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Hands-on climate engagement: principles for effective hands-on activities and demonstrations

Angus Croak and Graham J. Walker

Abstract

Communicating climate change to foster engagement and action is a challenge for science communication requiring novel, creative and diverse methods. In this practice reflection, we explore the potential of climate change related hands-on activities and demonstrations. Following a rapidly implemented COVID-19 project creating climate activities and workshops in the Pacific, we reflect on the underlying qualities of such activities to generate principles to guide design and facilitation of hands-on climate engagement. Through a fusing of theory, literature and practice, five principles are generated: personal and collective relevance, balancing risks/impacts with solutions, deliberative discussion and collaborative/participatory critical thinking, intrinsic motivation and positive emotional engagement, and opportunities for agency and action — with inclusive approaches providing foundation. We then describe applying the principles to refine content and create new activities.

Keywords

Environmental communication; Informal learning; Science centres and museums

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Introduction

Communicating climate change in ways that make a positive difference is fraught with challenges, whether in community or educational contexts. A key stumbling block is communication of climate change science — even if effective — does not lead to taking action [Whitmarsh, Poortinga & Capstick, 2021]. This has stubbornly remained the case since climate change entered mainstream conversation late last century [Abrahamse & Matthies, 2018; Staats, Wit & Midden, 1996] and, critically, also applies to youth [Hanushek & Woessmann, 2012; OECD, 2022] — the generation who have to find solutions and live with climate impacts. To transition awareness to deeper engagement — and with it meaningful action — we require new methods that share ideas in ways people, particularly youth, find experientially transformative, personally relevant, promote dialogue and empathy, and acknowledge risks and impacts while also giving hope and solutions.

While communicators have employed diverse methods including interactive tools for climate engagement [Moser, 2017], one method attracting scant attention — particularly in the science communication literature — are hands-on activities and demonstrations. While a mainstay of classroom science education, here we argue activities have untapped potential in broader community engagement, informal learning contexts and with more diverse audiences — they are not just 'for the kids'. The experiential nature of hands-on activities provides an embodied experience where people physically, affectively, and cognitively engage — supporting agency for action. To do this, hands-on climate activities need effective design.

This practice reflection draws on interdisciplinary evidence and models to generate principles for effective, engaging climate change hands-on activities and demonstrations. We focus on evidence from youth contexts as young people and families are likely to be the largest (though should not be the sole) beneficiaries of such methods. While evidence suggests principles are transferable, we focus on the Pacific Islands context due to the practice setting and imperatives around climate justice and elevating perspectives of those most affected by climate change.

Firstly, we describe the practice context developing hands-on climate activities and other engagement in the Pacific and the region's climate context. We then discuss inclusion as a foundation, and generate five principles for effective hands-on climate activities based on synthesis of the literature and practice experiences. We conclude with discussing application of the principles, directions for future research/engagement, and a summary of the activities.

Practice context

In 2021 our team was invited to provide online workshops for Pacific teachers and NGOs for ASPIRE, a component of the Australian Government's regional response to pandemic education disruptions. Previous *Science Circus Pacific* projects had, unsurprisingly, highlighted climate change as a priority for the Pacific. The urgency of pandemic-response meant a suite of hands-on activities and demonstrations (henceforth 'activities') was developed in just weeks. Hence while theory and best-practice were considered, activity design was mainly influenced by activities on hand, existing activities apt for climate recontextualisation, and a generous sprinkling of short deadlines, intuition and creativity. A resource booklet was created to support online workshops. We warmly acknowledge feedback and discussion with Pacific partners and teachers during workshops that has helped inform thinking in this paper and beyond.

We conducted different versions of the online workshops based on audience and context, ranging from talks showcasing live activities (e.g. https://www.youtube.com/watch?v=voRqIwQgK1E&t=2989s) through to hands-on formats where activities were done simultaneously by facilitators and participants over Zoom. We provided webcams and microphones to partners to enable/enhance such formats and use elsewhere during pandemic-triggered online engagement — digital equity remains a major barrier for online workshops. These mirrored hands-on sessions were logistically more complex, requiring materials to be collected beforehand by Pacific participants, but more valuable — particularly informal discussions following activities. Sessions ranged from 45 to 120 minutes and included participants from across the Pacific and Southeast Asia, with a focus on Samoa (320 participants; noting some attended multiple sessions), Fiji (99), Kiribati (33) and Tuvalu (23) along with multilateral 'drop-in' sessions and guest lectures/talks for universities and a Pacific ocean focused NGO.

