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Collective intelligence for advancing ocean literacy

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ABSTRACT

Ocean literacy is an understanding of the ocean's influence on us and our influence on the ocean. A lack of ocean literacy presents a significant obstacle for citizens to engage in environmentally sustainable behaviour, and thus is acknowledged as a 'complex problem' that requires deliberative participation and joint-action by stakeholders across domains. The aim of the article is both to demonstrate the value of Collective Intelligence (CI) as a methodological tool to advance and enhance the promotion of environmental literacy, and to share outcomes from using the CI approach. The participatory context behind CI illustrates that working 'with' a range of stakeholders across marine education, outreach, regulation and policy, to debate how to better promote ocean literacy among young people, improves ocean literacy and broadens society's awareness of sustainable marine environments. Findings reveal a hierarchical barrier structure localised to each country, a valuable order of echelon toward environmental change.

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Ocean literacy; marine education; collective intelligence; argumentation; participatory research

Introduction

Global ecosystem services provided by the ocean, and on which we depend, include raw materials and food, coastal protection, water purification, carbon sequestration, tourism and recreation (Barbier et al. 2011), to name but a few. Human activities such as fishing, maritime transport, energy, tourism and waste discharge all impact the marine environment (French et al. 2015). A recent assessment of Europe's seas found that, although productive, they cannot be considered healthy or clean (European Environment Agency 2015), the impact of which renews the urgency of addressing this complex and challenging issue if a sustainable environment is to be achieved (Sterling and Witham 2008; Van Poeck and Östman 2018). To address this concern, Fletcher and Potts (2007) suggest ocean literacy[1] as an essential prerequisite, within the context of the public understanding of marine environmental issues. This paper builds upon the marine environmental contributions from Chen and Tsai (2016) and Fauville, Strang et al. (2018) regarding the necessity to move beyond ocean knowledge towards an informed level of ocean literacy.

Environmental awareness and education, and the extent to which an individual is committed to ocean literate behaviour are essential for environmental sustainability (Chen and Tsai 2016). In addition to individual behaviour (McKinley and Fletcher 2010), a wider social movement is needed (Domegan, McCauley, and Davison 2010; Lysgaard, Reid, and Van Poeck 2016) to ensure

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the sustainable use of ocean resources (Guest, Lotze, and Wallace 2015), as well as the responsible design of environmental marine policies, regulations and management strategies arising from multiple perspectives and interests (Mora et al. 2009).

The research reported here advances the latest social research on citizen and stakeholder attitudes, perceptions, and values to help identify and design impactful and feasible calls to action, focused on education, community and governance actors, and is directly targeted at citizens. While education and traditional advertising can be effective in creating awareness, numerous studies document that behavioural change rarely occurs as a result of simply providing information, but rather comes about through diverse initiatives (Domegan et al. 2018; Hastings and Domegan 2014) delivered at the community level focusing on removing barriers to environmental literacy which in turn increases the effectiveness and impact of change (McHugh et al. 2016a). Barriers to an individual's environmental literacy is a complex problem and Markos et al. (2017, 231) acknowledge this in their description of an individual's environmental literacy as:

> the outcome of a number of interplaying attributes: affect, ecological knowledge, socio-economic knowledge, knowledge of environmental issues, skills, additional determinants of environmentally responsible behavior, and environmentally responsible behavior.

One cannot be 'science or environmentally literate without being literate in ocean and aquatic concepts' (Boubonari, Markos and Kevrekidis 2013, 232). The process of identifying solution-based strategies to complex societal issues and social messes (Sun and Yang 2016), such as addressing an increase in ocean literacy across a sector of society, requires consultation and action by multiple and diverse stakeholder groups. 'Any complex social problem always demands that those wider deliberative frames that create and position the notion of a field are engaged' (Lysgaard, Reid, and Van Poeck 2016, 320), especially when 'no problem exists in isolation, but is influenced by other issues afflicting society' (Sun and Yang 2016, 5).

Collective Intelligence (CI) was chosen by the authors, as this methodology brings together a range of stakeholders to discuss and debate ideas and propose scenarios to tackle 'wicked problems' (Sun and Yang 2016). It has great potential to offer new perspectives on difficult questions, where collective groups are introduced to alternate perspectives that they may not have previously considered. The aim of this research is both to demonstrate the value of CI as a methodological tool to advance and enhance the promotion of environmental literacy, and to share the outcomes garnered from the process in one of eight European countries. The article begins with a brief introduction to CI as a research methodology for addressing complex problems. This research process is purposefully detailed in order to share the method with other *Environmental Education Research* readers and illustrate its value in decision making around environmental sustainability. The participatory research context is then explored through a discussion of the process, findings and participant analysis, producing an environmental/ocean literacy roadmap for future action. The article concludes with a brief reflection on the collaborative method and outcomes as an impactful contribution to sustainable marine education.

