Inclusive Child Engagement in HCI: Exploring Ocean Health with Schoolchildren

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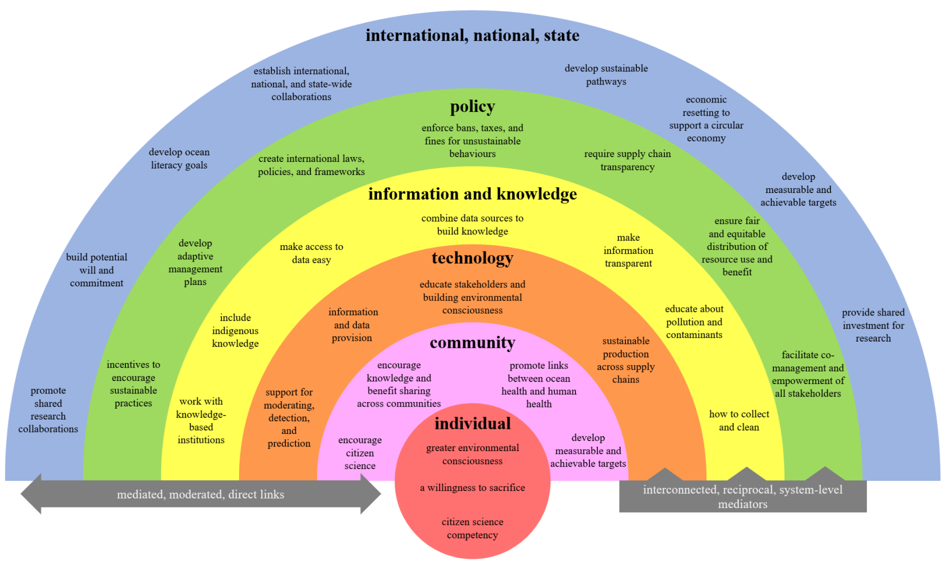


Figure 1: Rainbow model of ocean health [11].

ABSTRACT

In a ten-week project with nine school classes across the North West of England we explored ocean health with IT-enabled solutions. We describe the activities carried out under headings of participation, learning, and design. Participation activities, which included recruitment, focused on setting the parameters for children's inclusion and ensuring they understood how data might be used, and that handing in artefacts to the research team was their choice. Learning happened in an environment of contextual relevance that

IDC '24, June 17–20, 2024, Delft, Netherlands

ACM ISBN 979-8-4007-0442-0/24/06
https://doi.org/10.1145/3628516.3655750

enabled children to develop data literacy whilst we could explore relevant research questions. Design was a journey from individual to whole-class design, while developing engineering thinking and social cohesion. We reflect on the journey showing that children learned from the activities and acquired a new enthusiasm for their local coastline. We reflect on how our inclusive approach can broaden HCI research to wider communities of children and encourage others to apply our model.

CCS CONCEPTS

• **Human-centered computing → Human-computer interaction (HCI)**; • **Applied computing → Education**.

KEYWORDS

Inclusive participation, STEM learning, ocean health, design, ethics, data science, case-study

ACM Reference Format:
Janet Read, Matthew Horton, Daniel Fitton, John King, Gavin Sim, Julie Allen, Ioannis Doumanis, Tony Graham, Dongjie Xu, Michelle Tierney, Mark Lochrie, and I. Scott MacKenzie. 2024. Inclusive Child Engagement in HCI: Exploring Ocean Health with Schoolchildren. In *Interaction Design and Children (IDC '24), June 17–20, 2024, Delft, Netherlands.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3628516.3655750

1 INTRODUCTION

Within the IDC and HCI community there are many instances of work with children carried out through the auspices of STEM and STEAM practice where enthused researchers engage with children on projects that are primarily intended to encourage marginalised youngsters into science, technology and engineering (and art) subjects [36]. Examples of these activities that have found their way into publications include university sponsored STEM days for girls [33], remote STEM days [45], and STEM activities at science festivals [27]. Participation in STEM activities is beneficial to children bringing them education [19], confidence [24], enthusiasm to go into STEM careers [14], and introducing then to scientific and engineering thinking [15].

