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Emergent methodology: Bridging the ocean tangibility gap with experimental design methods

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ABSTRACT

The ocean covers 71% of our planet, yet we know more about the moon. While climate change tipping points in the ocean are likely to be some of the most powerful future drivers for human adaptation to change, the ocean remains a distant dumping ground, badly understood and disconnected to human experience on land. Design can make ocean issues tangible and co-design can leverage lived experience into more adaptable solutions. We set out on a long term design project researching across a series of ocean voyages connecting coastal communities across the Atlantic Ocean. We report on our emergent methodology and the decision making and reflexiveness that was required. Tensions between wandering and research direction were explored as a process for re-focussing our goal refinement. Reflecting on the knowledge production emerging from our methodology we recognised design for future transformation as a quality that may be claimed retrospectively.

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1. Introduction

Design has challenges and opportunities in engaging with climate change. While design research for land based activities has moved on from sustainability to regenerative design, multi-species design and circular economy, other global spaces are less explored. We realised that although we live on a blue planet where the ocean has some focussed problem solving activity, there is less strategic longer term design effort in this important context.

The goal of staying within the 1.5 °C heating goal of the Paris climate accords (UN 2016) is a major challenge requiring collective design effort. At the same time, we lack enough trained design capacity to rapidly build co-design skills. Beyond problem solving ocean issues the most significant

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challenge is how design can support new economic models for the ocean that allow regeneration, income for all, support for ocean cultures and long term behavioural economies of change. We receive critical services from the ocean including food, transportation, leisure, aesthetic, recreation and of course weather. Only 5% of the ocean has been explored by humans (UNESCO 2022) and out of all the UN SDG's (UN 2023) the ocean is by far the least funded (Adamkiewitz 2022) with the World Economic Forum stating that '$175 billion per year is needed to achieve SDG14 by 2030, and yet, between 2015 and 2019, just below $10 billion in total was invested' (Johansen and Vestvik 2020; WEF 2022).

Researching to improve the relationship between humans and the ocean is particularly challenging. While over 2.4 bn people live within 100 km of the coasts (NASA 2023), humans find it difficult to relate to the scale, complexity, diversity and distance between life on land and life in the ocean that exists in a medium which is hundreds of times denser than air and mostly obscured to us. Situated between science and technology and with strengths in collaborative creativity, problem solving and making tangible (linking problem perception to personal agency for action) through visualisation, design is well placed to make a positive strategic contribution to the future of the oceans. Donnelly et al. (2020) give a compelling example for how turtles have become a flagship species through documentaries and images motivating action for the ocean. However, we don't have images that can produce these changes for a 2 °C increase in ocean temperature which is a much greater scale of risk. In such complex research contexts methodologies cannot be easily prescribed and need to remain fluid as new findings and opportunities clarify and adjust research aims and questions. Here we report on developing an emergent methodology in the ocean climate nexus that can respond to complexity, shifting insights and new opportunities.

We have structured the following sections by integrating practice and theory making a case for the contextual need for an emergent methodology by reviewing some of the key texts from design research, the social sciences and complex systems. A description of participatory workshops and how these link ocean objects to developing narratives is provided (Section 2). We follow this by outlining our design research fieldwork stages and research narrative including the emergence of insights that directly impact the direction of the research (Section 3). Sections 4 and 5 describe how goal improvement was facilitated by the reflexive awareness of emergence as a result of these insights. This is followed by section 6 where we consider how this approach aligns with the goals of action research and recent work by the authors on design ontology to establish how an emergent methodology can be rigorous and a form of knowledge production.

2. An emergent need

New Economic Models for the Ocean (NEMO) is a long term research project focusing on actions that aim to explore how design can move beyond solutioning and accelerate economic change. We expected that our goals and research questions would shift over time and that our activity would cover several projects that would feed into each other. This could make conventional project frameworks and methods driven by a predetermined issue over-constraining. In terms of our thematic focus it would be easy to choose a popular issue like sewage discharge, ghost gear or plastics in the ocean, all of which are serious issues needing design effort. However, the most significant of all the climate risks comes from cascading regime shifts driven by temperature increase (Waters et al. 2016), in other words how a single tipping point (Rocha et al. 2018; OECD 2022) can cascade others creating rapid change and complex impacts on ecosystems. The ocean has the largest number of entangled tipping points and the ones that are most sensitive to change. An example of this type of impact is a 2°C temperature rise where we are projected to lose all the world's coral reefs creating a major reduction in biodiversity and impacting our food supply along with significant changes to weather and sea level rise (UNEP 2020).

Our project is blue sky funded research supporting UNESCO's International Oceanographic Commission (IOC) as an Ocean Decade Implementing Partner (DIP). Translating data into actionable initiatives is challenging as identified in UNESCO's IOC's implementation plan (IOC 2021) highlighting the gap between ocean science and community engagement as a critical issue. The report recommends co-design as an important strategy to tackle ocean issues. The question we asked ourselves is how can a group of design researchers begin to position themselves to understand how to focus effort for reducing the risk of a 2°C hotter world?

Falling into an issue selection trap early on was one of our key concerns and the long term nature of our commitment required a research approach that could flex and accommodate new insights leading to goal refinement. We understood that design needs to position itself in collaboration with a wide range of disciplines to fundamentally change humanity's relationship with the ocean *via* supporting new economies of change. The work we have decided to embark on aims to move beyond design as solutioning to enable new economic models for the ocean (NEMO) supported by design led innovation, design research, enterprise support and educational initiatives. This drives the need to explore new flexible methodologies for ocean design work.

