**Creating a Climate for Learning-
Experiences of Educating Existing and
Future Decision-Makers About Climate
Change.**

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Abstract

Climate change is one of the most serious issues to affect modern society. What originated as a scientific question has evolved into a complex political and social issue. The policy context recognises the pivotal role of education in encouraging effective engagement and behavioural responses to projected climate changes. It is relatively easy to nod assent to the principles of climate change education and engagement, but harder to deliver. This paper explores experiences of educating and engaging current and future decision makers, namely pupils, teachers, charity workers, small business owners and councillors on the subject of climate change in Wales. It draws conclusions about the existing climate for learning as well as the potential for overcoming challenges associated with information needs of these existing and future decision-makers. It considers the broader issue of whether current climate change information and education frameworks are fit for purpose and able to support effective climate change mitigation and adaptation activities. The findings suggest that many climate change communications from international organisations are not being received or understood at local levels, indicating a need for further and simpler 'translation' of science. Despite a strong formal education system in Wales, there are variations in basic skills (such as map reading and graph interpretation), required for simple climate change science interpretation. Finally, our results point to a need for climate literacy to be gained through interactive long-term learning rather than one-off training, particularly given some of the entrenched views of the older age groups involved in the study.

Keywords
climate change education, education framework, climate change engagement

Highlights
Reviews existing climate for learning
Develops experiences for educating and engaging various audiences in climate change
Considers the information needs of existing and future decision-makers
Provides discussion on climate change information and education frameworks.

1. Introduction:

1.1 The Need for Climate Change Education

Long-term climate change is potentially one of the most serious problems facing global society [1], with predicted relative sea level rise potentially displacing millions of coastal communities [2]. Wales is a relatively small country of 3.06 million people [3] located on the west coast of the United Kingdom. Whilst unlikely to see mass coastal evacuation in the next century, Wales' extensive coastline (1,207km) and largely rural interior are likely to face significant challenges from changes in temperature, precipitation and weather patterns. It can be expected that modifications to the natural environment and the human activities that rely upon it will result in widespread environmental, social and economic change [4]. There are concerns that climate change impacts may marginalise the economy and in particular, key sectors, such as tourism and forestry [5], [6]. The need for a step change in the approach to addressing policy questions has become evident in recent times through the consideration of maintenance of fluvial and sea defences at local level. At a time of escalating costs and declining statutory body budgets, this is becoming an even more pressing issue [7].

If Wales and other nations are to have a chance of overcoming the challenges posed by climate change, their societies and communities must understand and engage in climate affairs [8]. Given limited public knowledge and understanding of climate change ([9]; [10]; [11]), education, both formal and informal, has an important role to play ([12]; [13]), particularly as a catalyst in reshaping public views ([14]). Indeed, a significant amount of work has already been undertaken to prioritise education efforts (see, for example [15], [16]). However, there remain many challenges to developing effective climate change education ([17]; [18]) and much debate as to its specific role in engendering behaviour change ([19]; [20]; [21]) as well as how climate change education should be delivered. The latter not only includes consideration of the learning setting [22] and associated learning methods (for example, [23]; [24]), but also how messages are framed within educational discourse [25] particularly in the context of climate change uncertainty (Stevenson et al. 2017 [26]). Within discussions on climate change education there is some consensus emerging that it should be multi-disciplinary [27] and cross-disciplinary [28] and should embrace consideration of values as well as the 'scientific' facts [29], reflecting the nature of climate change as a complex social as well as a scientific issue [30]. However, whilst there has been a significant amount of work involved in identifying foci and approaches (for example, [31], [32] and [33] highlight that much of the academic literature on the subject is reliant on anecdotal evidence).

In the context of such debates on climate change education, this paper outlines a study which evaluated attempts to impart climate change knowledge and promote critical thinking skills to a range of audiences across Wales, including school children and local councillors. As such, our study embraced calls for education programmes to cater for a wide range of audiences ([34]; [35]; [36]) and to focus on 'impressionable' adolescents ([37]; [38]). This paper focuses on extracting key lessons about effective engagement approaches and the information needs of different audiences in the context of other researchers' suggestions that the nature of the process of learning, particularly participatory approaches, can improve learning outcomes [39]. Our study also includes an evaluation of the effectiveness of using IPCC and other high quality, publically available scientific literature for a range of audiences.

Following a brief overview of the policy context for climate change education, a methodology and results are presented. The paper concludes with a discussion of the implications of the findings, including a review of lessons and recommendations for the global climate change community, including IPCC, educationalists and policy makers.