Feedback and evaluation of selected sessions showed the sessions were well received, with most participants strongly agreeing the activities/workshops were relevant, curriculum linked, accessible, useful for the classroom, and inspiring, however links to culture and indigenous knowledge were mixed. Participants commented positively on the links to everyday life, use of common materials and 'improvisation', and the experiential, exciting, hands-on nature of the activities. Most feedback, however, was in the form of informal conversations during sessions and assessment of workshop outcomes. This paper focusses on the activities themselves, however a short documentary showcasing outcomes in Samoa can be found at https://www.youtube.com/watch?v=OtMeFFJlgoI. Ethical approval was granted by the Australian National University Human Research Ethics Committee (Protocol 2017/107).

Following implementation, there was time and impetus for reflection, theorising and exploration of the literature to critique the activities. To provide an independent assessment, author one who had not been involved in the design or delivery of the activities first examined the activities, feedback, internal reports and meetings, and conducted a literature review to produce a critique (which formed the basis for this paper). This critique then underpinned a deliberative process with author two who had written the activities and delivered the workshops. Both authors then updated the activities based on the findings of the process. Here we reflect on this process and use it to develop principles to guide activity design. A refined booklet with 18 activities is available at http://hdl.handle.net/1885/289738. A summary of the activities is given in Table 1. We welcome feedback, activity remixing/repurposing and opportunities for research or practical collaboration.

Climate change and the Pacific

Climate change is an existential challenge for the Pacific [IPCC, 2014b]. It is predicted to impact most severely on low lying and other small island countries, and will disproportionately burden low- and middle-income countries who are unable to make adjustments without assistance [IPCC, 2014a]. This is despite the fact that "climate change today is clearly caused by the collective [greenhouse gas emissions] of the larger and richer countries of the world" [Weir, Dovey & Orcherton, 2017].

The interaction of rising sea level with high-water-level events is a major risk for low-lying coastal areas [Weir et al., 2017], threatening food security, tourism, fisheries, livelihoods, and coastal villages where the majority live [Weir & Pittock, 2017]. While Pacific peoples are resilient and have significant traditional knowledge to aid adaptation [Weir & Pittock, 2017], building on these strengths through effective climate engagement and education is a growing need [Moser, 2017].

Table 1. Summary of the activities and how they connect with the five generated principles.

Activity/section	*Description*	*Rationale*	*Related principles**
General introduction to the resource booklet	Outlines the overall structure, additional resources, encourages improvisation with materials, and highlights relevance and localising the content, safety, curriculum links, systems thinking, the principles in this paper and author positionality	– Puts the booklet in context – Provides users with background information on how best to deliver the activities	All
Section introduction: What's happening? The science, causes and impacts of climate change	Activities were divided into causes/impacts and adaptation/mitigation sections	– Arranges the overall booklet to balance causes/impacts (negatives) and adaptation/mitigation (positives)	#2
Greenhouse effect ball bounce model — how do greenhouse gases trap heat?	A model of how the greenhouse effect operates, visualising the heat trapping effect of added greenhouse gases	– Allows abstract/invisible role of greenhouse gases on a global scale to be made concrete — reveals largely invisible mechanisms involved – Process encourages critical thinking and the scientific method as to the effect of increasing greenhouse gases – Required items can be substituted easily, aiding accessibility	#1 #3
Greenhouse effect: warming water in a bottle greenhouse	Compares warming of water in two bottles — one which traps more heat — as an analogy for the role of greenhouse gases	– As above – Includes a background section on the scientific method, unpacking thinking processes	#1 #3
Warming Oceans — heat capacity of water	Heating water or air in a balloon using a candle to illustrate how water (oceans) absorb (atmospheric) heat	– Shows the role/relevance of oceans in climate change. – Ocean activities had high relevance for the initial Pacific audience. – The balloon will pop with air, but not with water, enhancing emotional responses such as interest and surprise.	#1 #4
Sea level rise — thermal expansion of water	A device to show the thermal expansion of water is made from simple items	– Shows the role/relevance of a warming ocean for sea level rise (addressing misconception ice melt is the primary cause) – Ocean activities had high relevance for the initial Pacific audience – The device needs to be built before it can be used in the activity, enhancing emotion and motivation via ownership	#1 #4
Ocean acidification from dissolved carbon dioxide	Bubbling carbon dioxide through water to show a pH change; how oceans absorb carbon dioxide	– Simulates the largely invisible process of carbon dioxide dissolving into the ocean, increasing pH – Unpacks flow on impacts for people, animals and their interactions	#1 #4
Acid or base? Making acid base indicators from common items	How to make a pH indicator for the above activity from household items (not specific to climate change)	– Increases accessibility of pH related activities – Testing of everyday items increases relevance	#1
Colour changing noodles using red cabbage pH indicator (YouTube video)	Variation on above two activities, communicating pH in a different context (food) and effects of ocean pH increasing	– Produced by a student intern/youth climate activist on their own initiative, building on above two activities – Food context adds relevance – Effect of pH indicator colour change is surprising — emotional engagement	#1 #4 #5
Ocean Acidification — effect on marine life	Eggshells or old coral pieces (calcium carbonate) are placed in vinegar, simulating and accelerating the effect of increasing ocean pH	– Simulates and speeds up effects of rising ocean pH on coral and other marine life — makes largely invisible, slow processes salient – Eggshells/coral react vigorously as the vinegar solution is much more acidic than seawater — text notes the simulation is sped up to prevent overly negative emotions	#1 #2