Emergent methodology has been discussed in design research with work led by Gaver, Krogh and Koskinen supporting an approach for tackling complex, emerging and shifting design issues. Sometimes called 'drifting by intention' (Krough and Koskinen 2022) it forms a cornerstone of a

constructivist approach to design research methodology where it is accepted that the research process itself generates findings that require shifts in goals and methods. There are relatively few detailed design research case studies in this area and even fewer (none that we have yet found) that relate to the meta design challenges facing the future of the ocean.

Early work by Gaver et al. (2004) explored cultural probes and the opportunity of uncertainty for driving design research. Later work focussed on emergence as a feature of practice based research (Gaver et al. 2022) as a response to attempts to constrain Human Computer Interaction (HCI) research with requirements to pre-registeraims used to assess research outcomes in the future (for example during publication or research review). While this may suit some branches of HCI it was seen as a major limitation for social and design research which require more reflexivity, something described by Kurt Lewin as 'if you want to truly understand something, try to change it' (Tolman 1996, p. 31). It also finds common ground with frequent disagreements in design research between positivist and constructivist approaches to research with preset aims verses emergence that can redefine goals.

Krogh and Koskinen (2020) pursued a similar line of enquiry *via* 'drifting by intention' through surveying a range of design doctoral theses to understand how methodology focussed research questions allowed space for exploration and serendipity. Dixon (2023) has also suggested that alternative methodological evolutions are possible in design research by moving beyond reliability, validity, and objectivity while Zimmerman, Forlizzi, and Evenson (2007) have discussed 'extensibility' as a similar feature of design research where research transgresses beyond initial boundaries. Emergence, drifting by intention and extensibility all describe research with goals which can only become clearer as the researchers tune and refine methodology according to discoveries that shape their path.

Work in the social sciences has for some time explored emergence in methods and its value in complex social contexts. Dick (2001) has recognised the value of emergence for both action research and grounded theory:

> 'Grounded theory and action research can both be used as emergent, data-driven methodologies. This allows them to be flexible, and responsive to the situation. Action research can learn from grounded theory, particularly for thesis and dissertation research, by giving more attention to providing an audit trail.' (Dick 2001, p47)

Dick (2001) goes further by describing the arguments between those who see grounded theory as a creative process verses those who have systematised it into a linear step based process. This is detailed in later work by Strauss and Corbin (1990) that is criticised by Glaser (the original author of the seminal work on grounded theory (Glaser and Strauss 1967)) as being overly reliant on step based systems and missing the entire emergent point of the original method with its strong generative concept for facilitating

theoretical originality. The suggestion that action research and grounded theory can be used as emergent methodologies as opposed to delivering emergence within methods is a contentious point and one that often drives discussions of methodological slipperiness. In our work we hope to show how emergence can be a property of an over-arching methodology.

The emergent approach we have developed is similar by considering all of our methodology as experimental (Hall 2011) and constructivist akin to Popper's searchlight (1974) or Gibson's 'Ask not what's inside your head, but what's your head inside of' (Mace 1977, p47). One of the clear risks with this approach is undermining the research by wandering away from the most significant routes or corrupting the research by lacking rigour and a framework to justify decision making. We hope to show how we have steered these action challenges in our research to make a contribution to what the authors have described in previous publications on design epistemology as *knowledge for future transformation via* an ontological mirror that argues for rigour retrospectively (Hall and Galdon 2023a; 2023b). Negotiating confidence and doubt in this context is part of the research challenge (Hall and Hohl 2023) and by tracing through the evolution of our methodology we hope to provide an example that deals with some of the long term questions of rigour and navigation in emergent methodology.

Literature on emergence in complex systems notes the power of the image in supporting thinking around intangible issues with Golstein quoting Suzanne Langer 'We are suffering today from the lack of suitable images of the phenomena that are currently receiving our most ardent scientific attention…' (Goldstein 2018, 65). Boehnert (2018) reports on the CECAN project which develops visual codes through participatory practice for understanding complexity in systems concluding with a series of 16 key characteristics. Bozhinkova, Richard and Zavate (2023) propose a multi-ocean MOSF framework using visual metaphors *via* a mixed methodology of systemic design, ecosystem thinking, and strategic design to tackle ocean economy issues. The three building block of oceans, players [stakeholders] and monsters mirrors our interests and the use of ocean monsters as method of eliciting new imagined opportunities and risks.

Valuable work is being done to explore the power of visualisation to understand how we can leverage understanding leading to behaviour change in complex systems. While this work develops valuable insights into the link between visual imagery and complex systems the work remains largely theoretically driven with deeper longer term impacts on communities harder to gauge. The majority of the focus in this field is on emergence as a behavioural property in complex systems in the context of systems design, policy and service design. Emergence as a property for guiding methodology is underreported. Furthermore, the links between visual representation and large scale behaviour change in response to complex climate nexus issues is at the very early stages.

We also intend to build on previous methodology work by the authors (Fig. 1) (Hall et al. 2019) that focussed on saving lives at sea showing how methods can migrate across projects allowing the identification of capability gaps.