Using CI for complex problems

CI, also referred to as Interactive Management, was developed in the 1970s and 1980s (Broome and Chen 1992; Broome and Keever 1989; Warfield 1976, 1990; Warfield and Cárdenas 1994) to deal specifically with complex problem situations. CI is a barriers and value structuring methodology. As such, it involves a process of critical learning and reflection 'with' people rather than on their behalf. It is a methodology that facilitates group discussion and consensus building through deliberate, organised conversation (McHugh et al. 2016b). Throughout CI, researchers assume an objective facilitator role and do not contribute to the deliberative discussions between stakeholders. Within these nominal group discussions, *argumentation is crucial*, as stakeholders from different backgrounds and sectors work collaboratively to reach a consensus on

how best to address a complex issue. The argumentation and discussion of ideas, all of which are proposed by the stakeholders themselves, engages participants in a process where they must consider and weigh alternative perspectives, and for some, re-examine and/or blend their views. CI encourages participants to engage in consensus-based logic and reflective negotiations. This explicit engagement with complex problems not only benefits participants, but also the researchers, as sessions provide deeper insights into how attitudes are influenced by group work itself (Broome and Fulbright 1995; McHugh et al. 2016b).

Complex problems, are that 'class of social system problems where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing' (Churchman 1967, 141). Tackling such problems involves identifying and selecting who the affected stakeholders are, bringing groups together, considering the possible outcomes and solutions, and the facilitation of exchanges and interactions between the diverse stakeholder groups (McHugh and Domegan 2013). Solutions to complex problems necessitate the incorporation of multiple stakeholders at multiple levels of influence, such as at the individual, organizational, community, societal and policy levels (McLeroy et al. 1988). CI provides a methodology that can facilitate this and is described in the literature as interactions among group members, which demonstrate intelligent features, such as generation of new knowledge, consensus decisions, and the emergence of smart behaviour patterns (Li et al. 2017). CI empowers a group of people to act as a coherent, intelligent organism working with one mind, rather than as individuals, when set with a task (Smith 1994). The collective capability emphasises decision augmentation, which has been shown to elevate the decision capability of individuals (Bonabeau 2009). That is, CI works on two levels, as a collective consciousness, and as a research methodology. In the illustrative study presented here, the research question considered by stakeholders in both phases (online forum and face-to-face workshop) is *what are the barriers to teaching 12–19 year olds about the ocean*?

Methods

The research strategy for this article is related to that of participatory research (Bergold and Thomas 2012), which plans and conducts the research process 'with', not 'on', the participants under study. Research outcomes arise from the convergence between two perspectives—science (researchers) and practice (participants), with the intent that both benefit from the process. Participatory research is open-ended and flexibly designed to enhance stakeholder buy-in and empowerment (Hamby et al. 2011). The unit of analysis is at the level of a marine education system, across eight European countries—Denmark, Greece, Belgium, Ireland, Sweden, Spain, Portugal and the United Kingdom. The specific research findings reported in this article are from one country, Ireland, yet all eight countries followed the same rigorous CI process to ensure consistency and reliability.

Sampling and recruitment

In this study, five individuals were brought together as an internal working group for sampling and recruitment to ensure stakeholder diversity and inclusivity. Two teacher trainers, both with formal and informal teaching experience, engaged in the process. An individual working in the field of marine education policy and an aquaria educator with a remit for informal science education also participated. In addition, one marine change agent, knowledgeable in applying behavior change techniques to marine science communication and outreach, completed the team. The internal working group identified cohorts of groups or individuals, acknowledged as experts in their respective sectors, across education, outreach, regulation and policy decisions. Sixty prospective stakeholders were identified and contacted through a purposive sampling

strategy whereby they were first classified as Incumbents, Challengers, or Regulating Agencies (15 minimum from each group). Incumbents are the *dominant actors*, these stakeholders establish the prevailing order and wish to preserve the status quo. Challengers are less privileged than incumbents. They often conform to the prevailing order, but are awaiting new opportunities to challenge the structure of the existing system. Regulating agencies *defend the status quo* (Layton 2015). The appropriate classification of stakeholders in this study was vital as it ensured an inclusive approach, incorporating multi-level thoughts, beliefs, and mental models to balance the dual worlds of possibility and tension for ocean literacy (Lysgaard, Reid, and Van Poeck 2016). If the study omitted an appropriate stakeholder grouping, it would have increased the risk of multiple and uncoordinated attempts at addressing the issue of teaching 12–19-year olds about the ocean, especially if all stakeholders who may affect or be affected are not included.

The importance of inviting representation from each of these diverse and yet connected groups cannot be overemphasized. Each sub-group brought their own interests, values and motives from their respective marine organisations, as opposed to as individuals alone, and having all present in one space generating ideas and scenarios for change allowed for a dynamic interplay and development of argument.