1.2 The Policy Context for Climate Change Education

At the global level, the 1992 United Nations Framework Convention on Climate Change (UNFCCC 1992 [40]) provides the basis for action on climate change with Article 6 directing countries to provide national scale education, training, empowerment and engagement, as a first line of response. In support of this, Action for Climate Empowerment (ACE), targets goals 4.7 and 13.3 of the Sustainable Development Goals which are part of the 2030 Agenda for Sustainable Development. These focus on raising climate change awareness and Education for Sustainable Development (ESD)

at an international level [41]. The latter promotes the acquisition of knowledge, as well as appropriate skills and attitudes for empowering communities to contribute to addressing 'wicked,' complex issues, such as climate change. UNESCO (United Nations Education, Scientific and Cultural Organisation) provides considerable support to UNFCC through its Global Action Programme on Education for Sustainable Development as well as through climate-change specific initiatives, including the Climate Change Education for Sustainable Development initiative (UNESCO 2010 [42]) and the Climate Change Information Network (UNFCC 2012 [43]). Despite considerable guidance and promotion of exchange of relevant experience through international workshops and various web platforms, UNFCCC has recognised the need to step up efforts under its recent UNFCCC Adaptation Committee and through its Communication, Information and Outreach Strategy [44].

Within a plethora of European strategies (e.g. [45]), communications (e.g. [46]), directives (e.g. [47]), regulations (e.g. [48]) and discussion papers (e.g. [49]), promoting the reduction of greenhouse gas emissions and adaptation to climate change, the EC Strategy on Adaptation to Climate Change (EC COM 2013 216) is most noteworthy. This promotes research, information-sharing and enhanced awareness-raising, but does not explicitly consider education or training. Despite efforts of the European Environment Agency (EEA [50]) and European Space Agency (ESA [51]) in undertaking climate change research, producing vast amounts of data and reports, and developing the European Climate Adaptation Platform (Climate – ADAPT) to promote better scientific awareness and adaptation capacity, specific references to education and measures to engender engagement with the general public are limited. Once again, there has been a nod of assent towards the significance of climate change education, but a general lack of co-ordinated delivery of frameworks, tools and case studies at local level. Having said this, there have been efforts to develop training opportunities for professionals and communities through pan-European projects and web-based platforms, such as the current and extensive 'open' knowledge exchange platform PLACARD (PLAtform for Climate Adaptation and Risk reduction [52]) and the previous INTERREG IVb SIC-ADAPT cluster of trans-national projects [53]. However, most have been short-term and many limited to researchers, funders, policymakers and practitioners, rather than

engaging with the wider population and education *per se*.

At UK national level, various mitigation, adaptation, engagement and education measures have developed, primarily emanating from the Climate Change Act [54]. In addition to five-yearly UK-wide Climate Change Risk Assessments, a wide range of knowledge exchange outputs have been produced, supported by various national committees and bodies, including UKCIP (UK Climate Impacts Programme) [55], an institution with extensive expertise in training, knowledge exchange and communication. Whilst the Stern Review [56] advocated education as a useful tool to help engender behaviour change, the UK government was slow to engage with formal education. Progress was hampered by political debates about whether climate change should appear at all on the statutory national curriculum for England (for example, [57] and [58], climate change education is now taught within a number of subjects including Geography [59] and Science [60] up to Key Stages 3 (ages 13 to 14) and 4 (ages 15 to 16), respectively.

In Wales a steady flow of climate change documentation has flowed from the Welsh Government since the publication of its *Climate Change Strategy* in October 2010 [61]. This has included assessments of climate change risk (for example, [62] as well as various action plans to operationalise commitments to greenhouse gas reductions and climate change adaptation in the context of the Welsh Government's statutory duty to sustainable development [63] and Welsh Ministers' powers under the Climate Change Act. However, there is no explicit mention of formal education within this strategy [64]; instead, it advocates a focus on active public and stakeholder engagement. Whilst there is some climate change content within the Welsh national curriculum Geography [65] and Science [66] programmes, Peter Davies, the former Climate Change Commissioner commented recently that there has been 'considerable variability in the way in which climate change was covered within the education system' [67] in Wales over the last decade.

Despite this less than explicit policy framework for climate change education in the UK and Wales, there exists a myriad of providers of educational materials for schools, supplying on-line and hard copy resources for a broad range of ages and abilities. This includes national governmental and professional bodies, including the Meteorological Office [68], the

Royal Geographical Society [69], the Hwb - Digital Learning for Wales [70] and the UK publicly funded Environmental Change Network [71]. The latter have been particularly active and offer ad-hoc teaching sessions. International, national and local voluntary organisations such as Oxfam [72], UNICEF [73], the Young People's Trust for the Environment [74] and the West Wales Eco Centre [75] also offer resources including school speakers and teaching materials, providing further opportunities to engage with climate change.

