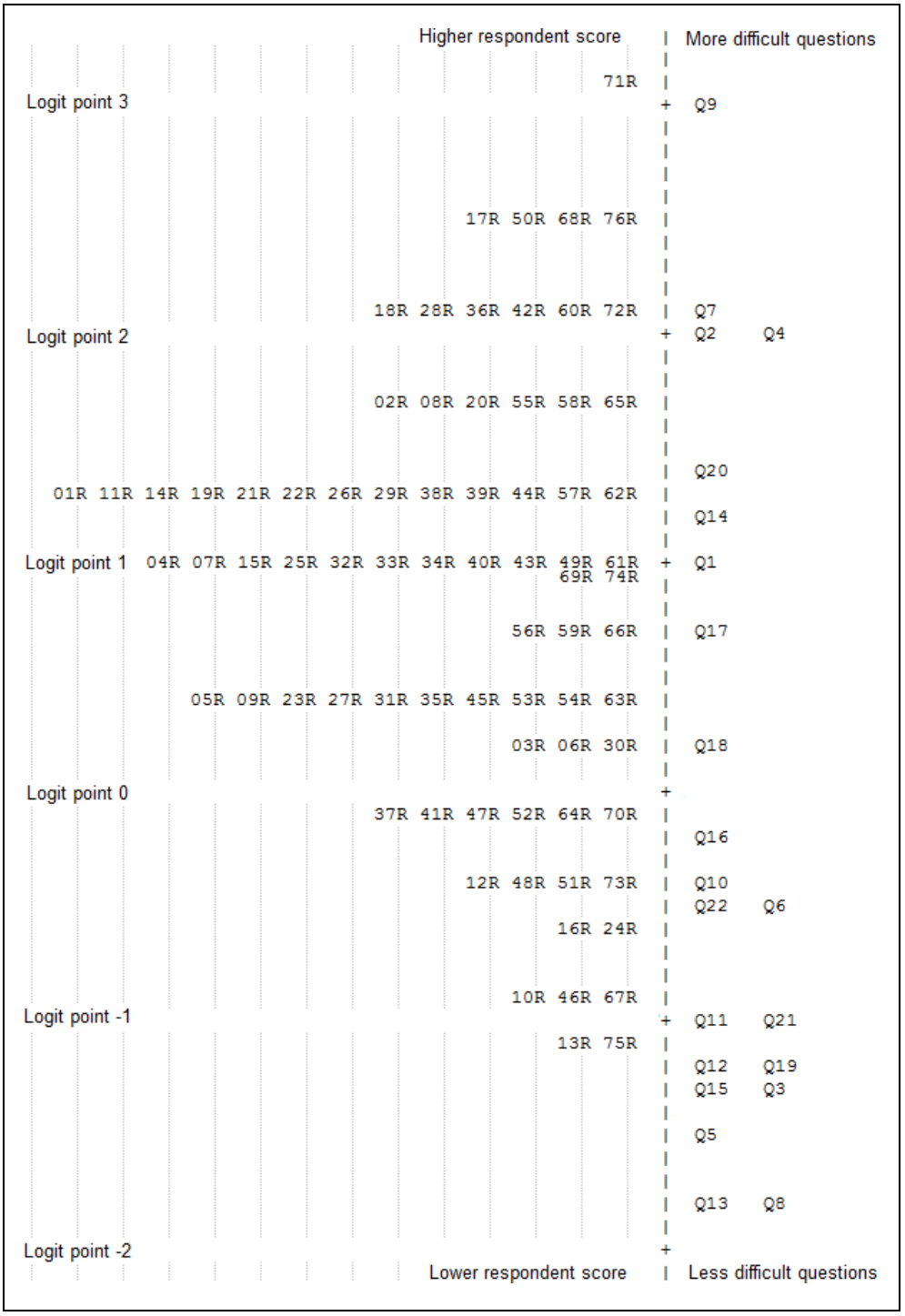
Based on the results of the Rasch analysis of the coastal tourism responses, Question 9 was the most difficult question for the respondents. The text for question 9 is "Please choose the responses to coastal erosion from the list below", and the options provided to the respondent to answer the question were Building erosion barriers parallel to the beach, Building houses close to the beach, Building erosion barriers perpendicular to the beach, and The replenishment of sand on eroded beaches. An analysis of the answers chosen by the respondents to this question shows that 71% of the respondents chose the option "Building erosion barriers parallel to the beach" which was one of the correct answers. Only 46% of the respondents chose the option "Building erosion barriers perpendicular to the beach" which was one of the correct answers. 30% of the respondent chose the option "Building houses close to