Personalised email invitations were then sent to the 60 stakeholders inviting them to participate in both the online CI forum and the CI face-to-face workshop. Of the 60 invites, 25 stakeholders (9 incumbents, 11 challengers and 5 regulating agencies) participated in the online Ocean forum, Phase 1. Twenty-one of the twenty-five confirmed availability for the one-day CI Workshop (8 incumbents, 9 challengers, and 4 regulating agencies), Phase 2; but due to work and personal commitments, seven people withdrew. In total, 14 participants attended the workshop (5 incumbents, 6 challengers, and 3 regulating agencies), which took place on 19 May 2016.

CI process, findings and participant analysis

The framework for the CI process involved two phases: (1) Idea Generation and (2) Argumentation, illustrated in Figure 1.

Phase 1: CI idea generation

Phase 1 involved an online forum where participants were asked the following trigger question via email: *What are the barriers to teaching 12–19-year olds about the ocean*? Participants were prompted to identify up to five barrier statements in response to the question and were provided with a number of starter phrases (e.g. Failure to … , Conflict between … , Demand for … etc.) to assist them in generating their barriers. Each participant was also asked to clarify each barrier using a clarification sentence. In total, 25 participants generated 128 individual barriers to the trigger question.

Phase 2: CI argumentation

The second CI phase involved a face-to-face, day-long, workshop where the participants, representing a variety of perspectives, were brought together to debate and negotiate barriers and calls to action (clarify category groups, rank individual barrier importance, determine influence between barriers and identify calls to action).

Barrier categorisation

Once the online idea generation was complete, the researchers utilised paired comparison and collective engagement to create categories of common barriers. In total, 15 categories were

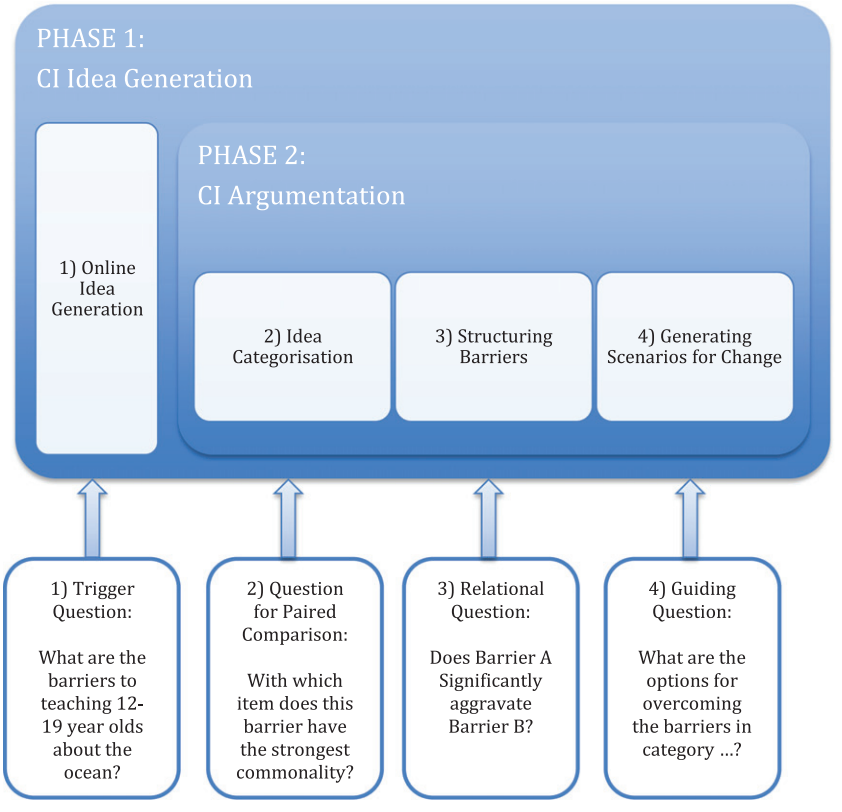

Figure 1. CI phases.

produced from the 128 barriers. In the CI workshop, participants reviewed the 15 categories and associated barrier statements. If participants felt that some barriers would be more appropriate in another category and/or category labels needed to be changed; this was carried once group consensus was achieved.

Participants then engaged in a voting process to identify the most important barriers within each category, using coloured sticker dots, for their inclusion in structuring. This is equivalent to the early stages of coding traditional qualitative data by individual researchers. Table 1 lists the confirmed Barrier Categories aligned with top voted barrier(s) within each category.[2]

In terms of the top-voted barrier categories, almost half of the barrier categories (1, 3, 4 7, 8, 9 and 15) spoke to challenges in formal education. Almost one-third of the barrier categories (3, 5, 8, 11 and 12) spoke to the challenges in informal education and public awareness. Finally, two of the categories related to the impact of the political role (2 and 3), as a possible obstruction to ocean literacy.

Structuring barriers

Interpretive Structural Modelling (ISM) software was employed as it provides a virtual structure for building consensus in group management decision making (Bolanos et al. 2005; Jones, Christakis, and Flanagan 2007; Sahney, Banwet, and Karunes 2006). The 15 barriers that received the highest votes (see Table 1) were entered into the ISM software, where a series of relational questions, 'Does Barrier A *significantly aggravate* Barrier B?' were asked to the stakeholders. The group was given the opportunity to think about the question, then vote yes or no, and present arguments for their vote. Once a consensus of at least 60% was achieved, results were recorded

Table 1. Barrier categories aligned with top voted barriers.