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Table 1. *Continued from the previous page.*

Activity/section	*Description*	*Rationale*	*Related principles**
Fossil fuels: natural gas cannon	Natural gas combustion is used to power a small cannon that fires marshmallows made from a softdrink bottle	– Makes invisible carbon dioxide emissions visible by showing combustion reaction and ejection of a projectile – Uses everyday items, including some appealing to youth (marshmallows) – The device needs to be built before it can be used in the activity, enhancing emotion and motivation via ownership – The combustion reaction and high-speed projectile are exciting — emotional engagement	#1 #4
Comparing Fossil Fuel CO_2 emissions	Two balloons of different sizes represent carbon dioxide emission made by charging an iPhone using electricity from coal or natural gas, including underlying mathematics	– Makes invisible carbon dioxide emissions tangible through by showing gas volume in balloons – Mathematics used to calculate emissions in stepwise procedure – Uses highly relevant context of charging a phone	#1 #3 #5
Section conclusion: Relevance reminder!	A note encouraging users to adapt activities to their own contexts and enhance relevance through connections to everyday life, usefulness and identity/cultural links [Priniski, Hecht & Harackiewicz, 2018] and the curriculum	– A prompt to increase local relevance while adapting activities, which can amplify emotional engagement, agency and action	#1 #4 #5
Section introduction: What we can do — mitigation, adaptation and solutions	Activities were divided into causes/impacts and adaptation/mitigation sections	– Arranges the overall resource booklet to balance causes/impacts (negatives) and adaptation/mitigation (positives) – Finishes on a positive note – Summarises various adaptation/mitigation measures (e.g. replacing fossil fuels with renewables)	#2 #4 #5
Biofuel cylinder engine exploding can	A simple model of a car cylinder is made then powered using methylated spirits (ethanol)	– Uses the everyday and curriculum-linked context of an internal combustion engine – Shows how renewable biofuels can replace fossil fuels, particularly for transport – Discusses ethics of where biofuels should be grown, competition with food crops and deforestation to produce biofuels, encouraging deliberation and critical/systems thinking – Igniting the fuel causes an explosion and the cup shoots quickly off the cylinder, prompting strong emotional responses	#1 #3 #4 #5
Mangrove adaptations	Vegetables are coated with lip balm then exposed to salt to explore the effect of salinity and how mangroves cope with salty environments	– Focusses on mangroves, a plant common throughout the Pacific which plays a role in climate change adaptation/mitigation and has cultural significance, enhancing relevance – Uses the scientific method with two test samples and a control, encouraging critical thinking	#1 #3 #5
Solar Ovens — solar thermal energy	Common items are used to make a solar oven, showing solar thermal energy	– Shows how fossil fuel energy can be replaced with solar thermal energy – Uses everyday examples such as rooftop solar water heating alongside industrial solar thermal – The oven needs to be partially designed and built before it can be used in the activity, enhancing emotion and motivation via ownership	#1 #4 #5
Hydrogen fuel and electrolysis of water	Pencils and a 9-volt battery are used to electrolyse water, producing hydrogen	– Discusses how fossil fuels can be replaced with green hydrogen, including transport applications – Conducting a usually complex chemical process with simple everyday items provokes surprise and positive emotions	#1 #4

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Table 1. *Continued from the previous page.*

Activity/section	*Description*	*Rationale*	*Related principles**
Section introduction: Renewable tinkering	Background on tinkering and making as a climate engagement/education methodology	– Tinkering methods can engage emotion/motivation and develop problem solving and critical thinking skills, making a good context for developing responses to climate change – In line with tinkering best practice, general guidelines rather than explicit instructions are given for the below activities, requiring critical thinking during design	#3 #4 #5
DIY wind turbines	Model wind turbines are made from simple items with improvised designs	– Shows how fossil fuel energy can be replaced with wind energy – Participants design, build and iteratively test their turbine, fostering critical thinking in a physical context, and enhancing emotion and motivation via ownership – Although simple, the activity is emotionally engaging particularly when participants test their designs in a communal environment	#1 #3 #4 #5
Solar Toys — solar photovoltaic energy	Upcycled old battery powered toys are 'hacked' to run off solar panels	– Shows how traditional energy sources can be replaced with solar energy – Participants use their own toys, enhancing emotional engagement and relevance – Provides an accessible context for central parts of the physics curriculum (series and parallel circuits), adding relevance	#1 #3 #4 #5
Hydropower Contraption Challenge	Model hydropower devices are made from simple items with improvised designs	– Shows how fossil fuels can be replaced with hydroelectricity, and other applications of hydropower – Participants design their own hydropower contraption from the ground up, fostering emotional engagement and relevance – Examples of historical hydropower from different cultures are profiled, enhancing relevance	#1 #3 #4 #5

* As an outcome of the reflection during this paper, deliberative discussion (Principle 3) sections were added to all activities. For clarity, this has not been repeated in the rationale for each activity.