the beach" which was the incorrect answer. The combination of the number of respondents who do not know that building erosion barriers perpendicular to the beach is a way of protecting against erosion and those who think building houses close to the beach is a way of protecting against coastal erosion explains why so few of the respondents got this question correct.

The Rasch analysis shows that questions 8 and 13 were the least difficult of the questions for the respondents. Question 8 was "In the Mediterranean region, the construction of new marinas is a very profitable business, true or false". The text for question 13 was "The construction of structures on the coastline has a:" and the options provided to the respondent were Positive effect on nesting and breeding sites, Negative effect on nesting and breeding sites, and No effect on nesting and breeding sites. The fact that these questions were the least difficult for the respondents shows that the majority of respondents are aware that the construction of marinas is a profitable business, and that coastline construction has a negative effect on nesting and breeding sites. There is a low "Standard error" associated with the positioning of the questions on the logit scale. Questions 8 and 13 have the highest error (0.41) which is due to the fact that there are no respondents positioned at the lower part of the logit scale. The "outfit Zstd" for each of the questions in the coastal tourism survey is within the acceptable range of between -2 and 2 except for the fit value for question 2. The fit value for question 2 is 3.2 and the reason why this question has an unacceptable fit value may be due to the fact that more respondents chose the incorrect answer rather than the correct answer. This question could benefit from a review in order to improve its fit value.

The person-item map for the responses to the coastal tourism knowledge questions is shown below. A visual analysis of the person-item map reveals that the majority of the respondents are positioned between the 0 (zero) point and the point 2 on the logit scale. For example, there are 13 respondents positioned at the 1 logit point on the logit scale and they include respondents numbered 04R, 07R, 15R and 25R. The positioning of the majority of the respondents above the zero point on the logit scale indicates that this survey