At the same time, many IDC and HCI researchers engage with children in research and design projects with the express wish to hear children's voices and get their feedback on technologies. This engagement is core to the discipline and examples abound. Over recent years the IDC community has actively sought to 'improve and enhance' children's participation and has promoted discussions around the value of engaging multiple children on a single design task [31], on ways to expand children's involvement, and raise their voices, in participatory design [18], and on the general question of how our research might add value to children [2]. This latter paper, a reflection on CCI research, challenges our community to improve our methodological rigour, to better focus on issues of empowerment and inclusivity in participatory research and to consider more carefully the general ethics of participation while offering methods that others can adopt and use.

Methodological rigour is improved by an attention to detail and an appreciation of the meaning of found information[13, 35, 38]. Whilst more participants is not always correlated to better findings, rigour can be improved by working with larger (a review by van Mechelen et al. [40], found that most studies with children worked with relatively small (mean = 25) numbers) and more diverse, groups of children. This broader recruitment can make our work more inclusive, but it will bring with that inclusion a set of logistical and ethical challenges like access to children and timing [8], which fuels a tendency to work with easy to access groups [37]. In Read et al. [32] the research team simplified ethics by actively running a quasi experimental study whilst collecting no personal data at all about the children. The same paper described how data collection was done in such a way that children could choose to not participate. What was not clear, in this work, was whether children understood what such 'non-participation' meant. Informed participation, and informed assent informed [29], are essential if we are to truly buy into allowing children to dissent during research work [12].

As STEM activities are often held with underrepresented groups of children, and typically a school decides who will attend, they provide an opportunity for HCI and CCI researchers to reach groups of children with diverse backgrounds and with fewer selection biases. Much of the complexity of recruitment is simplified, school premises pose few risks, and school boards tend to take a sympathetic approach to researchers wanting to do STEM activities. If STEM based activities can bring these advantages, of broader recruitment, easier access and greater participation, the question is can these sorts of events also bring research insights and be designed in such a way that researchers can deepen the engagement of the children and better use everyone's time by gaining added value above the standard STEM offering. Can we move beyond recounting STEM activities in the usual way of reporting the children's engagement [4, 22] or the novelty of the educational content [10, 30, 47].

Taking inspiration from Antle and Hourcade's challenges, voiced in their critical assessment of our field,[2] we determined to consider how STEM activities could be arranged to facilitate broader and more empowered inclusion in research work. Our methodological paper describes how a STEM activity can bring added value and describes a process for better informed and facilitated assent and dissent. In the following sections we describe the STEM project we carried out in the summer of 2023 with children aged 9, 10 and 11 and then explore how, given the way we set up that project, it gave data that is allowing us to answer two research questions thus showing the added value of thinking about research while doing STEM work. We reflect on how our approach to "informed empowered" participation both supported the research effort but also ensured a great learning experience for a broad group of children. We conclude with some key pointers for others seeking to do similar work. The materials we used for the Smart Seas Project can be accessed at https://chici.org/2024/04/08/smart-seas/ and we are happy for others to use then in their STEM work.

2 THE SMART SEAS PROJECT

Engagement in environmental and nature-based projects strengthens and diversifies social learning, belonging, and inclusiveness [20]. Furthermore, there is compelling evidence that experiencing coastal areas promotes well-being [5]. The health of the oceans and seas is promoted in programmes like The Blue Planet[1] which

[1]https://www.bbcearth.com/shows/blue-planet

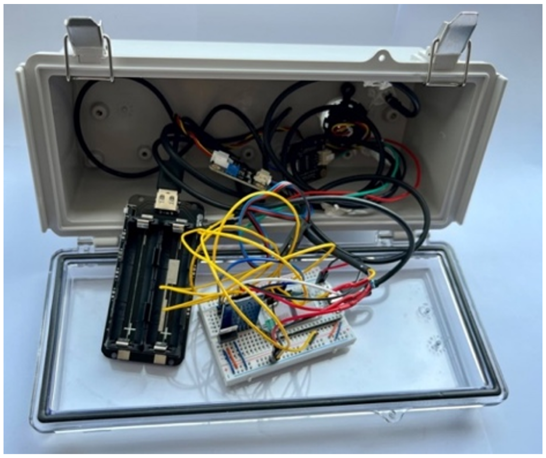


Figure 2: The Arduino buoy housing.

emphasises the vastness and variety of marine ecosystems. Terms like "marine citizenship" and "ocean literacy" emerged to frame conversations on what it means to look after the oceans and to define what to teach in schools and write into policy [26]. The consensus is that the more we care about the oceans, the more likely we are to change our behaviours, adopt a caring and responsible attitude towards the oceans, and to feel empowered to protect them [9, 26]. Whilst it is generally considered essential that children learn about the oceans, many schoolchildren know relatively little about the oceans. In a survey of eight European countries with 2,533 students, most children correctly answered less than 50% of the questions on ocean awareness. However, their lack of knowledge did not affect their enthusiasm which was very pro-ocean [21].