Principles for effective hands-on climate activities

This section synthesises findings from climate change communication, psychology, and STEM education with our practice reflections to generate five principles for effective hands-on climate activities. We share examples of the activities throughout to illustrate the principles in action. We gratefully acknowledge several review articles [Monroe, Plate, Oxarart, Bowers & Chaves, 2019; Moser, 2017; Rousell & Cutter-Mackenzie-Knowles, 2020] that broadly discuss climate change education and communication.

Before moving to specific principles, we emphasise inclusive science communication approaches [Canfield et al., 2020; Judd & McKinnon, 2021] are a precondition for engagement; they are not a principle in themselves, but rather a foundation on which other principles must rest if engagement is to be equitable and just. Aspects of inclusive science communication as defined by Canfield and colleagues [2020] are pertinent in climate change engagement, for example acknowledging past and current inequities, valuing lived experience and other knowledge systems, asset-based approaches that leverage strengths of individuals and communities, non-tokenistic participation, feelings of belonging and empathy, and multi-scale/systemic approaches. These qualities are evident in the principles below. Hands-on activities also raise practical inclusive aspects, such as wherever possible using locally available, low-cost items and having flexibility based on resources available — this underpins accessibility. These were key considerations working with Pacific partners in a pandemic context which made freighting materials problematic, but are critical for any activity designed to be inclusive, accessible and scalable. To foster a sense that climate activities are 'for me' — a key factor for inclusion beyond accessibility [Dawson, 2014] — activities themselves should also provide scope for and actively encourage localisation and framing based on participant's contexts, or better still be designed for and by actors from that context (or community, culture, etc.). This brings us to principle one.

Activities should be relevant

Personal relevance is essential for engagement aiming to motivate, whether activities focus on climate or general STEM [Monroe et al., 2019; Priniski et al., 2018]. Relevance enables audiences to connect previous knowledge with new material, see value, and instils motivation [Brophy, 2008; Hulleman & Harackiewicz, 2009]. Climate change presents challenges in being clearly relevant, e.g. greenhouse gases are not directly perceived, effects can be hard to link to causes, and iterative and cumulative effects can be hard to perceive directly [Monroe et al., 2019; Moser, 2010] — though this is not the case in many regions including the Pacific. Monroe et al. [2019] argue this can be overcome by technology allowing interaction with imperceptible impacts, directing attention towards proximal impacts, and thinking through adaptation and mitigation actions.

The same applies to low-tech hands-on approaches: activities that illuminate 'invisible' aspects of climate change should increase relevance. For example, we developed activities simulating the acceleration of slow-moving processes like ocean acidity impacts (using coral/eggshells in vinegar), highlight unseen carbon dioxide emissions through visible phenomena like combustion or pressure changes (a small butane powered cannon), and place carbon dioxide emissions in everyday contexts like car engines (making a biofuel 'car cylinder' using ethanol and a soft drink can). Furthermore, evidence from the Pacific suggests adapting terminology and concepts familiar to the target community [McNaught, Warrick & Cooper, 2014], e.g. replacing 'greenhouse' models with heat trapped in a iron roofed house [McNaught et al., 2014]. Indeed, some workshop participants noted a 'greenhouse' model lacked relevance, however we retained the term to align with curriculum and other materials.

While examples help, transferrable categories of relevance are more useful to tailor content to diverse audiences and contexts. Priniski et al. [2018] break relevance into three tiers with increasing personal meaningfulness and motivation. Firstly, *personal association*: "the perception that a stimulus... is connected to some other object or memory, and so forth, that is personally valued" [p. 12]. This could include shaping activities around students' everyday lives or interests, e.g. we used footballs to model solar radiation and the greenhouse effect. This invigorates learning, links with prior experiences, and extends appreciation and understanding [Priniski et al., 2018]. Secondly, *usefulness*: "the perception that a stimulus can be used to fulfill an important personal goal" [p. 12]. In other words, how might activities address problems or achieve goals in participant's lives, or benefit self-transcendent challenges facing communities or humanity broadly [Priniski et al., 2018] — the latter underscoring cooperation and teamwork during activities. Personally useful activities may provide impetus for individual behavior change, e.g. travelling by bike rather than car, or collective action such as mangrove restoration.