3. Methodological evolution

Our methodology began in 2021 when meeting the owners of the St. Helena ship creating an opportunity to install a sensor package for gathering data on a transatlantic voyage. At the time we were aware of the gap between ocean science and stakeholder action and knew that we had a considerable choice of the different types of data that we could gather. When considering the types of data we could capture from temperature, salinity, pollution, garbage, and ships to ocean biology we realised that a survey of ocean objects would allow us to focus on one of design's core strengths of leveraging objects for human behaviour change. Our aim was to see if we could make connections between ocean objects and coastal communities to better understand disconnection issues. We began a quantitative counting of 'all the things that are not the ocean', conducting a long distance experimental survey to test if we could make ocean-land connections and where they could lead. This would also give us an example of bridging a quantitative scientific approach with a qualitative approach, one of the UNESCO Ocean Decade challenges (IOC 2021).

3.1. Ocean data gathering

Over a 9 week period in 2021 we designed, developed, tested and built an AI sensor package including a test voyage on the Red Funnel ferry from Southampton to the Isle of Wight in the UK to check installation procedures, image quality and field of view. We worked with Sustainable Ventures who

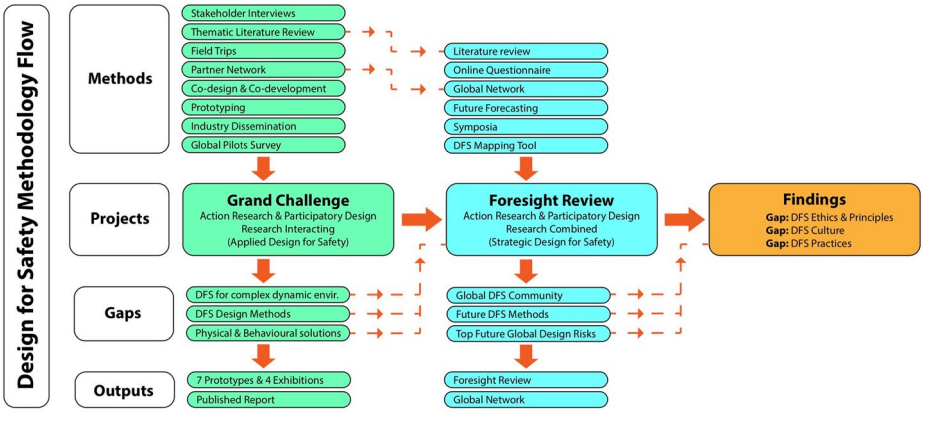

Figure 1. Design for Safety Methodology Flow illustrating how methods interact to generate findings that articulate knowledge and capability gaps (Hall et al. 2019).

provided design engineering, calculations, technology interfacing and camera shroud design support. The autonomous package was installed on the St. Helena ship, which was part of the Extreme E off-road race series (2024) delivering electric cars and sustainable power plant to an international event in Greenland. After the race the ship with our sensor package installed sailed from Kangerlussuaq in Greenland to Poole in the UK *via* the Azores, Gibraltar and Sardinia. We captured over 6,000 nautical miles of 4k footage 24 hours a day from two pairs of cameras mounted approximately 25 m above the ocean located on the ship's monkey island. The total footage was over 24,000 nautical miles, enough to circle the globe amounting to around 54TB of data.

After collecting the footage, we began building an analysis model realising that spatial separation into above, on and below the ocean alongside human made and natural object categories would provide a useful framework to engage participants. During the next 10 months we manually analysed the footage using the pomodoro technique (Cirillo 2018) for timing and compared it to the AI 'object' identification. Object emergence in the footage was enhanced by focussing on sectors of each frame and a shorthand list of vectors was developed by the reviewer who was able over time to see when different objects appeared in anticipated places. For example, whale blows were mainly in the top 3rd of the ocean view and garbage low down in the wake of the ship. We found 3,605 objects identified manually verses 164 by AI. The AI technology was included in the original camera specification and was not designed specifically for identifying ocean objects. Since 2021 ocean object AI has moved on with new technologies for preventing collisions making progress in general ocean AI object identification (e.g. Sea AI 2024). We imported all the GPS points and classified our objects into Cesium Ion (2024), a time based geospatial package that would allow us to study the journey data and share it with participants (Sommer et al. 2025).

3.2. Engaging communities and methods

Comparing the responses and insights from diverse communities was important for gathering a range of deep qualitative views from Nuuk in Greenland and Poole in the UK. To achieve this, we developed a series of workshops engaging ocean professionals (people whose jobs and livelihoods were directly engaged with the ocean) and coastal citizens to gather a broader social inclusion in both Poole and Nuuk. This allowed us to create a matrix across 4 sets of participants showing comparisons of ocean related experiences across different cultures, geographies and ocean issues.

For recruitment in Poole, we used our own network and recommendations from the Royal National Lifeboat Institution (RNLI) who are well connected with the maritime sector to recruit eight participants who represented roles including lifesaving, ship building, port management and activism for a one

day activity taking place in May 2023. In Greenland we recruited five participants from an age, gender and culturally representative group from a range of agencies including the port management and hunting and fishing organisation for a one day workshop in Nuuk with Kalaallisut (Greenlandic), English and Danish translation. A separate activity for citizens took place in the Nuuk city library with similar methods to those used in Poole. The original voyage track started in Kangerlussuaq in the Arctic circle, but this location was not suitable for running a workshop as it is a very small remote airport and port, so we chose the capital city Nuuk which the ship sailed past shortly after departing as a more representative ocean community.