1.3 Science for Existing and Future Decision Makers: A Major Challenge for educators?

IPCC has been extremely successful at collating best available global scale climate change data, synthesizing knowledge and assessing related risks [76]. Although scientific consensus on global warming is very strong [77], sensationalised campaigns and reports of scepticism have left the public, politicians and some decision-makers in a state of confusion, complacency and denial ([78]; [79]), most notably in the US where it has been recently reported that a US federal department has been censoring the use of the term 'climate change' [80]. While IPCC continues to call for concerted efforts to mitigate and adapt to climate change, based on best available science, there is considerable variation in levels of public climate change awareness [81].   As discovered during a number of Wales' based engagement activities conducted by the project team during the early stages of the Interreg IVB IMCORE project [82], the general public also seems to lack the skills and experiences required to develop effective climate change mitigation and adaptation responses. Hence, there appears to be a disparity between what IPCC calls for and the capacity of community-based responses. The situation has been worsened by the fact that for many communities in Wales, climate change is not considered to be an urgent matter [83] and efforts to discuss it, like elsewhere, have been hampered by barriers to communication ([84]; [85]) and basic understanding of the science [86].

Part of the problem may be that only a limited proportion of the public, and very few policy makers, are generally scientifically educated or trained [87]. This is true even in relatively well developed countries such as Wales where science has been a component of the compulsory curriculum for longer than countries elsewhere ([88]; [89]), including in neighbouring England where reportedly only roughly 4% of the Members of Parliament have a science degree [90]. Consequently, messages being transmitted by the IPCC and others are not being received or understood by those that most need them [91].

Financial and staffing constraints, institutional inflexibility, limited knowledge and technical capacity further limit the ability of decision-makers to translate scientific information into a format that can be worked with ([92]; [93]). Although there are clearly considerable efforts to address this issue, information provision alone does not necessarily lead to better knowledge or personal engagement with climate change [94], as noted by opponents to the simple information-deficit model (for example: [95]; [96]). Indeed, Adger et al. (2009) [97] suggest that adaptation is contingent on a range of contextual factors other than just knowledge. These consist of societal and cultural aspects [98], including entrenched 'worldviews' which some consider have a profound influence on attitudes and behaviours related to climate change ([99], [100]; [101]).

Although Moser (2016) [102] notes 'the field has become more diverse and theoretically more contested', the science of climate change communication is beginning to offer some insight into ways forward. For example, there are increasing calls for it to be embedded within wider environmental literacy programmes [103], to focus on enhancing knowledge and understanding of mitigation and adaptation options and to improving underpinning scientific knowledge [104]. A clear need for educators to better understand target 'audiences' is also evident. Stevenson et al. 2017 [105] and Moser (2016) [106] suggest this can enable educational products and processes to be tailored more appropriately, providing local, tangible settings and inter-relationships which are more conducive to learning [107].

Even with more aligned communication channels, barriers to engagement remain. These include a distrust of information sources, inappropriate information formats, inappropriate communication mechanisms, perceived information over-load and lack of locally relevant information ([108]; [109]; [110]). Clearly, many of these issues pertain to internet based climate change 'science', much of which may be overly technical, difficult to understand or locally irrelevant for the specific interests of many users.

In preparation for our study, a review of climate change education and training materials and websites along with some discussion with teachers (2010) revealed that much of the science being presented was of dubious quality, with few or no indicators to distinguish between high and low quality evidence. We consider it to be imperative for key users, particularly teachers, to have access to appropriate and accurate information and for this to be clearly signposted. This is vital so that they can cascade good quality, unbiased information about processes, impacts, implications and options related to climate change to future decision-makers. Our review also suggested further issues associated with the lack of an obvious feedback mechanism from the public and policy makers back to the science providers and collators, including IPCC. For example, with reference to Figure 1, it can be seen that there is no formal mechanism to indicate what information is most useful, engaging and understandable for decision-makers at the local level, the media and the general public. The authors' own experience of involvement in designing and implementing training programmes and educational materials as part of previous European projects prior to our study had suggested also little more than minimal opportunities for feedback and evaluation of such endeavours. In particular, our review revealed no mechanisms for feeding back to high levels which types of visualisation formats [111] are most effective for communicating and engaging with non-scientific audiences (Figure 1).

Figure 1.

Without doubt, an informed public and climate-literate cadre of decision-makers is essential for any successful climate change response [112], despite reservations about the relative role of scientific understanding compared with other influences on policy making [113]. We are currently falling short of this.

2. Methodology:

This paper draws its findings from the experiences of a small team of researchers from Cardiff University who designed and delivered climate change education and training materials and workshops for a range of audiences across Wales as part of an Intereg European coastal climate change adaptation project, IMCORE, and the national (Wales) Beacons Programme.