Thirdly, the most potent or motivational form of relevance, *identification*: "the incorporation of the stimulus in the individual's identity" [p. 12]. Identification can be prompted by connecting to individual's values and identity, or more broadly to culture and the collective identity [Priniski et al., 2018]. Hence, to promote identification we linked activities to iconic culturally significant contexts such as mangroves in the Pacific [Walker, 2024], showing how they have adapted to salty tidal environments and comparing that with the effects of salinity on vegetables. While we appreciated the role of mangroves in climate change and the ecosystem, the full cultural relevance of this activity was only revealed following generous dialogue with Samoan partners. Identity- and culture-based approaches are challenging for those outside the cultural group, highlighting the need for cultural capacity-building of practitioners and activity designers [Orthia, McKinnon, Viana & Walker, 2021; Tedmanson, 2012], codesign and — critically — more diverse science communicators who can leverage their unique scientific and cultural expertise for their local communities. These approaches can enable indigenous narratives and cultural practices to be woven together with climate activities and subsequent action; e.g. community discussion to identify local environmental concerns, then codesign including scientific and traditional approaches to inform actions [Harris, 2014]. Community-embedded relevance strategies can also involve cooperative participation that affirms communal identity of individuals and promote involvement of marginalised groups, such as women or people with disabilities, giving more diverse experience of climate change impacts and more inclusive responses [Harris, 2014]. This is especially significant as "gendered disparities in climate change vulnerability not only reflect pre-existing gender inequalities, they also reinforce and strengthen them" [Eastin, 2018, p. 291]. Moreover, community-led or codesigned activities can use traditional communication means such as oral storytelling or talanoa [Harris, 2014], e.g. to structure deliberative discussion (Principle 3), which should further promote identification and enhance activities.

Across all tiers, relevance may be highlighted by science communicators in activity design, or self-generated by individuals when content makes personal connections or they (co)create content themselves (as in the previous mangroves example). Activity design and facilitation should promote and allow space for self-generated relevance — it is generally more impactful for low expectation participants and creates meaning for underrepresented groups [Harackiewicz & Priniski, 2018].

Principle 1: *Climate activities should be relevant for the audience, use local language and contexts, incorporate everyday examples and knowledge/experience, show usefulness at the individual/community/country level, and/or invite participation to better connect with identities and cultures.*

Activities should balance risks/impacts with solutions to strike an empowering equilibrium

Acknowledging or directly experiencing climate risks is a requirement for effective responses — people must perceive threats to act — however exclusively negative messages may create defensive responses such as refusal and ambivalence toward climate action [Moser, 2017]. Hence, communication of climate risks must be accompanied with possible responses [Moser, 2017].

To strike this balance and not overplay negatives, risks and responses should be explored at scales audiences can comprehend and manage by focussing on the local level before considering global impacts [Monroe et al., 2019]. This might involve planning community-led adaptation and mitigation activities in educational or public contexts, gamification or role plays [Monroe et al., 2019], e.g. school energy saving programs. Climate change is, however, primarily driven by emissions at the global (north) level so this needs to be done sensitively; a purely local focus risks minimising climate justice issues — a crosscutting issue raised in several activities. Additionally, discussion of climate risks should pivot towards short-term impacts and solutions foreseeable in the current and next generations, rather than distant, uncertain, long-term possibilities [McNaught et al., 2014]. This approach enhances agency and potential for local action (Principle 5). Communicating uncertainty, while challenging, is also important as it influences trust and acceptance of information [McNaught et al., 2014; Moser, 2017].

Hence any activity or set of activities (e.g. a workshop, science show, lesson plan or curriculum) should balance negative risks and impacts with positive adaptation and mitigation solutions, while isolated solutions should note the corresponding threat. In the activities, we achieved this through separating the resource booklet into two sections: risks/impacts and solutions/mitigation/adaptation. Within activities this could involve a concluding deliberative discussion on solutions or threats, however we recommend using activity sets so practical experiences reinforce balance. Activity sets such as multi-activity workshops or science shows can communicate the impacts-to-solutions message though narrative [Walker, 2024], an effective tool for persuasion and behaviour change [Braddock & Dillard, 2016; Dahlstrom, 2014]. For example, an activity narrative could start with the natural gas cannon activity to explore emissions and give an exciting 'hook', then the greenhouse model activity to understand the effect of those emissions, then conclude with the wind turbine tinkering activity. This creates an activity-narrative that inspires and justifies the transition from fossil fuels to renewables.