Converting our quantitative ocean object data into qualitative workshop materials would allow us to engage communities at both ends for the voyage in Greenland and the UK providing a cross-cultural comparison and a potential knowledge exchange network. We developed a range of workshop tools including large 1.3 m printed maps, a kit to make a fantasy sea monster that represented future ocean hopes and fears, and a matrix of opportunities and issues that were used with ocean professionals (people who made their living on or related to ocean industries). A separate set of workshops were conducted with citizens in public spaces using a map and three questions; My connection to the ocean is….?, What worries me about the ocean is….?, My one wish relating to the ocean is…? These questions were framed as open ended provocations for participants to complete and conducted in May and September 2023. Developing this combination of methods allowed us to generate material that would support narrative engagement with the quantitative data and provide insights into our participants ocean connected worlds as illustrated in figures 2 and 3.

3.3. Qualitative analysis

Analysing across such a diverse set of media including diagrams, drawings, annotated maps and matrixes was challenging and we decided to use grounded theory and thematic analysis (Glaser and Strauss 1967) using NVivo software (NVivo 2024; Welsh 2002) to capture all the different visual and written medium types. This was followed by a process of 'saying what we see' then 'seeing what we say' to arrive at a final set of findings that described the key concerns in each community allowing a comparison to be made across them. The combinations of methods and different output mediums allowed us to make tangible connections between distant ocean objects,daily lives and personal experience. Narratives emerged from personal experiences and were discussed across the groups leading to community 'pictures' as well as diverse individual connections and experiences of the ocean. We noted significant differences in attitudes relating to sewage release and the language used to discuss animals being much more intimate and closer in

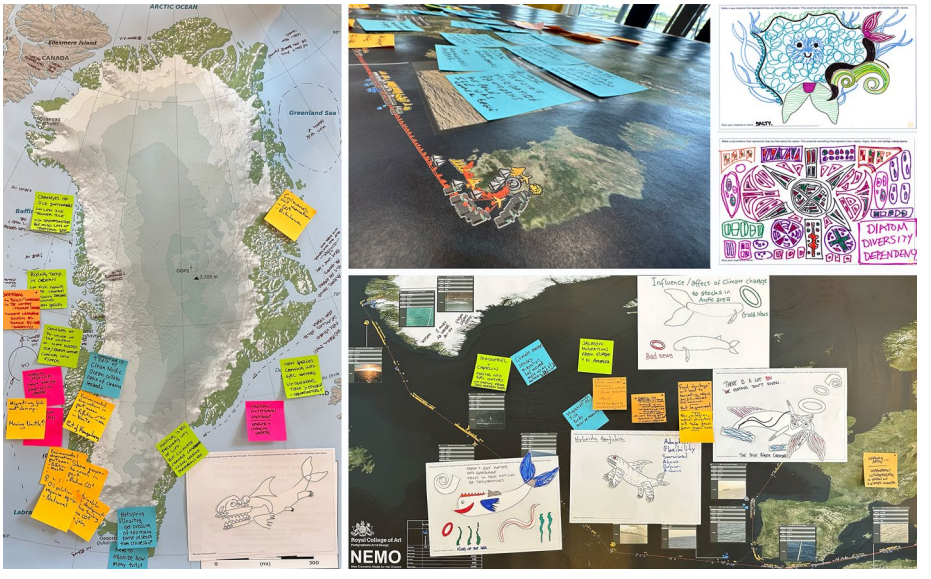

Figure 2. Illustrating how participants were encouraged to use quantitative object maps from the voyage alongside other tools including monsters to explore ocean issues and narratives.

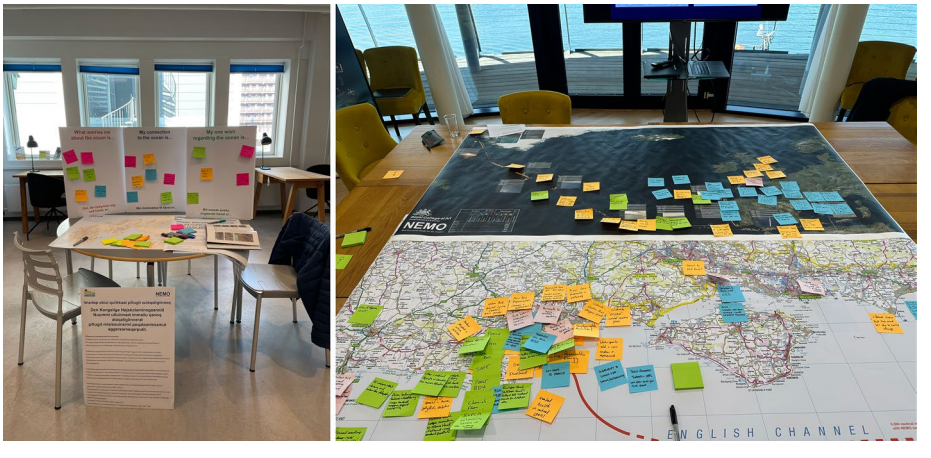

Figure 3. Ocean relationship questions as used in Nuuk Greenland Public Library and Object Maps as used by participants at the RNLI headquarters in Poole UK.

Greenland whereas it was more distant in Poole. The Poole workshop surfaced long histories of marine activity including the building of the port on empty clam and cockle shells, an explosion in the past that polluted the lagoon and a recommendation to study old pier postcards to see how the climate had changed sea levels and the coastline. Nuuk had a particular focus on 'ghost' fishing with many kilometres of old gear recently been

recovered from the sea. The narratives that emerged gave rich and insightful experiences of two very diverse communities where our networks of objects served as a library of ocean prompts for participants to start conversation making connection between land, ocean events, opinions and impact. This formed a backdrop to making connections between land based activities that can be reconsidered by participants to change behaviours to prevent a 2 °C ocean temperature rise. Full details of the participant work is reported in a forthcoming publication describing the pre-work, grounded coding, working across diverse mediums and emergent categories of comparison.