Material to be included in an education pack was trialled at four secondary schools in coastal towns and cities across Wales (n pupils=120) and amended based on pupil responses. In addition, a number of school workshops were held with 14–16 year old pupils (n pupils=300) between 2010 and 2012. Demand from additional sectors led to the adaptation of teaching materials and engagement techniques for a range of other audiences in subsequent years. These included a teacher training event for 30 secondary school teachers, workshops for pupils excluded from mainstream education (n=24), professional training events for charities and local businesses (n=160) and the production of a formal training pack for Welsh community and town councils (n=70) jointly with a local sustainable development charity, Cynnal Cymru [114].

In order to learn from the experiences of existing educators, youth workers and policy makers, the university team established a pan-Wales Steering Group to guide the project's development and agree appropriate themes, structures, activities and key messages. This included the Welsh Government, the National Grid for Learning Cymru Cyfanfyd (a sustainable development charity), Wales Youth Forum for Sustainable Development (now Dyfodol), the educational charity, Techniquest, and the Severn Estuary Partnership (an organisation that works towards sustainable estuary management). In addition, and to ensure material was presented in an interesting and engaging way, Techniquest, the UK's longest established science centre and independent educational charity, provided training on effective engagement techniques.

Having established the climate change related requirements of the Welsh national curriculum, appropriate good quality, unbiased information was sourced and adapted for use in an education pack and series of supporting workshops. Source material including IPCC text, graphs, tables and models was supplemented by evidence from UK Climate Projections [115], Environment Agency [116] and a range of local sources. Particular efforts were made to ensure information was meaningful to pupils, relevant to the location of workshop delivery and visually attractive through the use of strong images, graphs, photographs and maps.

Once finalised, the bilingual (Welsh and English) pack was distributed to 100 Welsh secondary schools. An electronic copy was uploaded onto the Severn Estuary Partnership's

website and all secondary schools in Wales were contacted via the National Grid for Learning Cymru and asked to cascade the link. The education pack was then formally presented to the Climate Change Commissioner for Wales, further raising the media profile of the education pack across Wales.

Despite the variability of the workshop audiences, there were similarities in the format and content of workshops which has enabled cross-evaluation of events and the science included within them. At the start of each workshop, the delivery team assessed existing levels of climate change knowledge and skills through a series of short opening questions. These included exploration of existing levels of understanding about environmental systems, such as the hydrological cycle, the greenhouse effect, differences between weather and climate and reasons for changes in precipitation patterns and sea level. Responses were collated and are summarised in Table 1. At the end of each workshop participants were asked about their need for additional information or support. The responses given at this point were also collated, which provided a useful indicator of how individuals and groups responded to the engagement activity. During workshops, all groups were given a common introduction to basic climate change science, potential international impacts, local projections and case studies and a range of adaptation examples. Participants were also encouraged to relate to their own, direct experiences of climate change related events.

Workshops for pupils excluded from mainstream education included the same introduction as for other groups, but evolved so that they were field-based, much more practically orientated and experimental and responded to the learning and engagement needs of this potentially more difficult to reach audience.

Throughout the process of workshop delivery, diaries were kept summarising engagement experiences and audience responses. These informed an evaluation of the effectiveness of approaches for different audience types.

Within the main evaluation, the following questions were explored:
1. What were the existing levels of climate change knowledge and skills?
2. How easy was it for groups to understand IPCC climate change outputs?
3. What kinds of evidence particularly engaged audiences?

4. What additional information was requested by different audiences?

The following section summarises responses to these questions, providing useful insights into the accessibility and engagement potential of existing climate change education and training resources.

3. Results:
3.1 Existing Levels of Climate Change Knowledge and Skills

Responses to questions relating to existing levels of climate change knowledge and skills are summarised in Table 1. Existing knowledge levels varied significantly among and across participating groups. In contrast to the teachers at the teacher training day, who were primarily Geography teachers with overall good levels of knowledge, the charity staff, business staff and most councillors failed to demonstrate knowledge of basic climate change science. Pre-existing knowledge levels amongst the school pupils and pupils excluded from mainstream education showed similarly wide variation.

Table 1.

School pupils that had studied Geography to Key Stage 4 level generally had a greater knowledge of basic climate change science and were aware of the differences between weather and climate as well as the fundamental differences between mitigation and adaptation, than those that had not. Furthermore, although school age pupils were aware of actions that could be taken to mitigate climate change risks, they were less knowledgeable about adaptation options. This may perhaps have been a reflection of their limited range of personal experiences, but may also be a reflection of the lack of time and knowledge to deliver in-depth teaching in the classroom.

Interestingly, when asked, no school age pupils were aware of reasons for climate change scientific uncertainty. Again, this may be a reflection of limited explanation of the subject in classroom environments, driven by curriculum, and with significant time and knowledge constraints. Having said this, it is important that a recognition of scientific uncertainty is incorporated into education activities, so that limitations of existing and future models can be appreciated. However, this may well be easier said than done and it is recognised that it is difficult to address and 'frame' this complex

concept of uncertainty [117]. This is particularly relevant, given the way in which humans are able to psychologically 'distance' themselves from extreme climate change and its impacts [118].