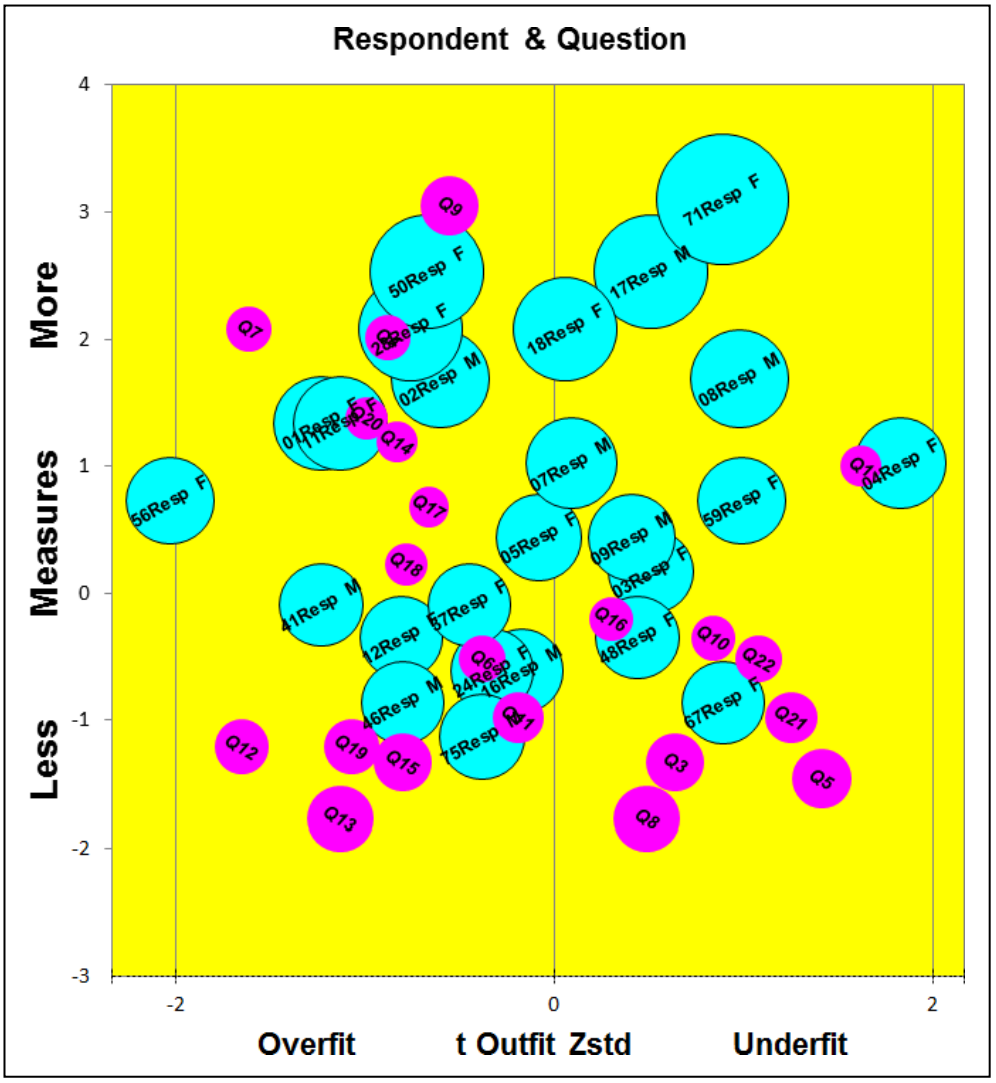
was not difficult for the group of respondents it was administered to. The positioning of the questions on the logit scale shows that there is a reasonably good spread of questions between the -2 and 1.5 points on the logit scale. In the figure below, for example, questions Q10, Q22, and Q6 are positioned at the -0.5 point on the logit scale. There is a gap in the spread of questions between points 2 and 3 on the logit scale which indicates that the survey could be improved by adding more questions which are more challenging for the respondents.



Rasch person-item map for the coastal tourism survey

The figure below shows the Rasch bubble chart for the questions and some of the responses to the coastal tourism survey. The turquoise circles are the respondents to the survey and the pink circles represent the questions. The positioning of the questions on the vertical logit scale is an indication of the

difficulty of the question. The more difficult questions are towards the top and the less difficult questions are positioned towards the bottom of the image. The positioning of the respondents on the vertical scale is based on the respondents' level of performance, with the better performing respondents positioned towards the top of the scale. The size of the circle indicates the level of error associated with the positioning of the questions and the respondents, and their horizontal distance from the centre (zero) line is an indication of their fit. Question 2 is not shown in the figure because it is positioned at point 3.2 on the horizontal "t Outfit Zstd" scale.



Rasch bubble chart for coastal tourism survey

Distractor analysis was performed on the responses to the coastal tourism survey to check the usefulness of each of the answer options provided to the respondent to answer the questions. There were 15 questions in the coastal tourism survey which were suitable to have their distractors analysed. Question 2, in the coastal tourism survey, was related to the respondent's knowledge of the extent of the growth of international tourism in the Mediterranean region. Two of the options provided to the respondent, "100%" and "5%", were chosen less than 5% of the time which indicates that these options are not useful in distracting respondents who are unsure about the correct answer. The correct answer to the question was "75%" and that option was chosen 21 times. However, the option "35%" was chosen 49 times which indicates that the majority respondents incorrectly think that the growth of tourism in the Mediterranean since 1995 is 35%. Question 12 was related to the consequences of the development of hotels, housing, services, and leisure activities in coastal tourism areas. The option "No change in biodiversity" was only chosen once which indicates that this option was ineffective and could be removed from the question. A number of other questions in the survey contained answer options which were chosen less than 5% of the time, so these questions would benefit from the removal of the lesser chosen options and the possible inclusion of more effective options.