The Smart Seas project was funded by the Royal Academy of Engineering, UK as part of their Ingenious Scheme. We built a curriculum for the project using ideas from a range of sources and focused activities on the individual (child), the ocean, and data. With reference to de Salas et al.'s Rainbow Model of Ocean Health [11], as seen in Figure 1, our work is firmly based on the **individual** developing **greater environmental awareness** and **citizen science competency**, on the **community** – the school in our case – **encouraging citizen science**, on **technology** for **monitoring**, and on **information** becoming more **easy to access** and **transparent** so that it can build **knowledge**. Towards this end, we focused on the design and use of sensing technology built into small Arduino kits that would be placed in watertight sealed boxes (Figure 2) and floated in the ocean to gather data tto inform children about ocean health.

Sensing technology is cheap, easy to access, and effective in learning about the environment [1]. It has a track record with children in programming tasks [39] and exploratory studies [23]. Once sensing technology is in situ, a stream of data is generated, and this promotes conversations about what the data might mean and how they can be used and visualised; that is, to promote data literacy. There is considerable interest in improving children's data literacy, despite little research on how to deliver this in the classroom. Suggestions include presenting data in contexts where children can relate to the data and use inquiry approaches [43]. In terms of context, Bilstrup et al.'s suggestion is to use "rich representations of data that tell the story of how and why data are collected and put into relationship with the surrounding world" [6, p. 233].

Our approach to data was therefore to collect, collate, and compare data (thus situating it), then organising and making sense of the data (inquiry). This touches on the notion of citizen science where children gather their own data from their devices (once in situ in the ocean) and make contributions to the public, thus instilling a sense of social good [25].

As an engineering project using a physical artefact, we focused on a design to cement learning and to think in physical terms. Our focus on a physical item encouraged "engineering thinking" [3], and collaborative decision making [41]. We also wanted to bring the communities together in making joint decisions about their eventual buoys. We included the design of a board game, and a poster, as a means to understand what children learned about cause and effect [28] and to understand what they took from the project.

2.1 Logistics and Participants

On gaining funding for the project, we approached primary schools in the local area by email using the local education authority's list of contacts. We emailed 10 schools and when one responded we added it to a list of possible schools. After the first 10 we had three candidates, so we then emailed another seven, securing two more, with further email to another five, and so on. As schools expressed an interest, we visited them to discuss the project in more detail and then asked them to confirm a day and time for our team to visit. The schools agreed to distribute consent forms to the children in order that they could participate.

In two of the schools, the teachers wanted us to work with multiple classes, one school dropped out before the project began, so we ended up working with nine groups of children, aged between 9 and 11, in six schools, as summarized in Table 1.

A team of twelve staff from the Engineering and Computing Department lead the sessions. A core team delivered two or three sessions a week for 10 weeks, mainly staying with one group of children, whilst other staff typically did one session a week (mainly staying with one group). In this way the children developed relationships with the staff over the 10 weeks. Sessions took place in standard school classrooms with no special equipment needed from the school. During the sessions, there was always a teacher or teaching assistant present. The university staff leading the sessions all had DBS (Disclosure and Barring Service)[2] clearance to work with children.

We took no data about the children we worked with. We chose not to record gender nor to gather ages as this was not relevant to what we were aiming to do. Each school was a local authority school, and each had a local intake of children from the region. The region we worked in has challenges with transient populations and low income. From discussion with teachers, it was evident that many of the children we worked with fell into those categories. In one school the teacher noted there were 27 different languages spoken. The university staff working with the groups remarked on

[2]https://www.gov.uk/government/organisations/disclosure-and-barring-service

Table 1: Participants and schools

School	Number of groups	Timing	Number of children	Duration of each session (minutes)
H	1	After school	18	60
A	1	After school	22	60
N	3	In school	107	75
R	2	In school	70	75
S	1	After school	30	60
W	1	After school	30	45

the changing composition of the classes which seemed to welcome newly arrived children on a weekly basis.