Our approach was close to Mills, Bonner and Francis's (2006) description of constructivist grounded theory placed on a methodological spiral, emphasising the subjective relationship between researchers and participants and ontological arguments relating to whether there were pre-existing truths that should or should not be included in the researcher's mindset. This resulted in a recognition that in grounded theory some pre-work is acceptable. We adopted constructivist grounded theory and used this as a part of our research journey rather than the whole, with our pre-existing experience a necessary condition for this method selection.

Following our analysis, we offered participants in Poole a reflection opportunity and returned to Nuuk in August 2024 to feed back our findings to our participants, agencies and NGO's in Greenland for further insights. One of our research principles is to avoid 'extractive and parachute research' and to ensure as far as we can that we engage participants all the way through the process including dissemination and planning follow-on co-design activities. The return visits allowed further insights based on the findings, respected participants as co-explorers and supports building longer term relationships. This also supports emergent methods where participants have a say in the interpretation of final participatory practices along with equitable and trustable processes that are vital for research which recognises that both researchers and participants are learners (Schular and Namioka 1993; Kensing and Bloomberg 1998; Ivey, et al. 2007; Kemmis and McTaggert 2007; Sanders, Brandt, and Blinder 2010).

3.4. Second and third voyage

During the spring of 2024 we were invited to join a science team from the National Oceanography Centre (NOC) as part of the NERC (Natural Environment Research Council) funded ReBELS project in the Labrador Sea (ReBELS 2024) onboard the RRS James Cook UK national research ship gathering data for creating a model of the Carbon Pump and other oceanographic data. The carbon pump data moorings and deployments were situated above the thermohaline pump which is a potential climate change tipping point as it pushes warm water towards Europe as part of the AMOC

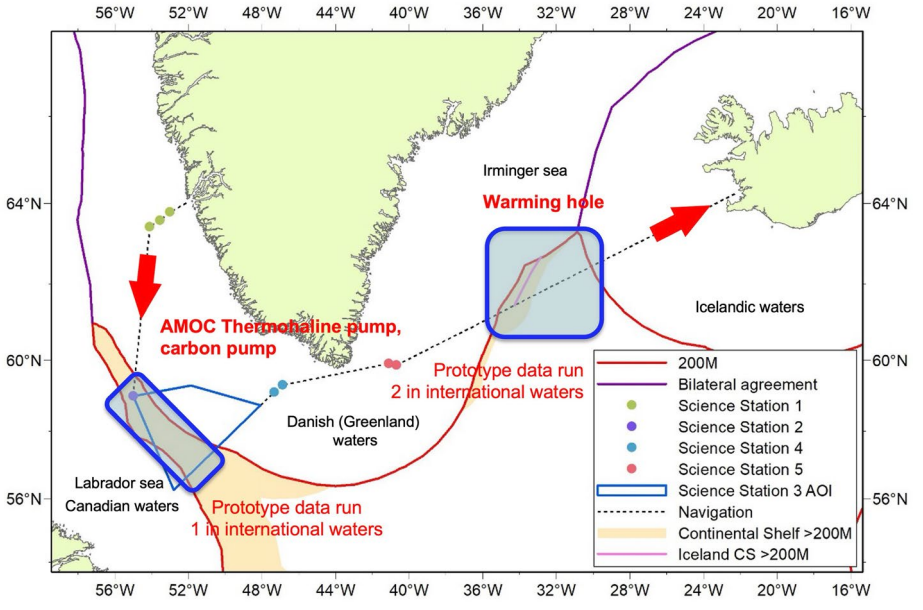

Figure 4. Voyage of the James Cook on the ReBELS cruise showing science deployments our transect data capture locations at the climate change tipping points in international waters (blue squares) (background map courtesy NOC).

(McCarthy et al. 2017; MET Office 2019; NOAA. 2024) making our climate significantly warmer (around 10 °C) than it should be due to our latitude in the UK. The ship also sailed across the warming hole between Greenland and Iceland (Keil et al. 2020; Park and Yeh 2024), the only place on Earth that is getting colder and the stormiest part of the ocean in the northern hemisphere. We used this opportunity both to revisit our participants in Nuuk for dissemination and feedback previously mentioned and to gather visual and ocean data from the two ocean locations.

For the ocean data gathering we captured transect images every 2/3 s using a GoPro and a pair of Insta Ace Pro's cameras mounted onto the port and starboard handrail on the wheelhouse top bridge wings approx. 25 m above the sea (Figure 5). We were also given command of the ship's route on four occasions to conduct a Charlie Sierra creeping line search patterns (USCG 2006) which would allow us to gather data from an area of the ocean (Figure 6).

Data gathering was successful with 2.2Tb/428,000 images and over 1.3Tb of ship's ocean science data from Acoustics, RVDAS, SURFMET, TechSAS, TSG, and Wamos backscatter radar. Sailing on the James Cook also allowed us to spend time with the ship's science team to understand more about ocean science and the methods of data capture that were being used. Some of these included deploying moorings 3 km below the surface that would be recovered a year later, Argo floats (UK ARGO. 2020) that would descend up

Figure 5. GoPro and Insta Ace Pro Cameras installed in shrouds designed by the research team on the rail over the wheelhouse top bridge wings on the James Cook approx. 25 m above sea level. Set to a transect timing ever 3 s (based on an average ship's cruising speed of 10 knots providing image overlap) 24 h a day in the EZ (international waters).