Appendix 6.4 Summary

The effectiveness of the OL tools created as part of the ResponSEAble project can be measured using my framework. Using the framework, the specific knowledge related to the elements of the DAPSIWR model on the topic was identified. The knowledge was used to create a coastal tourism survey which could be used as a pre- and post-survey to measure the effectiveness of O tools. The creation of the DAPSIWR coastal tourism model was a useful approach to the creation of a survey which measures respondent's knowledge, attitude, and behaviour in relation to coastal tourism from the point of view of the human-ocean relationship.

The analysis of the responses to the survey shows that there is a significant correlation between knowledge and attitude, attitude and current behaviour, and attitude and future behaviour. The attitude and behaviour questions have a high Cronbach's alpha value which indicates a high level of reliability between the questions. The comparison between the respondents' current behaviour and their future intended behaviour shows that they intend to behave more pro-ocean-environmentally in the future. The Rasch analysis provides a scale where the survey questions are displayed according to their difficulty which revealed gaps in the scale which could be filled by inserting questions of the appropriate difficulty. Both the Rasch analysis and the distractor analysis reveal insights into the quality of the survey and gives indications of how the survey could be improved. As well as improving the surveys, the results of the data analysis can be used to improve the OL tools associated with the survey topics. The research work performed to measure the knowledge, attitude, and behaviour of survey respondents is related to research objective five, and the analysis performed on the response data is related to research objective six.

Appendix 7

The content of the micro-plastics ocean literacy tool

Cosmetic consumption Patterns

DRIVER

The global beauty and personal care industry has grown over several decades. Today it is a multi-billion-dollar business, worth in the order of 433 billion US dollars in 2012 (about 377 billion Euros) (UNEP, 2015). The European market is the largest in the world, with a reported market value of 77 billion Euros in 2015, according to Cosmetics Europe (cosmeticseurope.eu, 2016).

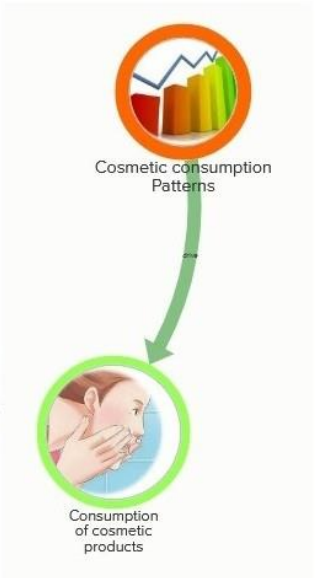
The United-States has the second largest market at 37.8 billion Euros and Japan has the third largest at 29.3 billion Euros.

Plastic in Cosmetics and Personal Care Products

These tiny plastic particles are used in a number of personal care and cosmetics products (PCCPs), including toothpaste, nail polish, skin creams, baby products, sunscreen, shaving cream, facial scrubs, shower gel, and lip gloss.

Since most of these are “rinse off” products, they end up as “down the drain products” in household wastewater streams and from there, released into the marine environment.

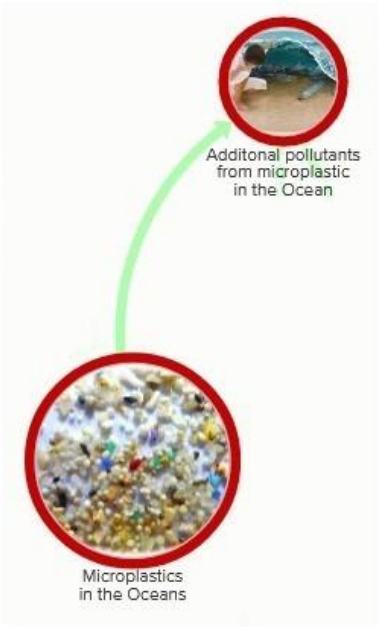
Only a proportion of the micro-plastics are removed from the water in wastewater treatment plants.