2.2 Programme and Activities

Our project had three main aims:

- To raise awareness of ocean health with children
- To provide opportunities for university staff to develop STEM teaching skills.
- To introduce children to aspects of engineering and computer science

In achieving these aims, the activities were organized with week 1 and 10 focusing on participation, weeks 2, 4, 6, 7, and 9 focusing on data, and weeks 3, 5, and 8 focusing on design.

3 ACTIVITIES

In this section we describe the children's main activities and show some of the outputs. For each session there was a short slide show presentation outlining the aims for the session and any key learning messages in the activities. This took 5 to 8 minutes. The rest of the time the children worked in their classrooms with one or two members of the research team and a class teacher. The last few minutes of every session were spent tidying up and receiving anything the children wanted to hand in. At every session, children were reminded that this was their choice.

3.1 Participation - Save or Share

In week one we talked to the children about the project and stressed that the overall aim was not to collect anything (to take away) but that in some cases it would help us to have their work. This led us to think about how we could facilitate this with the children and so we designed a set of activities to educate and inform children about what data was, and to help them in decisions around what they might want to **save** for themselves and what they might want to **share** with us.

We began the week with an A5 sheet asking for their name and age, a confidence score (out of 10) of how much they knew about the ocean, and a statement of whom they might like to be when they grew up (Figure 3a). We then asked them to hand these to the teacher stressing that this included "personal data," their name and age, and so should not be given to us. The children then played three of the shelf games with ocean themes and rated each, on an A4 sheet with a before and after Smileyometer [34] score (Figure 3a). We explained that such ratings were entirely anonymous but could be useful to us. We talked with the children about what this "data" could tell us.

Having played all the games, we asked the children to use the last part of the A4 sheet to draw or describe a new game design (see Figure 3a). We then talked about the ideas and designs the children had done and we explained that we could use these to maybe build a product, and maybe even make money. We explored this with the children and talked about where the money would go if we did make money, and about what that money might be used for. This conversation enabled children to understand that they should think about anything they made in the sessions and about what it could be used for.

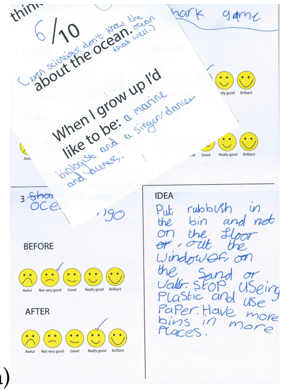
We then introduced the children to a red post-box,that we had bought for the project, explaining that as nothing would include their name, anything placed in there would be gone and they couldn't get it back. This was an example of what Dockett and Perry [12], refer to as "exercising agency," for example when deciding if they wished to hand things in. We explained that they should only post into this box things they were happy for us to have. We told them that the A4 sheet could therefore be handed in, could have the ideas section removed, or could be kept. Children then made those choices.

At the end of the ten weeks, we repeated the short survey on knowledge about the ocean and on what they would like to be when they grew up. In one class the teacher had kept the originals and was able to connect the before-and-after data. After talking with the children in her class, this teacher paired these up, and removed the names and gave us pairs of responses giving us a small amount of before-and-after insight. We reflect on this later in this paper.

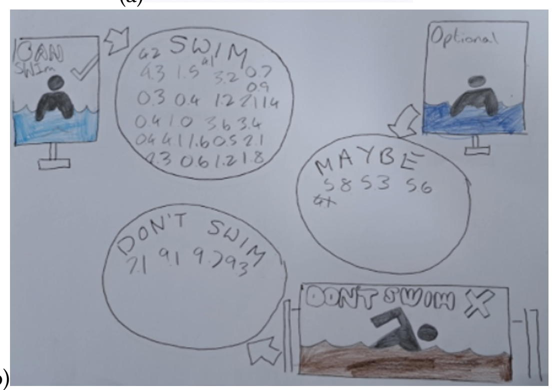
3.2 Learning

A main theme for the project was to instruct (teach) children about how data can be used to inform decision making. We began this journey in week two when children were given physical objects (e.g. thermometers and filter paper) to explore the acidity, temperature, and TDS (total dissolved solids) of a selection of jars of water in various states (see Figure 6). . We did not tell children how to organize their observations; they did this themselves. Then, we collected the readings and shared them with the rest of the class, pointing out discrepancies (of which there were many). We returned to this activity two weeks later when children put together Arduino sensors giving digital readings. With these, they again logged the data. For this exercise, temperature, turbidity, and TDS were measured.