Principle 2: *Activities or sets of activities should balance impacts/risks with associated adaptation and mitigation strategies, focussing on the local before the global.*

Activities should involve deliberative discussion and collaborative critical thinking

Well-reasoned, consensus-based collective actions are central to responding to climate change, yet are often elusive especially on the global scale. Climate change is a multi-faceted problem, requiring holistic approaches that span scientific and social considerations [Monroe et al., 2019]. Dialogue, consideration of different viewpoints, and critical debate are potent ways to understand climate science and reveal social factors to inform effective responses. Mbah, Shingruf and

Molthan-Hill [2022] argue critical thinking empowers youth, enabling informed judgements about emerging climate issues and reasoned responses to risks and impacts. Complementary to this, Monroe et al. [2019] notes the capacity for deliberative discussion to encourage participants to 'think more deeply about concepts, compare perceptions, understand different opinions, and reflect on what they know' [p. 801] — behaviours analogous to critical thinking.

Experimental studies show constructivist discussion-based approaches using active-learning methods (e.g. hands-on activities) combined with peer discussion are most effective for understanding climate impacts, responses and developing associated scientific reasoning skills [Holthuis, Lotan, Saltzman, Mastrandrea & Wild, 2014; Karpudewan, Roth & Chandrakesan, 2015]. Methods such as role plays on local impacts and solutions [Karpudewan et al., 2015] where deliberative discussion and reasoning are intimately embedded in the method were particularly effective, in line with other principles argued here. Using scientific equipment to measure and interpret climate-related phenomena also builds scientific reasoning skills [Cox, Kelly & Yetter, 2014; Gold et al., 2015; Hallar, McCubbin & Wright, 2011]. Based on this explicit integration of the scientific method was added to several activities, e.g. using a control and two experimental conditions to explore how the waxy substance suberin (simulated with lip balm which has the same active ingredient, glycerine) protects the cells of mangroves (simulated with common vegetables). Scientific reasoning and practices can be further embedded by involving local scientists [Gold et al., 2015], highlighting career paths and youth role models [Hallar et al., 2011].

Facilitators (i.e. science communicators or teachers) play an important role modelling how to pose probing questions that clarify alternate viewpoints and defend and enrich their own perspectives [Holthuis et al., 2014]. Similarly, Öhman and Öhman [2013] argue the important role of facilitators in crafting contentious yet constructive and respectful discussions and avoiding consensus-oriented dynamics which discourage diverse viewpoints and ideological differences.

Taken together, augmenting hands-on activities with inclusive deliberative discussion should be more effective overall and — critically — integrate broader opinions, social issues and collaborative problem-solving. In our activities, deliberative discussions were added at the start and end of most activities based on the findings of this reflection. This should increase relevance (Principle 1) and emotional engagement (Principle 4), particularly for those less scientifically oriented. Moreover, discussions may lead to greater engagement in low-interest audiences as they find societal-based entry points. For example, a participant may have little interest in the ocean pH chemistry but strong feelings about effects on local coral reefs and tourism — in turn giving more diverse perspectives to the conversation. It is crucial participants see climate change as not just a scientific problem with technical solutions, rather it will also require social change — dialogue is key here. With respect to hands-on activities and demonstrations, this suggest formats such as group interactive workshops which suit discussion may be more effective than more one-way formats such as science shows or teacher demonstrations. Nevertheless, these formats — with space for dialogue — remain valuable as some activities are not safe or practical for some participants (e.g. children) and shows and demonstrations can reach large groups with minimal resources.

Principle 3: *Climate activities should integrate inclusively-facilitated deliberative discussion, promoting critical thinking on climate science and social issues, at multiple points.*

Activities should spark positive emotions leading to intrinsic motivation and positive re-appraisals

People who take environmental action are often motivated by affective factors, often with little related knowledge [Rousell & Cutter-Mackenzie-Knowles, 2020]. This highlights the role of affect and positive emotions, which are influential in science education [Alsop, 2005; Pekrun, Goetz, Titz & Perry, 2002] and science communication contexts like science centres [Walker, 2012] — particularly to motivate and prompt action. Notably, studies using hands-on activities and demonstrations on sensitive health topics found interest and enjoyment, positive emotions which underpin intrinsic motivation, were associated with behavioural intention change [Walker, Stocklmayer & Grant, 2013]. Similarly, active student-centred methods which capitalise on intrinsic motivation and interactivity are effective in climate change education [Monroe et al., 2019]. Given many science communication settings are opt-in free-choice environments largely free of extrinsic motivators, intrinsic motivation and associated affective states like interest, enjoyment and curiosity are critical for people choosing and maintaining engagement [Csikszentmihalyi & Hermanson, 1999]. This is especially critical in climate change where audiences may be disengaged.