Microplastics in the Oceans

PRESSURE

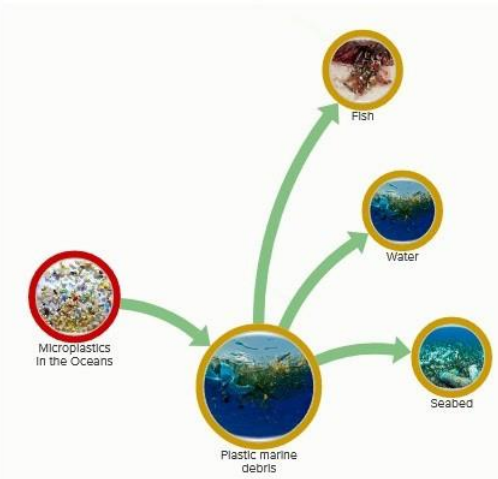
Microplastic accounts for the largest amount of plastics in the oceans although the total quantity of microplastics entering the ocean is not established as of yet. Once in the sea, microplastics get moved around by the wind and ocean currents. Depending on their size, weight and density, they can either float at the surface, or sink to the seabed. Sunlight can degrade the plastics in the ocean.



Attributes of plastic

Once plastics reach the ocean, their greatest strength – the durability of plastic, also provides the key cause for concern. The durability of plastic means that it persists in the marine environment for an unforeseeable time and thus plastic in the ocean is accumulating.

Other attributes of plastic are Low production costs and High flexibility.



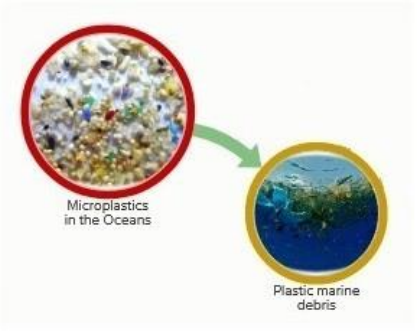
Plastic marine debris

STATE

Plastic debris is found almost everywhere on our planet, from the polar regions to the equator, and from remote areas to densely populated ones.

The equivalent of one rubbish truck of plastic waste is being added to the sea every minute.

The majority of our plastic waste ends up in the ocean.



Market response to phase out microbeads

RESPONSE

In 2012 Unilever (with brands such as Dove and Lux) announced that the company would phase out the use of plastic microbeads in response to environmental concerns.

Procter and Gambler is in the process of eliminating polyethylene microbeads from their toothpastes and cleansers, aiming to remove it completely by 2017. The company´s brands include Gilette, Head & Shoulders, Herbal Essence, Pantene, and Braun.

Single-use plastic

Almost 300m tonnes of plastic is produced each year and, with just 20% recycled or incinerated, much of it ends up littering the air, land and sea.

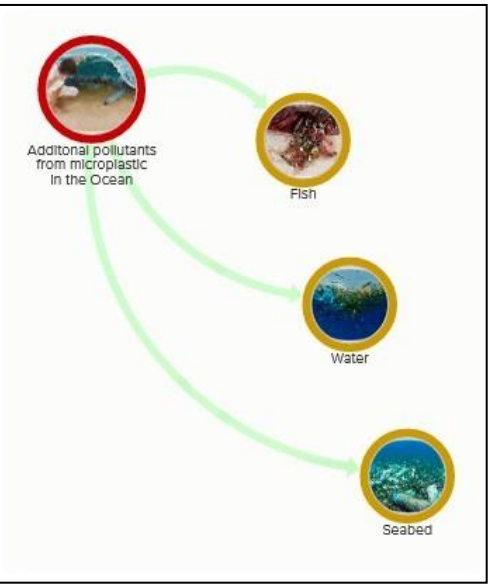
89% of ocean rubbish comes from single-use plastic i.e. things that were only used once and then thrown away.

Microplastics in the Oceans

Plastic is Dangerous for Marine Life

Marine life can mistake plastic for food and attempt to consume it.

If there are already pollutants in the surrounding water, they can attach themselves to microplastic particles, thereby creating larger, more toxic particles that can then be ingested by marine organisms.



How Plastic Reaches the Ocean

The tiny plastic particles, used in personal care and cosmetics products, can be released into the marine environment via household wastewater streams and sewage discharge. Other ways for micro-plastics to enter the ocean are through the breakdown of larger pieces of plastic and accidental spillage during transport.