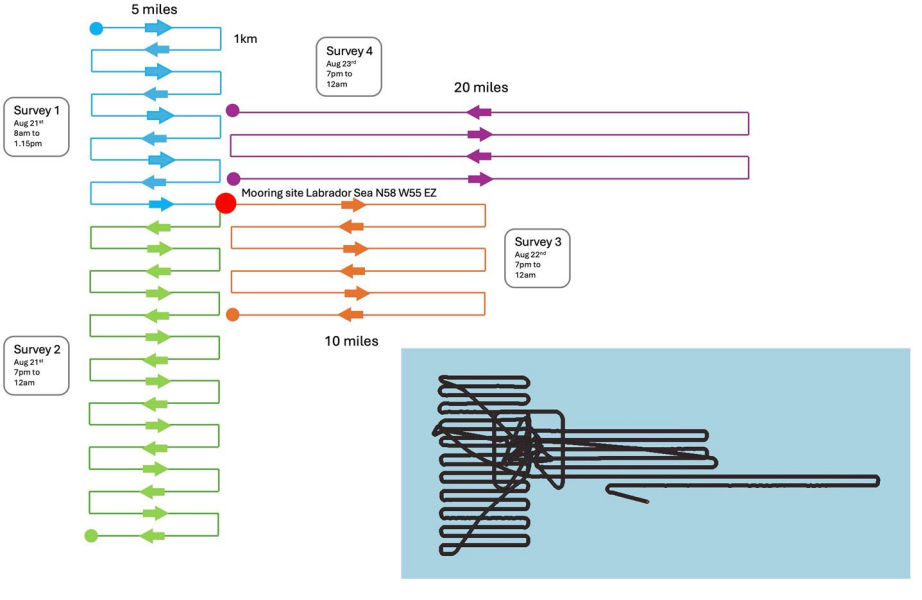

Figure 6. Four Charlie Sierra search patterns varying from 5 nm-20 nm per leg with 1 km between tracks as planned, and GPS track captured by ship data systems (inset).

to 1 km into the ocean, gather data and periodically surface for a satellite link to transmit back to the NOC, and CTD's that would gather data for ocean physics and biology.

Quantitative analysis of the objects from the second voyage using Zooniverse (2024) was planned, however projecting forwards to a workshop that would introduce quantitative science data and visual ocean data we realised that a rethink was necessary.

4. Emergent decisions and reflexiveness

During our research several significant methodological emergences took place that changed our focus bringing clarity for new research directions that could locate more significant relationships for tangibility and follow-on behaviour change that could eventually influence long term economic models.

The first of these took place on our initial voyage on the St Helena between Kangerlussuaq and Poole where we assumed that identifying individual objects would enable us to make tangible connections to human activities on land. A by-product of this phase of the research was understanding that our concept of an object needed to evolve. This happened as a result of realising *via* a malfunctioning AI algorithms that Hurricane Larry was a 500 mile object that we sailed through (Hall et al. 2024). This changed our research methods from a pure object focus to seeing objects within networks resulting in us using our mapped objects printed at large scale for participants to see the narratives and personal connections that may emerge. This also gave us a broader systems scope for the thematic analysis that followed allowing a greater breadth for more significant clusters. We also concluded that there was a risk of an overly anthropocentric focus emerging so we decided to ensure that the way we built networks of objects needed to de-anthropocentrise relational structures so that we could at later stages include diverse multi species perspectives and different scales (Hall et al. 2024).

The second voyage on the RRS James Cook from Nuuk to Reykjavik was the first time a team member was resident on the ship for the entire voyage - as opposed to installing an autonomous sensor package then departing as was the case for the St Helena voyage - and this led to a major shift of perspective. While capturing data over the thermohaline pump tipping point in the Labrador Sea (Fig. 4) it was clear there were few objects of interest this far out to sea as there was no visible evidence of us being located above a climate change tipping point. The sea was flat with a modest swell, a sunny blue sky and some seabirds. We could have been in many different parts of the ocean (Fig. 7). At any time of the year the Labrador sea can be a very stormy place but even then there are no additional signifiers of being located above a climate tipping point. This became a significant reflection that developed into an emergent methodology driver by realising that the research question is not what is there, and how can we make it tangible, but what could be imagined *via* visual data and creative methods, and how could it connect to personal narratives for change? In many ways this

Figure 7. A sample image (from 428,000) taken by one of our Insta Ace Pro action camera's mounted on the ship's rail above the wheelhouse bridge wings set to a 3 s transect linear mode from the starboard side of the RRS James Cook located at N58 W55 in the Labrador sea above the thermohaline pump.

mirrored our experience seeing the AI switched on for three days and imagining Hurricane Larry as a 500 mile wide object. If we could imagine a climate change tipping point as a behaviour changing objects, what could it be? Would ocean scientists and communities in Greenland and the UK see similar or diverse things?

A third voyage opportunity took place on the second and final voyage of the ReBELS research project with the NOC in August 2025 this time sailing from Nuuk in Greenland to St. John's in Newfoundland Canada to recover data from the deep mooring and the Argo floats deployed in 2024 that recorded a whole year of ocean data from 3,000 m deep and closer to the surface. Our initial methodology assumed that we would conduct a mix of remote and in-person workshops with scientists and in the UK if possible, in Greenland before the next voyage so that we could co-visualise the tipping point data.