Barrier category	Top voted barrier(s) within each barrier category
1. Curriculum	Lack of school programmes on marine subjects [65] (18 votes)
2. Lack of Policy Makers and Governance Structures	Lack of political will – Ireland's government is slow to act and implement on marine-related issues and marine education [116] (16 votes)
3. Lack of Knowledge	Lack of knowledge of our policy makers, teachers and lecturers [52] (15 votes)
4. Training	Shortage of suitable training available to teachers [22] (12 votes)
5. Aquatic Disconnect	Lack of understanding of the importance of the ocean in our cultural, social and environmental heritage [18] (11 votes)
6. Conflict	Lack of conflict resolution due to competing interests in the ocean environment [37] (11 votes) … in reference to commercial vs sustainable exploitation, agriculture vs fisheries, marine educators vs curriculum designers
7. Extra Work	Resistance from some students to doing extra work that gets no credit in an exam [30] (9 votes) … refers to being exam focused Lack of Transition Year providing a good opportunity to do extra-curricular work [119] (7 votes)
8. Education	Failure to educate young people about the sea [67] (9 votes) … both formal and informal education are referred to within this category Fragmented approach to promotion of Ocean Literacy [104] (4 votes)
9. Teaching Resources and Infrastructure	Lack of existing teaching material that conforms to the Irish curriculum [81] (9 votes)
10. Connecting with the Youth	Lack of opportunities for student to feel, touch and experience the science rather than read and imagine [127] (9 votes)
11. Careers	Lack of awareness of maritime career opportunities [7] (9 votes)
12. Lack of Awareness and Interest	Lack of awareness of the subject matter at societal level [100] (8 votes) Lack of interest in environmental issues [84] (3 votes)
13. Lack of Personal Experience	Lack of personal experience on the ocean [24] (8 votes)
14. Lack of Access	Lack of opportunities for young people to interact with the marine environment [8] (7 votes)
15. Priority of Time	Lack of time – if it is not timetabled on the curriculum it may not get covered [32] (6 votes)

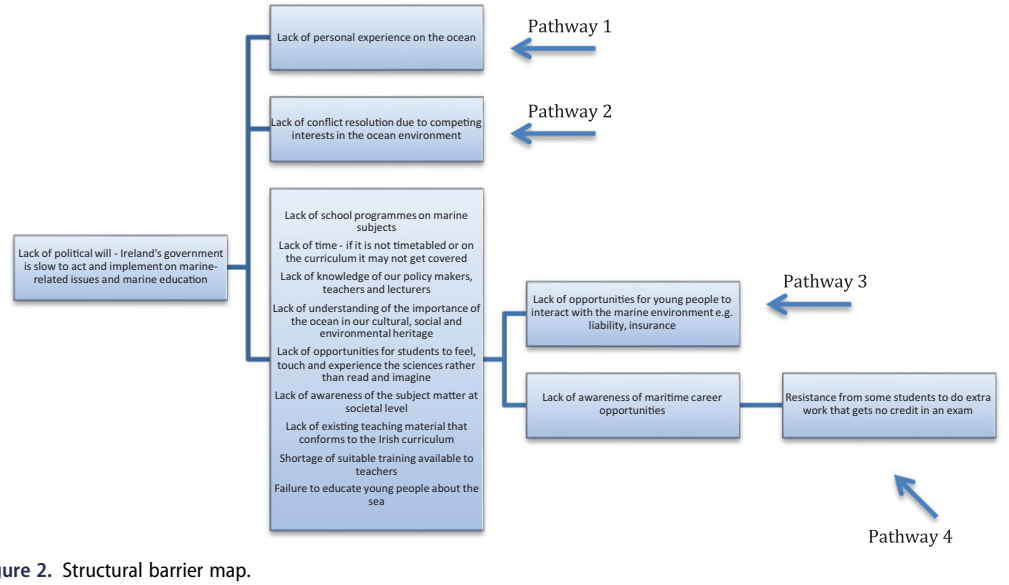

Figure 2. Structural barrier map.

in the software. Structuring continued until all relational barriers were voted upon and a structural barrier map was generated (see Figure 2).

The structural barrier map is the most tangible output from the CI process. The map is read from left to right with the barriers to the left significantly aggravating the barriers to the right. Barriers that are grouped together in one box are reciprocally inter-related and significantly aggravate one another.

Four different barrier aggravation pathways were outlined in Figure 2 with directional arrows indicating aggravating pathways. All pathways began with, 'Lack of political will—government is slow to act and implement on marine-related issues and marine education'. This barrier significantly aggravated all of the remaining barriers in the map.