For each exercise, we talked about what the measures meant. In week six we presented some "homemade" data to the children

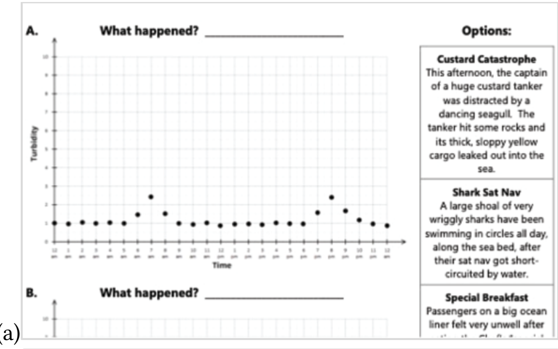


(a)

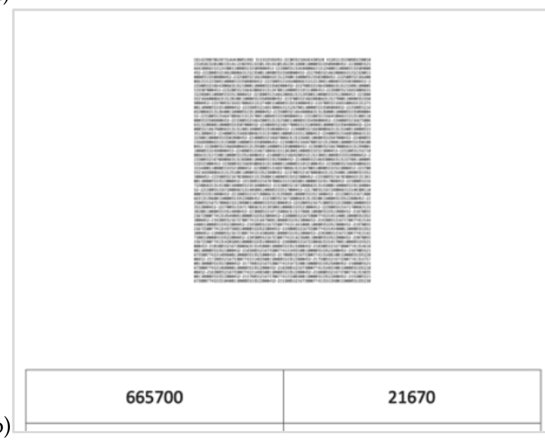


(b)

Figure 3: Understanding data (from schools R, W and H), showing (a) a confidence score on ocean health, what the child wants to be upon growing up, and an idea for a board game, and (b) choices for matching turbidity scores with "don't swim", "maybe swim", and "swim."



(a)



(b)

Figure 4: Data exercise. (a) Interpreting data over time and (b) big data.

and asked them to organize the data. The data were printed on small cards and the children had glue sticks to affix them to large sheets of paper. We then gave children a large sheet of paper with three circles marked "SWIM", "MAYBE SWIM", "DON'T SWIM" and asked children to put turbidity data (that we read out loud) into each of these circles (Figure 3b). In this way we moved the children's thinking toward "what the data might mean" with the children making decisions.

The last two sessions on data considered changes over time and big data. For data over time, we read out data while children plotted it on a graph and used this to talk about what might have happened to make the spikes in the data. We followed this with a "match the graph to the incident" activity (Figure 4a) where children interpreted a set of six graphs and decided which told which story.

Our last data session focused on big data as being high volume, high velocity, and highly varied. To introduce high volume, we showed data sets from real ocean studies, then printed a subset of this data making them very tiny to look at (Figure 4b). We gave children a set of codes to find on the sheet and gave them magnifying glasses to help in their search. For velocity we made a voice recording of 45 data points and then sped it up before playing it to the children and asking them to write this down. They all struggled, and we were able to use this as an example to talk about clustering and chunking. To explore variety, we read out (at normal speed) a set of data that was varied, the first three things might be temperatures then a count of fish, then a TDS score, etc. This illustrated that children took different approaches to capturing such data and again we used this to talk about how data could be organized and what was lost or gained with different methods.

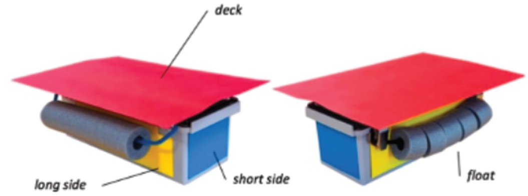
3.3 Design

Each school class was aiming to have their own floating buoy (e.g., Figure 5a) to place in the sea and gather data. The goal was how to design and engineer this device with the children. We introduced children to the mechanics of floating by giving each group a bowl of water and plasticine and asking them to float the plasticine in the water. Most children found this really hard. We then gave children A3 paper on which to design their buoys. Following this we moved to a physical design session taking bags of items into the classroom with roughly one bag per three children. Each bag contained pipe cleaners, Play-Doh, scissors, Sellotape, balloons, foam, cards, coloured plastic, and a foil tray that was roughly the size of the intended floating box. An example product is seen in Figure 5b.