Our third revelation was to relocate this method into the third voyage to run ocean climate tipping point workshops in Nuuk just before the voyage, on ship with the science team and finally in Canada once we docked in St. John's. Linking the co-visualisation work to the voyage and linked coastal communities would bring participation from scientists and coastal communities to the heart of a voyage that crossed the tipping point.

Figure 8 expresses the current methodology as a linear set of events. It should be emphasised that this does not visualise feedback loops and some of the nonlinear processes we experienced.

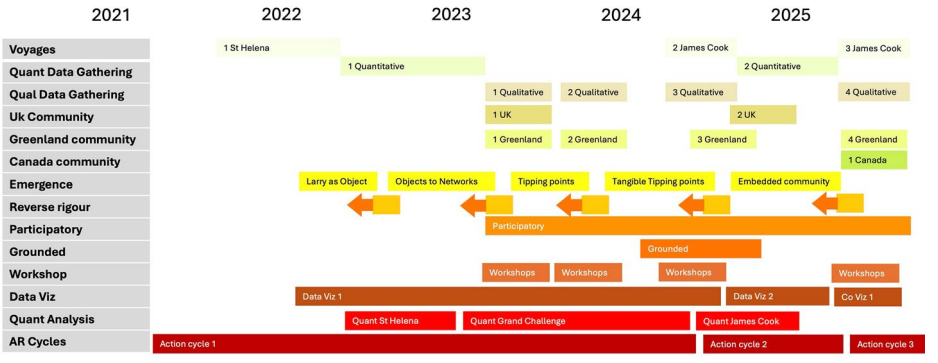

Figure 8. Methodology expressed as a linear process.

Table 1. Illustrating the layering of our methodology and its relationship to methods, tools, toolboxes etc.

Level	Description
Epistemology	Constructivist
Theory & Philosophy	Object Orientated Ontology, Boundary Objects, De-anthropocentrisation
Approach	Practice based
Methodology	Emergent
Methods	Action Research, Participatory, Grounded Theory
Toolboxes	Data visualisation, workshops, visualisation, data analysis
Tools	Interviews, matrix, printed maps, nemo explorer
Techniques	Open ended interviews, facilitation, thematic analysis, coding, design engineering, pomodoro technique, participant engagement, database development, interaction design

Understanding the layering of our research elements is important with Table 1 positioning our activity from the meta to applied levels clarifying and positioning the role of emergent methodology in supporting the research scaffolding based on Crotty's methodology (1998). Our approach to theory and philosophy included Object Oriented Ontology (Bogost 2012; Harman 2018; Morton 2013), Boundary Objects (Star and Griesemer 1989; Scoles 2018) and de-anthropocentrisation (Hall et al. 2024) supporting insights on data construction, visualisation strategy, the nature of objects and their inter-relations. This included seeing Hurricane Larry as an object and the realisation that the NEMO Cesium Ion Explorer was a boundary object (Hall et al. 2024).

5. Goal improvement

Our goals improved over time transitioning from researching to finding direct connections between ocean objects and triggers for behaviour change on land back to an improved goal for finding an invisible unknown 'object' at the very heart of the tangibility issue namely an ocean tipping point. A series of four emergent instances involving objects to networks, seeing hurricane Larry as an

object, co-visualising tipping points as objects and tangibility from tipping points towards co-visualisation focussed our methodology at various stages.

In our work we recognised cycles of action research (Adelman 1993; Clem 1993; Lewin 1946; Susman and Morgan 1983) producing recursive activity generating phases of planning, acting, observing, reflecting and replanning. We have modelled the relationship between our three methodology cycles embedding the sub-research methods we used in each and have located the emergence of insights which we experienced primarily in the observe-reflect phases (Figure 9). This emergence is similar to what Rheinberger (1997) describes as 'concretising' when reviewing a series of DNA experiments in laboratories in the USA in research that undermines the idea that theory precedes experiment, and that instead theory is created from emergence in practice that creates new insights.

At each cycle what we experienced as emergences was driven by a combination of factors, yet all were experientially driven by observations, evidence and data from the environment. Most of these were produced by reconsidering what constitutes an object and how that could uncover new ways of making those objects tangible for future behaviour change.

6. Knowledge production and rigour

Our research methodology has similarities to the action research method (Lewin 1946) by going through cyclical phases with the addition of a series of sub-methods and emergence points which redirected the research in each of the four action phases. In our experience an emergence is significant as it produces an unexpected development in the research which necessitates a reconsideration of the research goal. It creates more than a drift away from current trajectories and offers an improved impact or potential knowledge gain.

In terms of rigour (indicated in Figure 8) the emergence points coincide with what we term a retrospective rigour, looking back to where we have come from and noting that a chain of evidence has emerged for an improved aim indicating that we have produced knowledge suitable for future transformation. In earlier publications the authors argued that the scientific rigour model of repeated experiments to confirm theory is equivalent to a mirror situation in design where our rigour is projected forwards as the confirmation of a successful transferral of knowledge (Hall and Galdon 2023a; 2023b). We referred to this as an ontological mirror reflecting science-repeatability with design-transferability as profoundly different approaches to knowledge generation. The mirror shows how ontological essence, validation, core practices, experimentation, time and function can exists between design and science as oppositional pairs. If science is producing knowledge of the world as it is, then design can claim to produce knowledge of the future world as it could be (Chris Jones 1992, p10) *via* creative methods and research. Reproducing or