Charity staff, business staff and most councillors were unable to clarify differences between mitigation and adaptation approaches and were unable to explain reasons for uncertainty in climate projections. Having said this, these adult groups demonstrated the greatest levels of scepticism, denial and misconception, which is unsurprising given various other researchers recognition that pre-existing worldviews can have a profound influence on attitudes to climate change ([119]; [120];. [121]). Comments such as, "climate change is made up by the USA to stop China expanding", "of course climate change is caused by that hole in the ozone layer" and "we're too busy dealing with today's crises to worry about 20 years from now", were common during adult training workshops. This demonstrates how, despite UK and Welsh Government's best efforts, the messages about climate change causes are not really modifying the general public's views.

One reason for this scepticism, however, may be attributed to the fact that many adults within these workshops may have had no involvement with compulsory education for several decades and therefore have not been influenced by recent changes in the National Curriculum. Adults that left compulsory education before the introduction of widespread climate change science in the 2000s, therefore, have had to rely on other information sources. In support of this, workshop participants reported that their primary source of climate change information was the popular media such as television, newspapers and the internet.

Skill levels varied across participating adult groups, with the charity, business and councillor groups demonstrating the most greatly developed skills of analysis and synthesis. Analysis skills involved drawing conclusions about temperature changes over time and synthesis skills involved drawing conclusions about how projected temperature, precipitation and sea level changes could affect their local area in the future. Interestingly, a number of individuals within these groups commented that they could only draw such conclusions if they felt able to trust the sources of information, which at that point, they did not.

In contrast, analytical skills varied considerably amongst the school-age pupils and synthesis skills were generally lacking. However, most pupils were able to conclude that temperatures were increasing over time. Difficulties with the synthesis activity may, however, have been partly a reflection of the broad ability range of pupils engaged in the workshops and a general lack of personal experiences, as would be expected of this age group.

3.2 Ease of Understanding Climate Change Core Evidence

Table 2 summarises the extent to which workshop participants were able to understand the IPCC climate change outputs. Whilst all groups appeared to understand visual representations of data far more readily than raw data or technical descriptions, there was still a need to explain graph axes and in particular, symbols and acronyms used on many graphs.

Table 2.

Pupils and teachers easily understood basic geographical models that demonstrated projected changes in global temperature [122] and partially understood tables, maps and graphs, but commented on the complexity of data and use of technical terms such as "radiative forcings". When asked about reactions to textual information, taken from the IPCC's Summary for Policy Makers [123], both pupils and teachers commented that there was too much information to digest and that the material presented was overly technical for their purposes.

Pupils excluded from mainstream education were particularly vocal about IPCC material and refused to read text or look at any of the graphs. As mentioned previously, this was a particularly hard to reach group, but represents an important aspect of the community that would benefit from active engagement.

In contrast, the charity, business and councillor groups responded fairly well to models and maps showing projected global temperature changes. However, as with the school pupils and teachers, they found interpreting text and tables difficult. Graphs were slightly more acceptable, as long as a facilitator was able to explain processes and outcomes and provided adequate time was given to digest new concepts. .

3.3 Kinds of Evidence that Particularly Engaged Audiences

Table 3 summarises the responses of groups to various engagement approaches. This suggests that, regardless of age or experience, nearly all the participants responded best to interactive, non-technical approaches. Clearly, this is in direct contrast to the one-way traditional communication approach adopted by many academics and policy makers.

Table 3.

Those involved in formal education, namely school pupils, excluded pupils and teachers responded most positively to hands-on experiments such as sampling water temperatures and measuring land loss due to projected sea level rise. Teachers also responded well to discussions about their own direct personal experiences of events such as heatwaves and flooding.

Similarly, representatives from charities, business and council groups enthusiastically recalled and discussed climate related events. Photographic evidence and local case studies were particularly useful in stimulating discussion in this area, particularly where images were familiar and recent.

Whilst very few pupils were able to identify with such personal events, possibly due to their age and lack of experience, they were able to relate to short-term changes in weather such a recent very dry spring of 2011 when there had been forest fires. Recalling such experiences the pupils were able to imagine how that might become more frequent in the future. This is an important factor to take into account when designing future education activities.

Finally, all participants were most actively engaged and responsive when they felt that potential climate change impacts such as disruption to energy and water supplies could directly affect their daily activities. This resulted in a willingness to explore mitigation and adaptation measures, including the development of some innovative ideas. In many cases, this naturally led on to discussions regarding who should be responsible for the implementation and associated funding of mitigation and adaptation measures, a key issue not currently included in the UK or Welsh national curriculum.

3.4 Additional Information Requested

Further information topics and sources requested by participants at the close of the workshops are listed in Table 4. Whilst each group provided very different responses to this question most groups were confident that they had enough information to reduce their carbon footprint, but were less sure of how they could adapt existing and future behaviours in a changing climate.