Whilst there were roughly six to ten designs from each school class at this point, the intent was to build one box per class and so in week seven we took a democratic approach to finalizing the

(a)
(b)


Figure 5: Design. (a) The physical box that was being designed with design materials, and (b) a completed design from school S.



(a)

Colour of Deck	
Shape of Deck	
Colour of long sides	
Colour of short sides	
Additions to long sides	

(b)


Figure 6: The democracy of design – firming up the details. (a) Voting sheet and (b) board game to teach cleaning up the ocean.

details per class. We gave each child a voting sheet (Figure 6a) and used the results to decide on the colour scheme and main features for each class box. This activity closed off the design of the buoy. However, we came back to design a week later when we talked about solutions to clean up the ocean while asking for a board game to teach others about such thing. In this session we gave each group a large piece of cardboard, a set of playing cards to write on, dice, and tokens to play with. An example board game is seen in Figure 6b.

4 FINDINGS

4.1 Children's Overall Experience as STEM attendees

Returning to de Salas et al.'s Rainbow Model in Figure 1 [11], we raised the awareness of the children on ocean health. The schools visited all felt empowered to do more as a result of the project. Whilst findings are by necessity observational rather than entirely quantitative or empirical, we highlight below findings from the work by exploring subsets of the materials handed in. The designed buoys are currently being assembled and in due course children will see their school's design and will get real live data. The last session of the project asked children to design a poster to talk about the project. Many children chose not to hand these in but looking at the posters created showed that at a good proportion of the children took important ideas from the ten weeks. The example posters in Figure 7 (from school W) reveal how children felt they learned about design, data, and ocean health.

The design activities moved from individual to the whole class. When children explored the concept of floating, they were tasked with a very simple action of creating a dish shape in plasticine that could float – this provoked a lot of collaboration, competition, and conversation. More than any of the data activities, the design activities lent themselves to conversation and cooperation as well as to gaining an understanding of physical limitations. In the physical designs children often wanted to add school logos and flags and such but were also mindful of designs that did not harm fishes whilst also keeping gulls at bay with spikes on the top and even CCTV cameras to protect the system that would be gathering the data.

From one group (school R), we were able to match-up the before and after ratings on the children's enjoyment and learning. A paired t-test showed that confidence in their knowledge about the ocean (scored out of 10) rose significantly over the ten weeks ($t_{23} = 6.4$, $p < .001$), from the start of the study ($M = 5.1$, $SD = 1.8$) to after ($M = 7.7$, $SD = 2.3$). Between the two reports, 19 children of 24 raised their scores, two went down, and three were the same. One of the

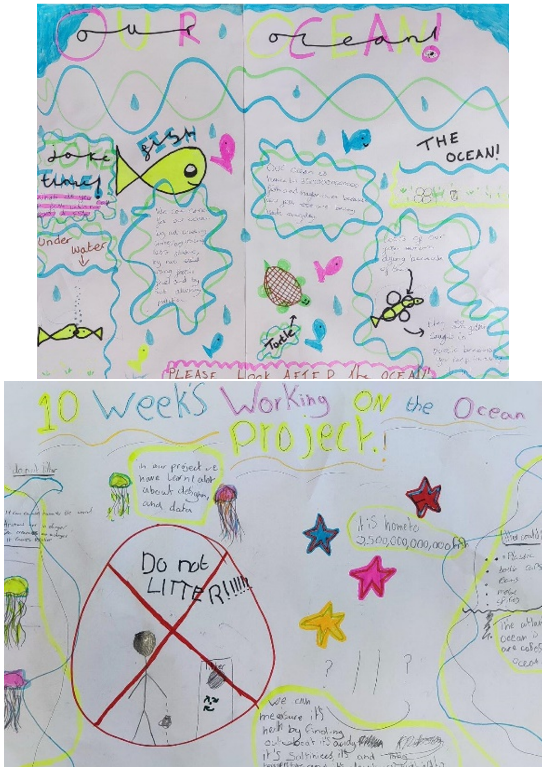


Figure 7: Posters created on the theme "What we learned."

responses noted that "even scientists don't know the ocean that well."