The positive emotions associated with creative and intrinsically motivating hands-on activities contrast with the overwhelmingly negative emotions young people report regarding climate change globally [Hickman et al., 2021]. So how might hands-on approaches address such negativity? Young people suggest realistic but positive messages that provide hope, which implies seeing potential for favourable change and anticipation their actions can have impact [Galway & Field, 2023; Ojala, 2012]. Hope highlights the role of positive emotions in facilitating more resilient and effective engagement through the process of 'positive re-appraisal', whereby the threat of climate change is acknowledged but positive emotions give individuals strength and solution-oriented active responses, i.e. intrinsic motivation [Ojala, 2012]. We argue here that hands-on activities could be a potent setting for positive re-appraisal, whereby exploration of climate content and positive emotions evoked by the activity build resources in individuals to motivate further action. This is supported by evidence positive emotions are associated with favourable changes in climate attitudes, intentions and in some circumstances behaviour [Schneider, Zaval & Markowitz, 2021]. Hence, hands-on activities that evoke positive emotions should be effective, particularly when content relates to adaptation and mitigation opportunities giving an outlet for associated motivation. The three renewable tinkering activities, particularly retrofitting battery powered toys with solar panels, are prime examples — participants enjoy the activity and the positive associations of children's toys, while also experiencing the potential of photovoltaic solar energy which is an accessible mitigation measure for many households and communities.

Given the role of positive emotions and intrinsic motivation — which is enhanced by giving autonomy, choice and control — some types of hands-on activities and demonstrations may be more effective. Demonstrations or demonstration sets (e.g. science shows) which provide less autonomous engagement with lower choice and control may be less effective than hands-on activities that, when well designed and facilitated, give audiences more control. Furthermore, STEM activity methods such as making and tinkering that actively prioritise autonomy and problem solving are likely to be particularly effective — they can enhance motivation while developing novel solutions. Making and tinkering methodologies are used in various activities, e.g. making a solar oven from an old pizza box to 'cook' food while discovering solar thermal energy. Nevertheless, despite lower control and hands-on experiences, demonstrations and science shows can evoke positive emotions and intrinsic motivation and affect behavioural intentions [Walker et al., 2013] and can reach large numbers efficiently, so should not be discounted. Combining science shows for large audiences with workshops, tinkering and other approaches for smaller more targeted audiences is likely to yield the greatest overall motivation.

Principle 4: *Activities should evoke positive emotions like interest, enjoyment and curiosity promoting intrinsic motivation and positive re-appraisal, while not downplaying the realties and threats of climate change.*

Activities should provide pathways to or direct opportunities for agency and action

Positive emotions, intrinsic motivation and positive re-appraisal underpin a 'can-do' approach which is an asset for effective adaptation and mitigation. Taking action — ideally real but also simulated — is the end game, however having agency over that action is important. Feeling powerless is a key factor for climate disengagement and poor mental health outcomes in youth [Gunasiri et al., 2022], hence genuine agency and action is critical to solidify the fleeting positive re-appraisal that may occur during a hands-on activity. This is especially important for marginalised or less powerful groups such as youth or women and girls who, while possessing knowledge pivotal for effective responses, are often sidelined [Figueiredo & Perkins, 2013]. Models of community and youth participation unpacking choice, decision making and the relative roles of adults and youth or any groups experiencing power imbalances will be helpful for practitioners to design agency-supporting actions [Hart, 1992; Shier, 2001]. Ensuring agency also allows people to bring their own unique expertise to taking action (e.g. community or traditional knowledge) and lets them frame the problem with suitable scope for action (as per Principle 2). Without agency to define problems they risk being beyond participant's power and control, which in turn exacerbates issues that prevent action in the first place. There is broad evidence that local level interventions such as school or community-based projects provide both effective on-the-ground responses and improvements to how people relate to climate change. Exemplars include more sustainable and reduced use of energy at school/home through youth tracking and managing usage; or school-community interventions planting and advocating for the ecological value of trees [Monroe et al., 2019]. These methods prioritise agency and share power and decision-making for the actions taken.

Hands-on activities can support climate action in various ways and sequences. Hands-on activities can simulate a manageable, bounded context for prompting, designing, testing and getting feedback on actions before they are implemented externally, e.g. germinating and raising seedlings of climate resilient indigenous trees. They provide a 'safe space' to practice and refine possible actions, however wherever possible activities should be followed up with real-world actions (e.g. a community working bee planting the seedlings) to create impact, build self-efficacy and maintain motivation — people need to see their actions make a difference. Real-world action may also occur directly during a hands-on activity. Hence, real-world actions may occur during, soon after or well into the future after participating in the activity. For example, a community group may run a mangrove restoration activity with action at the time, whereas a tinkering activity on solar powered toys may, in time, lead to actions using solar power at home. While we built agency supporting methods into our activities, e.g. open-ended tinkering activities on renewable energy, further work is required to better connect this with real-world actions.