The first and second pathways ended in a single barrier. The stakeholder group felt that the main aggravator significantly aggravated the (1) Lack of personal experience on the ocean, and (2) Lack of conflict resolution due to competing interests in the ocean environment, but for these barriers, the path ended, as the group felt that these two barriers were not significant aggravators for the remaining barriers.

However, pathways three and four both lead on through nine barriers grouped together in the same box, such as 'Lack of school programmes on marine subjects', 'Lack of awareness of the subject matter at societal level' and 'Failure to educate young people about the sea'. These reciprocally inter-related barriers significantly aggravated one another yet did not take more or less precedent over each other, thus forming this natural group. These nine barriers went on to significantly aggravate two more barriers (1) Lack of opportunities for young people to interact with the marine environment, e.g. liability, insurance and (2) Lack of awareness of maritime career opportunities). In pathway 3 'Lack of opportunities for young people to interact with the marine environment, e.g. liability, insurance', did not go any further. Participants felt that this barrier did not significantly aggravate any remaining barriers. Yet the fourth pathway revealed that 'Lack of awareness of maritime career opportunities' went on to significantly aggravate the rightmost barrier on the map, which is 'Resistance from some students to doing extra work that gets no credit in an exam'. That is, a lack of awareness of marine career opportunities impacted the ability of students to voluntarily increase their literacy level without external motivation.

Generating calls to action

To conclude Phase 2 participants engaged in a level of forward reasoning (Sun and Yang 2016), identifying potential calls to action, being mindful of the barrier map which indicated hierarchy among barriers and a structure of their interaction. Participants were divided into four subgroups, and each group was assigned two categories to initiate calls to action. Groups were provided with the facilitation question: 'What are the options for overcoming the barriers in the [category title]?' and were asked to explain their calls to action with the entire group. In total, 60 potential calls to action were proposed and each group presented their calls to action to the larger group and welcomed discussion, which led to further refinement. Next, participants discussed and voted (using coloured sticky dots) for the proposed calls to action they perceived to be the most feasible, impactful and timely in each category. The barrier categories and calls to action proposed are listed in Table 2.

Discussion

CI works on two levels, as a collective consciousness, and as a research methodology, as indicated earlier, and reflections on both entities are given below.

CI as a collective consciousness

Findings of the detailed collective analysis reveal that policy makers', 'lack of political will' was the most influential barrier in this regard. This is not a surprising discovery, considering that Education for Sustainable Development (ESD) is primarily policy-driven (Van Poeck and Vandenabeele 2012, 541). Yet, what is interesting is examining the hierarchical barrier structure that is offered for each European research partner country, reflecting their localised social,

Table 2. Barrier categories aligned with top voted scenarios.

Barrier category	Number of scenarios generated	Top voted scenario(s) to each barrier category
1. Education	6	• Change or incorporate aquatic education into the relevant curricula e.g. history, geography, biology, chemistry etc. (10 votes)
2. Curriculum	6	• Certificate for Transition Year* students from the National Governing Body in ocean literacy. This should lead on to more work experience in the maritime industries (11 votes) • Develop 'aqua' short course for new Junior Cycle syllabus (water ecology etc.) (7 votes) • Recognise strengths' in the current curriculum (5 votes)
3. Connecting with the Youth	12	• Fun water sport camps coupled with learning sea shore habitats (7 votes) • Target youth groups and align objectives and marine programmes (5 votes)
4. Lack of Personal Experience	7	• Making World Ocean Day a community event/linking in with a national one day school event (15 votes) • Develop a national sail training plan with strong emphasis on environment, ecology and marine employment opportunities, e.g. 5 boats, 5 ports, 5000 kids per year (9 votes)
5. Training	8	• Crash Courses – e.g. Aquarium in-service day (7 votes) • Identify areas of interest/potential already on curriculum (6 votes)
6. Aquatic Disconnect	11	• National media (all) campaign for all aquatic interests and activities – commercial + leisure (14 votes) • Encourage all aquatic organisations to involve politicians in their activities and sport (5 votes)
7. Lack of Policy Makers and Governance Structures	6	• Dedicated self-funded marine department (13 votes) • Submission to Seafest by Sea Change outlining its vision (5 votes)
8. Conflict	4	• Incorporate requirement for external input into national curriculum (8 votes)

*Transition Year is an optional one-year school programme taken by students prior to initiating senior cycle in secondary schools in Ireland. Its mission is to promote the personal, social, educational and vocational development of pupils.

cultural and economic environment. It is acknowledged by Sterling and Scott (2008, 386) that there are four thrusts of education for sustainable development:

1. Improving access to quality basic education;
2. Reorienting existing education to address sustainability;
3. Developing public understanding and awareness; and
4. Providing training programs for all sectors of private, governmental and civil society.

In the instance of Ireland's findings, if political will is not shown, then it is postulated that all other elements were impeded and a particular order of echelon was given. What is also interesting in terms of the CI process is that earlier in Phase 2 (Idea Categorisation), the results indicated a dominance of barriers in the area of formal and informal learning, yet later in the process (structuring barriers), once ranking was considered 'lack of political will' was revealed as the dominant barrier in terms of hierarchical structure. Thus, the hierarchical structure itself was a very valuable outcome in terms of planning for solutions to this complex question.