With the same data, in terms of job choices before and after the ten weeks, five children wanted to be scientists at the start and stayed with that choice at the end, one wanted to be an engineer, and another a mechanic and they too kept that choice, three wanted to be nurses or teachers, a couple wanted to be actors, and a couple wanted to be footballers. There was no evidence of children changing their minds towards science or engineering because of the STEM days, but it was surprising to see how many children stayed with a choice they had made ten weeks earlier given that they did not have access to their earlier responses on the day they filled in their later forms.

4.2 How Data Provoked Scientific Thinking

In the early stages, children measured turbidity, temperature, and TDS. When the data were brought together and shown to the children, they were surprised with the variability in results. (Recall that all the children had the same liquids in the jars and used the same sensors.) A similar observation was made by Lechelt et al. [23] in their study on sensor technology and children. They observed that presenting the children with variability in data was a good learning experience. In our case we used these differences to talk about the importance of accuracy and of making multiple measurements for scientific enquiry.

In the last session on data, children listened to fast data. This presented an opportunity to talk about buffering and polling with the rapid delivery of data. During the magnified investigation of data, children in all groups noted that some numbers were common; we then talked about how data are coded and how some codes are repeated. When we gave children varied data, they typically either listed the data against a heading (e.g., number of fish, turbidity) or wrote each number with a label alongside. Giving this choice to the children let us talk about what was lost with the first arrangement (assigning data to headings) but also that it is difficult to organize data with the second arrangement (giving each code a label). In all these explanations we were able to talk about data in the context of where it came from, as encouraged by Bilstrup et al. [6].

4.3 Research Insights

The data interpretation sessions produced interesting findings that we contribute here as early research data in this paper. Children arranged numbers in order of size when given streams of "like data." The activity where data were interpreted offered an opportunity to discuss boundary values. The chart in Figure 8 shows the way 15 children sorted the numbers for turbidity according to whether to swim based on those scores. As seen, there was a trend that low numbers were good for swimming and high numbers bad, but the boundaries were quite fluid. This was a great opportunity to discuss the differences between quantitative data and individual interpretation; data from the larger population is currently being analysed for a research paper on this topic.

The design work has also given us data that can be used to answer an ongoing research question around how children's designs both stay the same and develop over time [31], as well as how the materials affect the designs [44]. With over 100 drawn designs, over 50 constructed designs and with summary design choices from each of the ten groups - this is rich data set that can be explored.

4.4 Informed Participation

Having laid an early foundation on how to participate, it was encouraging to see that 10% - 60% of the children decided to keep their work. In the first session, when asked about smiley-face data and ideas, 74% of the children handed in their sheets and of these 8% removed the ideas section (see Figure 3a). This was a good outcome as it showed that children understood that they had agency to make that decision.

4.5 Reflections

Over ten weeks, children learned science, design, and ways that adults monitor the ocean's health. We conjecture that this knowledge has empowered children, not only to understand the ocean, but to understand wider environmental issues such as climate change through appreciating how data are gathered, used, and visualized. Other researchers and teachers can use and adapt the activities we deployed herein to help children learn about data science and societal challenges in a wider context. The materials are available at https://chici.org/2024/04/08/smart-seas/.

From the STEM activity we have data that can help us understand better how children interpret data and how they think about design. This data, given to us from children whom we believe understood