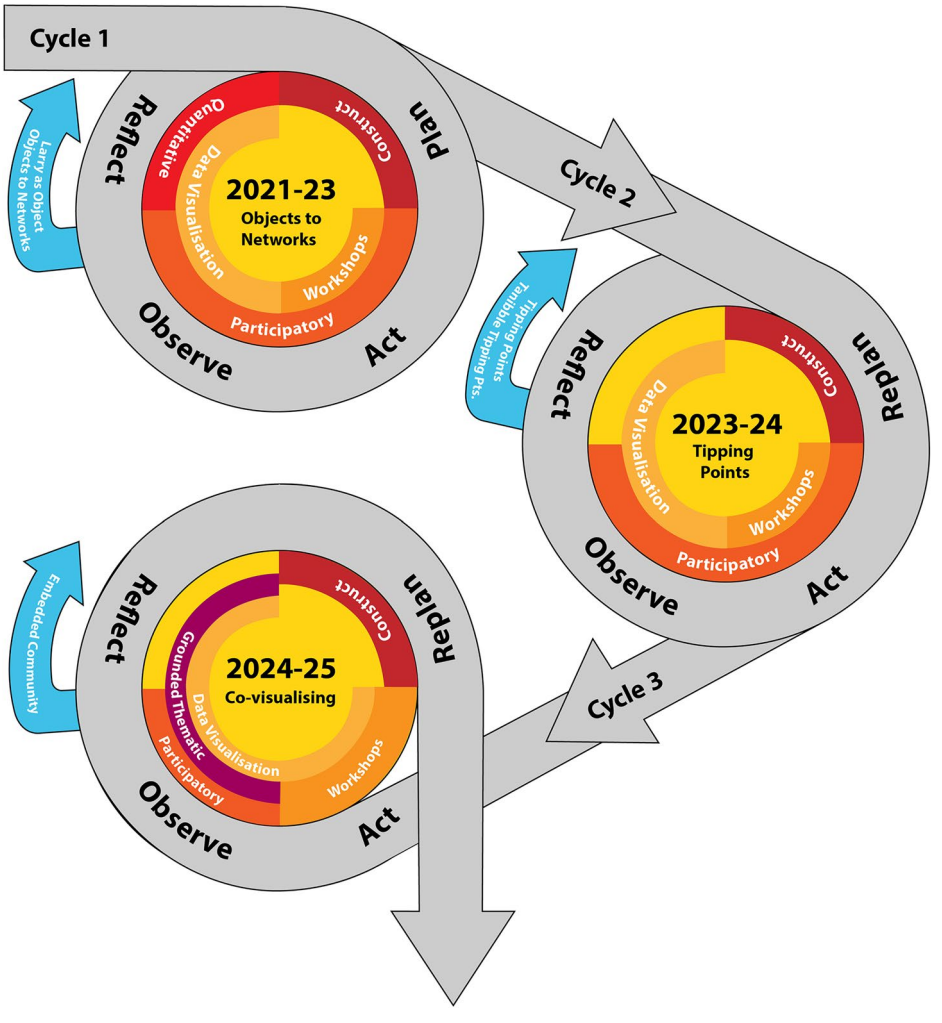

Figure 9. Methodology expressed as a series of action research cycles positioning sub-research methods within the cycle and locating emergence (blue arrows) within action research in the observe-reflect phases.

confirming experiments is replaced by trajectories or vectors showing the transferability of knowledge providing confidence. In fact, some (E.G. Glanville 2005) would argue that this is not knowledge per se, but knowledge that is always *about to be*, rather than *knowledge of* the world as it is, or was.

This agrees with Lewin's (1946) original argument that if you want to understand the world you need to change it. We realised that observing and measuring as well as participatory engagement make changes to the world that allows new creative opportunities for researchers to reinterpret events. It implies that there are forms of knowledge production that cannot function successfully by following a linear problem-theory-method-solution formula and that emergent methodology in a constructivist epistemology can support researching in hard to reach and hard to empathise with environments.

7. Conclusions

There are few examples of a detailed design research emergent methodology in the ocean climate nexus. We have shown that an emergent methodology can explore complex research challenges in hard to reach environments through a series of interconnected projects and allow new insights to emerge that are significant enough to adjust long term research goals. Linking design driven emergence to action research and embedding methods within research methodology cycles shows how we generate rigour going forwards through each research cycle. Crotty's methodology has provided a useful layering showing where an emergent methodology connects an approach and epistemology to methods and toolboxes.

Reflexivity and being open to insights from environmental experience, data and evidence has allowed the research to flex by adapting to unexpected insights from a challenging hard to reach environment. As we continue this work, we aim to develop cases for how different communities can begin to relate to one of the most difficult tangibility challenges of relating to tipping points in addressing climate change.

An emergent methodology can provide an approach for investigating complex challenges in difficult to reach climate change locations in the world's oceans. In particular, objects in remote locations can become tangibly reconnected to land based activity where participants and quantitative information can connect with deep qualitative insights leading to future behaviour change by encouraging agency and action linking ocean health with adapted human behaviour.

Future work can focus on how to develop more refined methods for linking tipping point visualisation to actions by individuals and groups to create positive feedback loops between actions on land that can regenerate positive and equitable ocean futures. While an emergent methodology can seem counterintuitive in some branches of research, opportunities to bring together transdisciplinary research teams to collaborate on climate challenges where the issues are complex can benefit from an emergent approach. A major issue for supporting this transformation needs to come from funders to move beyond problem-solution expectations towards adapting to trust emergent methods for complex and critical global challenges.

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