While local action is a good start and every action helps, it does not address the 'global' aspects of climate change and emissions reduction. In our experiences with Pacific audiences who already face significant climate impacts but create negligible emissions, the need for geopolitical civic action was a common theme — particularly as our project was run from Australia, a country with a large fossil fuel industry. While the personal views of our team differed from policy positions of the government, it underscored the importance of reflexive practice, explicit positionality and empathy within workshops and written resources. This also highlighted an aspect of taking action missing in our initial hands-on approach: civic/political action. For young people, movements like the School Strike for Climate have been powerful for supporting youth agency, voice and political action [Feldman, 2021]. Our team is currently working with undergraduate student activists (or past activists) to design hands-on activity activism for a broader audience.

Principle 5. *Activities should involve pathways to or directly involve short- or long-term opportunities for real-world actions — physical, civic or otherwise — and support participant agency.*

Using the principles as a reflexive tool

The five principles above, distilled from the literature and practice, provide a rubric of sorts to both refine existing and design novel activities. In this section we share how we structured a reflexive process based on the principles.

Initially, all activities in the draft resource booklets were rated for alignment with the principles on a four-point scale (non-existent, poor, good, and excellent). This showed clear strengths — most activities satisfied fundamental considerations for accessibility, were fun and intrinsically motivating, and balanced risks/impacts with solutions. Gaps and weaknesses were similarly evident — relevance was low in many activities particularly when viewed from a local or Pacific perspective, deliberative discussion was highly lacking, scientific reasoning and critical thinking were not always maximised, opportunities for agency and action were more implied than directly facilitated, and more nuanced inclusive aspects could be incorporated, e.g. systemic approaches to climate justice and use of traditional knowledge. Following this quantitative approach, four representative activities were analysed as case studies to unpack how these strengths and weaknesses manifested qualitatively in practice — this allowed more targeted adjustments. Finally, activity topics and strengths and weaknesses were cross-referenced with common climate and energy topic areas — this highlighted where more effective methods could be used across topics, and which topics were absent.

This led to modifications and additions to the resource booklet and associated workshops including: an introductory section on relevance prompting users to reframe, adapt or reinvent activities to suit their own context; an introductory section on systems thinking, climate and sustainability and edits to link activities; building deliberative discussion into all activities; discussion of models, hypotheses, fair tests and other features of scientific thinking; and, edits and examples to highlight social justice issue and global inequities. Regarding adaptation and mitigation, modifications better highlighted potential actions, though as actions depend on context and relevance — there is no one size fits all — effective activities in this space may take the form of flexible processes for participants to design actions. Making and tinkering methods combined with design thinking elements may be useful for such aims. Through these refinements, linkages and dependencies between principles began to emerge, e.g. deliberative discussion enables unpacking of communal values and relevance to society through discussion of socio-scientific issues, and underpins scientific reasoning by revealing prior knowledge to support constructivist learning.

A section highlighting the principles was added to the resource booklet, giving users guidelines for adapting and creating new hands-on content. Several new activities were also designed: renewable energy activities on wind, solar and hydropower using tinkering methods that support agency, problem solving and critical thinking; a mangrove activity highlighting cultural and geographic relevance and the value of traditional knowledge; and, a noodle-based edible activity exploring the effects of rising ocean pH. For workshops in the Pacific, these latter two new activities were grouped with others relating to climate change and oceans into a separate ocean-themed booklet, however we have now merged all activities into one resource to suit a global audience.

Conclusions and further research

This practice reflection brought evidence from the literature together with reflections on practice to generate principles to guide effective hands-on climate activities and engagement. We argue activities and demonstrations have untapped potential in climate communication, particularly outside the classroom and with broader audiences including adults. Due to their experiential nature, hands-on climate activities can be effective facilitators of climate action, potent tools to build motivation, and helpful ways to reframe and reappraise how people relate to climate issues. Future research should test the validity and relative importance of these principles for activity outcomes, and test hypotheses derived through this reflection, e.g. the role of hands-on activities in positive reappraisal or supporting real-world action. Moreover, future research and engagement should explore if and how these principles apply across different cultures and contexts.

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Authors

Graham J. Walker is a lecturer in science communication at the Centre for the Public Awareness of Science (CPAS) at the Australian National University. His current research and engagement investigates international partnerships and capacity building, emotion and motivation in science communication, with a focus on science centres, science shows and hands-on approaches, and using these methods to engage with social and environmental issues. He also teaches in these areas.

g.walker@anu.edu.au

Angus Croak is a undergraduate chemistry/science student who has developed an appreciation for science communication through roles such as a student staff leader at the National Youth Science Forum and a university laboratory demonstrator. He is currently undertaking an internship with the Australian National University Centre for the Public Awareness of Science in the Science Circus Pacific program, refining and developing climate change resources.

frogsx9@gmail.com

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