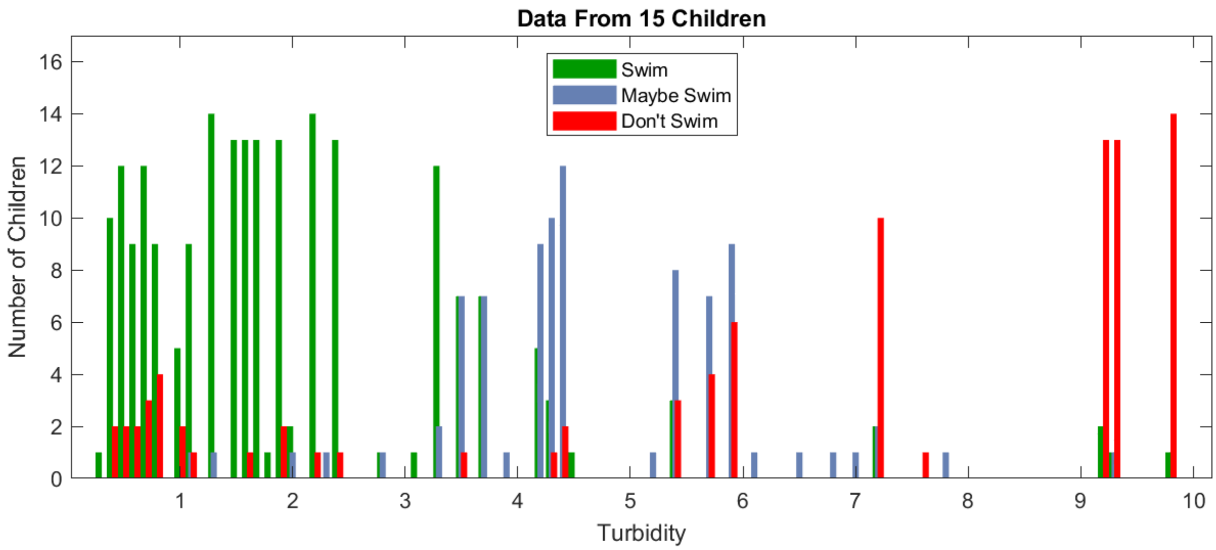


Figure 8: Would you swim in this?

the implications of handing it in, is from a broad range of children who might otherwise not have been natural recruits to a research study. Our decision to use the first session with the children, to do our best to help them understand the different aspects of data with our **Save or Share** activity, and of how assent (and dissent) can be practically integrated into a study, gives us confidence to use what the children gave us.

We suggest to other researchers doing related activities, whether as STEM, or as design workshops, to consider activities like the ones we used to empower children to participate. We encourage others to:

- Consider ways to **recruit** as **diverse** a set of children as possible with activities and venues that make it easy for parents to consent
- Once children have been recruited, actively **ensure** they **remain anonymous** throughout the studies
- Before beginning any work, take time to **inform** children, within their abilities, of what it means to **hand in data** in its various forms - we recommend activities like our **Save or Share** activity to contextualise this
- During the activities, constantly and diligently **enable** children to **choose to keep** anything they have made

There are many limitations to our approach and we do not consider it to be optimal for all situations; doing research in other ways is very beneficial. Linked workshops with small numbers, as seen in KidsTeam studies are clearly ideal for developing understanding of an idea over time [7, 42]; quasi experimental settings are ideal to answer questions about effect, especially as children can participate in different conditions [16], and working with full consent, to gather non anonymous data, with a small group of children allows triangulation of results, for example surveys and observations as seen in [46], and explorations of the development of ideas and understanding [17].

Our suggestion in this paper is of a way to broaden participation but that broadening does bring restrictions. That said, we do believe that the community as a whole can consider how to better inform children in all situations, of the implications of their participation and of the possible outcomes from data they contribute.

5 CONCLUSION

We described a ten-week multi-location project introducing ocean health to children in the North West of England. Activities focused on informed participation, understanding data, and product design. A key feature of this work was to empower, but also educate, through the Save or Share activity, children to assent to handing in artefacts they designed, completed, or constructed. This empowerment allowed us to gather data that can eventually be used to answer research questions while adding value to the activities the children did and while not getting in the way of the week by week learning.

We encourage others to consider the linking of STEM work with child-centred research and design in order to widen participation in IDC and HCI research but also to bring greater value to the children. Our future work will present findings on children's understanding of data and on the design journeys that we were able to consider in this project. We will also seek ways to re-use the resources we made for the STEM activities with a new cohort of children in the region in order to further promote Ocean Health.

As researchers in CCI, we are uniquely positioned to influence children's lives by our ability to enthuse, educate and engage with them under the guise of academic work. This is a huge opportunity and a huge privilege and we should never tire of seeking ways to be more inclusive. For the child who wanted to be a marine biologist and a singer/dancer and actress, we say hurrah to that, it was lovely to work with you on our project.

6 SELECTION AND PARTICIPATION OF CHILDREN AND REPORTING BACK

Children were recruited by headteachers to after school sessions and where the whole class worked with us in school time there was no selection. Consent for children to participate was gathered by the schools from parents. The children were from an urban area and at least 20 per cent would be identified as low SES. Participation was not implicitly voluntary as these were sessions in schools but we emphasised that children had the absolute right and discretion to not hand things in. Children came to an away day at the University several weeks after the project and we fed back to them some of what we had started to think about. We will report back our findings to the children as papers are published.

ACKNOWLEDGMENTS

This project was funded by the Royal Academy of Engineering - Grant (ING2022-16-100171). We also acknowledge the contribution made by the many children and their teachers.

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