Participants revealed in their coding and analysing of the data that the lack of political will significantly aggravateed four possible pathways. Two of which highlighted the lack of opportunity for young people to explore/experience the ocean, be it through inadequate formal/informal education or lack of personal experience. The third pathway stressed the importance of the role of formal/informal education also, yet in line with knowledge of career opportunities and this participant cohort being focused on exam-only content. The final pathway spoke to a lack of conflict resolution due to competing interests in the ocean environment. Having key stakeholders generate, select and analyse 128 barriers to identify the most significant barriers which can

be ranked and structured assisted in moving from individual value-laden perspectives, to a collective, shared understanding that advanced viable, jointly agreed calls to action. In this way the tension of the 'complex problem' is diffused through a collaborative approach.

CI as a research methodology

In contrast to traditional qualitative research, data analysis in CI was carried out in parallel with the participant group as part of their participation using CI software. The participants' active participation throughout the process of data collection, analysis, and interpretation where they collectively considered barriers and potential calls to action placed the ownership of the analysis in the hands of the participants and they became active rather than passive agents for environmental change (Sterling and Scott 2008; Williams, McEwen, and Quinn 2017). In turn, the knowledge generated had greater meaning to the participants than data that was analysed by a research team without participants' input. Furthermore, the fact that the analysis and interpretation were conducted by diverse stakeholders with contrasting views on the research question offered a 'a better and shared understanding of the field's past and priorities' (Lysgaard, Reid, and Van Poeck 2016, 327). In this way, the analysis of the data retained a trustworthiness that is located in the community of experts and communities of practice that have come together, and through their discussions on barriers have weighed, debated, considered, blended, and in the end, have come to agree on how to promote and advance ocean literacy (Lysgaard, Reid, and Van Poeck, 2016) which would not be possible if a researcher were to interview any one participant, or all, and provide an interpretation through a researcher's perspective.

We would argue that this collective approach to resolving complex problems goes beyond measuring individual or even group silos of knowledge; instead multiple stakeholder groups are empowered to interrogate data and results are presented without researcher bias, thus offering a rigorous methodology that identifies steps towards building ocean literacy.

Experience of CI stakeholders

Findings also revealed that stakeholders valued the physical, temporal, and mind space for collaboration as a result of involvement in the CI process. In a participant feedback survey, 75% of participants valued the argumentation phase (debate and open dialogue); 75% valued the opportunity to engage with diverse stakeholders across the sector, and finally; 40% appreciated the experience as a networking opportunity. CI provided the space for stakeholders to come together to debate common interests and uncover potential options and scenarios for change.

Conclusion

While we are not arguing that CI is a panacea for ocean literacy, we believe it goes a long way to providing inclusive perspectives and practical ways forward in producing a greater knowledge of barriers that may not have been identified by individual parties alone. Complex societal problems do not occur in a vacuum. They incorporate multiple stakeholders at multiple levels of influence. Without a model such as CI to consider 'complex problems' (e.g. expanding ocean literacies), we run the risk of multiple and uncoordinated attempts at addressing the issue, without all parties at the table.

Like any methodological tool, CI has limitations. CI can be time-consuming for participants and researchers relative to the traditional survey or focus group. Another limitation of CI pertains to the absence of time paths and how to examine Ocean Literacy over time (Domegan et al. 2016). To overcome this restriction whilst accounting for eight European countries with various cultures, structures and predispositions towards Ocean Literacy, European partners were trained

in using CI and its free supporting software to build critical capacity across Europe for continued future use.

The intention of this paper was to demonstrate the process, and value of CI as a methodological tool to advance and enhance the promotion of environmental education, in this instance ocean literacies, and to share the findings from one such study. Findings reveal a hierarchical barrier structure localised to each country, and exhibit a valuable order of echelon in considering change. A meta-analysis across several countries who replicated this study and the outcome of a European Influence map has also been recently published (Fauville, McHugh et al. (2018)). In terms of demonstrating the method itself, it is hoped that the overview and discussion may serve as a model for other researchers and educators regarding broadening ocean literacies and mobilising an ocean literate society, relevant to the readers of this journal and other related disciplines.

Notes on contributors

Notes

1. Ocean literacy is defined as understanding the importance of the ocean to humankind; being able to communicate about the ocean in a meaningful way; and being able to make informed and responsible decisions regarding the ocean and its resources (Cava et al. 2005; Mogias et al. 2015).
2. The number in square brackets indicates the barrier number inputted into the ISM software, in this case it ranges from 1 to 128, in line with the barriers identified in online Phase 1.

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References

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman. 2011. "The Value of Estuarine and Coastal Ecosystem Services." *Ecological Monographs* 81 (2): 169–193.