Table 4 .

Specifically, school age pupils were interested in learning more about which local areas might be susceptible to surface water flooding and transport disruption. These were issues pupils were already familiar with, therefore it was conceivable to explore the possibility that these might become more common occurrences. Pupils were also interested in exploring how to adapt their homes to improve resilience against increased temperatures and heavy rainfall events and also how to produce local sources of energy. During workshops, pupils were asked to design eco-energy inventions and afterwards were keen to find out more about how they might turn these into a reality. This activity had purposely been included as a tool to capture pupils imagination, personalise the workshop and encourage thought about the positive sides of future adaptation. It succeeded in these respects.

Pupils were also keen to know more about which types of industry might be positively affected by a changing climate, for example whether Welsh tourism would be a growing sector that offers them a long term career, or whether farming would be more sustainable. It quickly became apparent that pupils were interested in finding out about the logistics of adaptation, rather than expanding their knowledge of mitigation or science and that they were capable of envisaging a future where changes could produce opportunities for them.

Finally, pupils were interested in finding out more about how they could influence decision-making, for example, how to lobby local politicians, how to initiate a petition and how to gain media interest in a story. As the academic team aimed to remain neutral throughout workshop activities, these particular discussions were not greatly expanded upon. However, there was certainly an indication at several schools that pupils were keen to actively influence decision-making.

Teachers, whilst emphasizing the need to use a broad range of approaches to engage their pupils, were more interested in acquiring additional teaching support tools than gaining further knowledge about climate change itself. Such tools included simple data sets, lesson templates, local and international case studies and hands-on activities and experiments. Interestingly, all teachers commented that their time was limited and that it was therefore essential for any new educational resources to clearly identify their relevance to specific parts of the National Curriculum.

Charity and business groups similarly requested more practical information that directly related to their operations. This included detailed local maps and projections identifying which operations could be disrupted, along with information regarding the severity and frequency of disruption. Individuals involved in businesses were also keen to find out about suppliers of eco-friendly products such as stationary and packaging, thus demonstrating a general support for sustainable operations, albeit in some cases, embroiled in some confusion about how such an approach reduced carbon production. This is unsurprising, given the complexity of the "system".

Councillors had a slightly different perspective and requested that simple briefing notes were made available that clearly explained local climate change impacts that could be passed to colleagues. They also requested information on cases of best practice, sources of funding and expert advice. These were all very functional requests and suggest that councillors' time and knowledge was limited but that there was a general willingness to improve climate change responses.

4. Discussion

Education and training play a pivotal role in developing a society that is able to take well informed decisions about climate change ([124]; [125]). As noted in Section 1.2, whilst the role of education and training is well recognised at international, UK, and Welsh levels, there remains a disparity between what is advocated at these levels, and what is actually delivered at a local level.

A review of knowledge and skills, ability to interpret climate change science, suitability of engagement approaches and the demand for supplementary information has provoked consideration of a number of further issues.

Firstly, results of the research reveal that climate change communications from organisations such as IPCC are not being received or understood at local levels. None of the groups we worked with were able to fully understand the IPCC information presented to them without assistance, including many local councillors, key decision-makers who influence existing and future adaptation choices. Indeed, there has been considerable concern about the ability of local councillors across the UK to interpret the science for some time, with significant issues revolving around the develop-defend cycle, whereby local councils have frequently placed undue confidence in coastal defences, encouraging new constructions in flood risk areas [126].

While it is accepted that some detail is required in the scientific literature to ensure transparency and clarity, it is essential that effective communication of key messages also takes place. At present, summaries for policy makers remain too complex for common use and in particular, there appears to be few mechanisms for feeding such messages back to the science providers and thus providing a reverse feedback arrow back to the science provides in Figure 1. This missing feedback clearly needs to be addressed.

Taking the discussion on a little further, our results indicate that offering audiences complex definitions, data and geographically distant case studies and asking for feedback is not enough to ensure active engagement and operationalization of climate change science. This finding conforms to similar observations elsewhere in the literature ([127], [128]), thus highlighting a major issue with the way we currently engage with audiences.

The majority of groups involved in the study, regardless of age or experience, responded most positively to a short introductory review of the science, followed by interactive exploration of local case studies in small groups and consideration of individual options for near future behaviour change. These results reflect wider views within the academic literature which suggest that participatory approaches are most effective (see for example: [129]; [130]) along with those that provide and engage with local, tangible settings [131]. The most engaging aspect within our study for most individuals was the opportunity to "play" with the evidence they had been presented with, for example, being able to plot a transport route through a local interactive map with flood risk areas highlighted,

or exploring how they might retrofit a local existing building to cope with changing climate conditions. Such approaches also enabled the discussion of values alongside 'scientific facts' and also facilitated the development of critical thinking skills and problem-solving, well recognised important elements of climate change education [132]. However, from our own observations it is clear that engaging in meaningful discussions about climate change impacts and adaption, is not feasible or realistic for participants without a sound understanding of the basic science, an acknowledgement of uncertainties associated with it and knowledge of local characteristics.

Secondly, despite a relatively strong formal education framework, our experiences from Wales reveal a variable knowledge and skill base across all age ranges. The relatively recent inclusion of climate change on the national curriculum (from 2008) may partly explain the higher knowledge levels of the adolescents compared with the adult groups. The contrasting skill levels of the different age groups is less easily explained, although the stronger skill sets of adults may reflect the longer-time period over which they have been able to apply and develop skill sets in real-life settings, compared to pupils' limited short-term experiences in classroom settings. This is re-iterated in a recent OECD (Organisation for Economic Co-operation and Development) report, which revealed Wales' education and skills ranking below the OECD average [133].

In addition, there have been reports and concerns raised about the teaching of geography, where most climate change science is taught and key map and graphical interpretation skills are learnt, has been in decline in the UK [134]. Alongside the relatively weak educational attainment in Wales, noted above, science literacy of the general public is also a key concern [135]. This finding may be related to the academic scientific foundations of individuals, as well as the frequency with which they use such information formats in their day-to-day activities.

Until now, there has been little mention of those adults that are beyond the compulsory education system and who are unlikely to participate in climate change related work-based training. At present, adult learning is not influenced by any nationally agreed education guidelines, nor do the majority of adults have the time or inclination to develop their own climate change response capacities. Some governments, and certainly Welsh Government

has been investing in societal learning [136] via its *Welsh Climate Change Engagement Strategy.* This has been actively supplemented by on-line guidance and funding that aims to promote a lower carbon and more sustainable Welsh society [137]. Although commendable endeavours, the former Climate Change Commissioner has recently queried the level of resources dedicated to climate change awareness raising across Wales, highlighting issues associated with reaching all target audiences [138]. In the context of the Well-Being and Future Generations (Wales) Act 2015 and the establishment of a new Future Generations Commissioner with a climate change portfolio alongside a newly established climate change Expert Reference Group, it is to be hoped that such resources will be forthcoming.

Thirdly, while participants generally demonstrated an interest in developing further knowledge about climate change, it is recognised that this was partially prompted by our workshops which encouraged them to consider some of the far-reaching implications of climate change on their and their communities' futures. For those that showed interest in further development, it is important to recognize specific learning needs, but also to provide practical support which extends beyond that delivered at the workshops. For example, this might involve creating a self-sustaining community network which focusses on developing and cascading knowledge and skills at all levels, for all age ranges within the community. Furthermore, it might extend to promoting principles such as sustainable development, exploring local applications of climate change science and jointly developing local mitigation measures. The usefulness of such a network could be maximised if it is able to operate within a broader national or international support framework and also if skills such as campaigning and fundraising are included within its remit.

5. Conclusions

Whilst the pivotal role of education in preparing societies for taking more informed decisions about mitigating and adapting to climate change is widely recognised, enshrining this within international and national policy is only a fairly recent, and, indeed, a preliminary first step. The climate for learning remains temperate.

Good words need to be followed by actions: governments across the world need to enable

and facilitate learning at local levels before it is too late and international bodies and initiatives must continue to provide education, training and public awareness materials and guidance relevant to local needs. Our results show there is not only a requirement for scientifically sound information to be provided in attractive and suitable formats, but also that engagement mechanisms should be more aligned with the needs of the multiple 'audiences' within communities, whether they be existing or future decision-makers. Whilst it is recognised that the 2016 ACE guidelines highlight the need to accelerate climate change solutions through the development of national ACE activities, many of the resources to-date have, for very obvious reasons, focused on developing countries. Our study suggests developed countries, with a very different range of impacts and issues, are also in need.

Whilst it may be relatively easy to amend nationally prescribed curricula and provide formal education resources, particularly in a well-developed country such as Wales, there remain questions about educating those outside the compulsory education system in these countries. Is it too late for the rest of us? Indeed, our results along with others' [139] suggest that there is an urgent need to foster community knowledge and skills.

Clearly, our recommendations require significant investment and are potentially labour-intensive. Short-term investment in such activities, although potentially expensive, should reap long-term benefits to society, particularly as the costs of non-adaptation escalate. We suggest that societies must be both "'climate literate" [140] and "climate active" [141] if they are to engage in decision-making which will result in decisions that are scientifically sound as well as politically and socially acceptable.