Bergold, J., and S. Thomas. 2012. "Participatory Research Methods: A Methodological Approach in Motion." *Historical Social Research* 37 (4): 191–222. doi:10.12759/hsr.37.2012.4.191-222

Bolanos, R., E. Fontela, A. Nenclares, and P. Pastor. 2005. "Using Interpretive Structural Modelling in Strategic Decision-making Groups." *Management Decision* 43 (6): 877–895. doi:10.1108/00251740510603619.

Bonabeau, E. 2009. "Decisions 2.0: The Power of Collective Intelligence." *MIT Sloan Management Review* 50 (2): 45–52.

Boubonari, T., A. Markos, and T. Kevrekidis. 2013. "Greek Pre-Service Teachers' Knowledge, Attitudes, and Environmental Behavior toward Marine Pollution." *The Journal of Environmental Education* 44 (4): 232–251.

Broome, B. J., and M. Chen. 1992. "Guidelines for Computer-Assisted Group Problem-Solving: Meeting the Challenges of Complex Issues." *Small Group Research* 23 (2): 216–236.

Broome, B. J., and L. Fulbright. 1995. "A Multistage Influence Model of Barriers to Group Problem Solving: A Participant-Generated Agenda for Small Group Research." *Small Group Research* 26 (1): 25–55.

Broome, B. J., and D. B. Keever. 1989. "Next Generation Group Facilitation: Proposed Principles." *Management Communication Quarterly* 3 (1): 107–127.

Cava, F., S. Schoedinger, C. Strang, and P. Tuddenham. 2005. "Science Content and Standards for Ocean Literacy: A Report on Ocean Literacy." Accessed 28 November 2018. http://www.cosee.net/files/coseeca/OLit04-05FinalReport.pdf.

Chen, C.-L., and C.-H. Tsai. 2016. "Marine Environmental Awareness among University Students in Taiwan: A Potential Signal for Sustainability of the Oceans." *Environmental Education Research* 22 (7): 958–977.

Churchman, C. W. 1967. "Guest Editorial: Wicked Problems." *Management Science* 14 (4): B141–B142.

Domegan, C., V. McCauley, and K. Davison. 2010. "Realising the Management Challenges for Science Communication Outreach: A Social Marketing Perspective." *Irish Journal of Management* 19 (2): 89–108.

Domegan, C., P. McHugh, M. Devaney, S. Duane, M. Hogan, B. J. Broome, R. A. Layton, J. Joyce, M. Mazzonetto, and J. Piwowarczyk. 2016. "Systems-Thinking Social Marketing; Conceptual Extensions and Empirical Investigations." *Journal of Marketing Management* 32 (11-12): 1123–1144.

Domegan, C., P. McHugh, V. McCauley, and K. Davison. 2018. *Social marketing in action: Cases from around the world*. New York: Springer.

European Environment Agency. 2015. "State of Europe's Seas." EEA Report No2/2015. Accessed November 28 2018. http://www.eea.europa.eu/publications/state-of-europes-seas/at_download/file.

Fauville, G., P. McHugh, C. Domegan, Å. Mäkitalo, L. Friis Møller, M. Papathanassiou, C. Alvarez Chicote, et al. 2018. "Using Collective Intelligence to Identify Barriers to Teaching 12–19 Year Olds about the Ocean in Europe." *Marine Policy* 91: 85–96.

Fauville, G., C. Strang, M. A. Cannady, and Y.-F. Chen.2018. "Development of the International Ocean Literacy Survey: Measuring Knowledge across the World." *Environmental Education Research*. doi:10.1080/13504622.2018.1440381. https://www.tandfonline.com/doi/pdf/10.1080/13504622.2018.1440381?needAccess=true

Fletcher, S., and J. Potts. 2007. "Ocean Citizenship: An Emergent Geographical Concept." *Coastal Management* 35 (4): 511–524.

French, V., N.-C. Chu, F. Santoro, I. Sousa Pinto, D. Borges, and N. McDonough. 2015. "Review of Ocean Literacy in European Maritime Policy." *EU Sea Change Project*. Accessed 28 November 2018. www.seachangeproject.eu.

Guest, H., H. K. Lotze, and D. Wallace. 2015. "Youth and the Sea: Ocean Literacy in Nova Scotia, Canada." *Marine Policy* 58: 98–107.

Hamby, A., M. Pierce, K. Daniloski, and D. Brinberg. 2011. "The Use of Participatory Action Research to Create a Positive Youth Development Program." *Social Marketing Quarterly* 17: 2–17.

Hastings, G., and C. Domegan. 2014. *Social Marketing from Tunes to Symphonies*. 2nd ed. London: Routledge.

Jones, P. H., A. N. Christakis, and T. R. Flanagan. 2007. "4.5. 4 Dialogic Design for the Intelligent Enterprise: Collaborative Strategy, process, and Action." *INCOSE International Symposium* 17 (1): 717–732.

Layton, R. A. 2015. "Formation, Growth and Adaptive Change in Marketing Systems." *Journal of Macromarketing* 35 (3): 302–319.

Li, W., W. J. Wu, H. M. Wang, X. Q. Cheng, H. J. Chen, Z. H. Zhou, and R. Ding. 2017. "Crowd Intelligence in AI 2.0 Era." *Frontiers of Information Technology & Electronic Engineering* 18 (1): 15–43.

Lysgaard, J. A., A. Reid, and K. Van Poeck. 2016. "The Roots and Routes of Environmental and Sustainability Education Policy Research – An Introduction to a Virtual Special Issue." *Environmental Education Research* 22 (3): 319–332.

Markos, A., T. Boubonari, A. Mogias, and T. Kevrekidis. 2017. "Measuring Ocean Literacy in Pre-Service Teachers: Psychometric Properties of the Greek Version of the Survey of Ocean Literacy and Experience (SOLE)." *Environmental Education Research* 23 (2): 231–251.

McHugh, P., and C. Domegan. 2013. "From Reductionism to Holism: How Social Marketing Captures the Bigger Picture through System Indicators." In *Contemporary Issues in Social Marketing*, edited by K. Kubacki and S. Rundle-Thiele. UK: Cambridge Scholars Publishing Ltd.

McHugh, P., C. Domegan, V. McCauley, K. Davison, N. Burke, and C. Dromgool-Regan. 2016a. "Our Irish Ocean Conversations Report – Sea Change Irish Conversations Report." *EU Sea Change Project*. Whitaker Institute, NUI Galway, Ireland, 1–63.

McHugh, P., C. S. Domegan, G. Gotensparre, E. Fauville, L. Copejans, M. Friis Möller, V. Papathanassiou, et al. 2016b. "Sea Change – Our European Ocean Conversations Summary Report." EU *Sea Change P*roject. Whitaker Institute, NUI Galway, Galway, Ireland, 1–23.

McKinley, E., and S. Fletcher. 2010. "Individual Responsibility for the Oceans? An Evaluation of Marine Citizenship by UK Marine Practitioners." *Ocean Coastal Management* 53 (7): 379–384.

McLeroy, K. R., D. Bibeau, A. Steckler, and K. Glanz. 1988. "An Ecological Perspective on Health Promotion Programs." *Health Education & Behavior* 15 (4): 351–377.

Mogias, A., T. Boubonari, A. Markos, and T. Kevrekidis. 2015. "Greek Pre-Service Teachers' Knowledge of Ocean Sciences Issues and Attitudes toward Ocean Stewardship." *The Journal of Environmental Education* 46 (4): 251–270.

Mora, C., R. A. Myers, M. Coll, S. Libralato, T. J. Pitcher, R. U. Sumaila, D. Zeller, R. Watson, K. J. Gaston, and B. Worm. 2009. "Management Effectiveness of the World's Marine Fisheries." *PLoS Biology* 7 (6): e1000131. http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1000131.

Sahney, S., D. K. Banwet, and S. Karunes. 2006. "An Integrated Framework for Quality in Education: Application of Quality Function Deployment, interpretive Structural Modelling and Path Analysis." *Total Quality Management & Business Excellence* 17 (2): 265–285.

Smith, J. B. 1994. *Collective Intelligence in Computer-Based Collaboration*. Mahwah, NJ: Lawrence Erlbaum (Reprinted 2008 by CRC Press).

Sterling, S., and W. Scott. 2008. "Higher Education and ESD in England: A Critical Commentary on Recent Initiatives." *Environmental Education Research* 14 (4): 386–398.

Sterling, S., and H. Witham. 2008. "Pushing the Boundaries: The Work of the Higher Education Academy's ESD Project." *Environmental Education Research* 14 (4): 399–412.

Sun, J., and K. Yang. 2016. "The Wicked Problem of Climate Change: A New Approach Based on Social Mess and Fragmentation." *Sustainability* 8 (12): 1312. doi:10.3390/su8121312.

Van Poeck, K., and L.Östman. 2018. "Creating Space for 'the Political' in Environmental and Sustainability Education Practice: A Political Move Analysis of Educators' Actions." *Environmental Education Research* 24(9): 1406–1423. doi: 10.1080/13504622.2017.1306835.

Van Poeck, K., and J. Vandenabeele. 2012. "Learning from Sustainable Development: Education in the Light of Public Issues." *Environmental Education Research* 18 (4): 541–552.

Warfield, J. N. 1976. *Societal Systems: Planning, Policy, and Complexity*. New York: Wiley.

Warfield, J. N. 1990. *A Science of Generic Design: Managing Complexity through Systems Design*. Salinas, CA: Intersystems.

Warfield, J. N., and A. R. Cárdenas. 1994. *A Handbook of Interactive Management*. Ames: Iowa State University Press.

Williams, S., L. J. McEwen, and N. Quinn. 2017. "As the Climate Changes: Intergenerational Action-Based Learning in Relation to Flood Education." *The Journal of Environmental Education* 48 (3): 154–171.