Given the limited literature evaluating specific climate change education programmes, it is hoped that this paper provides a useful contribution to global climate change education debates. Whilst it is recognised that this research may be somewhat biased by the perceptions of the delivery team [142] and is based on the experiences of a relatively high income, well-educated nation, we suggest that our lessons should be relevant elsewhere. This review provides valuable insights based on a systematic study of a wide range of experiences, engagement activities and participants, including teachers, secondary school pupils, local councillors, charity workers and business representatives. Clearly these

lessons are most relevant to other developed countries with democratic decision-making structures, but our workshop experiences may also have wider significance. This is particularly true in terms of the need to strengthen linkages between science providers and science users. Whilst it is recognised that the former may be somewhat reluctant to engage in such endeavours [143] and may undervalue appropriate 'message framing' ([144]; [145]), it will be essential for them to contribute appropriate knowledge. There is, therefore, a vital role for climate change communicators and appropriate 'boundary organisations', as noted elsewhere in the academic and grey literature (for example, [146]; [147]). In the context of informal learning mechanisms, these might be best delivered by the third sector, who have a broader remit, dedicated training resources and extensive local level experience. However, at the global level, there remains a continued need for centralised and trusted resources to be developed in partnership with the IPCC and other science advisors and producers to enable the necessary two-way communication flow, which will ensure climate science, and associated decision-making, are fit for purpose.

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Table List - Reis and Ballinger

Table 1   What are existing levels of climate change knowledge and skills?

	Pupils (n= 300)	Excluded pupils (n=24)	Teachers (n=30)	Charity Staff (n=60)	Business Staff (n=100)	Community and Town Councillors (n=70)
Knowledge of basic environmental systems	◐	◐	○	●	●	●
Knowledge of basic climate change science	◐	◐	○	●	●	●
Reasons for uncertainty	●	●	●	●	●	●
Differences between mitigation and adaptation	◐	◐	◐	●	●	●
Options for mitigation	◐	◐	○	○	○	○
Options for adaptation	●	●	◐	●	●	●
Analysis skills	◐	●	○	○	○	○
Synthesis skills	●	●	●	○	○	○
Comments	Moderate (only ok if covered basic science in geography. Confusion between mitigation and adaptation). Lack of skills.	Low (limited formal education in science, lack of interest to engage in classroom activities). Lack of skills.	Moderate (mainly geography teachers, otherwise lack of understanding of basic science).	Very low (not an issue for them, cynicism).	Very low (not an issue for them, cynicism, denial, apathy).	Low (some misconceptions, cynicism).

○○   very positive response
○   positive response
◐   slightly positive response
●   negative response
n/a   not applicable

Table 2   How easy is it to understand IPCC climate change outputs?

	Pupils (n= 300)	Excluded pupils (n=24)	Teachers (n=30)	Charity Staff (n=60)	Business Staff (n=100)	Community and Town Councillors (n=70)
Text	●	●	●	●	●	●
Graphs	◗	●	◗	●	◗	◗
Maps	◗	●	◗	○	○	○
Tables	●	●	●	●	●	●
Models	○	n/a	○	○	○	○
Comment	Moderately difficult	Very difficult	Moderately difficult	Moderately difficult	Moderately difficult	Moderately difficult

○○   very positive response
○   positive response
◗   slightly positive response
●   negative response
n/a   not applicable

Table 3　　　**What other kinds of evidence particularly engaged audiences?**

	Pupils (n= 300)	Excluded pupils (n=24)	Teachers (n=30)	Charity Staff (n=60)	Business Staff (n=100)	Community and Town Councillors (n=70)
Photographs	O	O	O	O	O	O
Case studies	O	O	O	O	O	O
Hands-On Experiments	OO	OO	OO	O	O	O
Direct experience	n/a	n/a	OO	OO	OO	OO

KEY:
OO　　　very positive response
O　　　　positive response
◗　　　　slightly positive response
●　　　　negative response
n/a　　　not applicable

Table 4　　　**What kind of additional information was requested?**

Pupils (n= 300)	• Examples of how to adapt • Which general areas were likely to be affected by flooding/ drought/ landslides etc. • How to directly influence decision-making
Excluded pupils (n=24)	• How to get adaptation inventions produced and traded • What business areas they should go into
Teachers (n=30)	Tools for teaching e.g. • Simple data sets • Lesson templates • Local case studies • Experiments • Hands on activities (*all specifically related to the National Curriculum)
Charity Staff (n=60)	• Logistics disruption information • Detailed information on when, where and how severe climate changes are likely to occur • Help with identifying which of their operations might be affected • Local maps
Business Staff (n=100)	• Where to buy low-carbon products • Detailed information on when, where and how severe changes will occur • Help with identifying which of their operations might be affected • Local maps
Community and Town Councillors (n=70)	• Case studies of best practice • Sources of funding • Sources of advice • Simple material to give to their colleagues

Figure 1. Conceptual Model of Information Flows from Science Producers to Decision-Makers and the Public (Source: authors**)**