National Co-ordinating Centre for Public Engagement

Reviewing public engagement with physics and engineering in REF2021

A report for the Ogden Trust and the Science and Technology Facilities Council (part of UK Research and Innovation)

Final report

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National Co-ordinating Centre for Public Engagement

Contents

Purpose

The NCCPE was commissioned by the Ogden Trust and the Science and Technology Facilities Council (part of UK Research and Innovation (STFC)), with the involvement of the Institute of Physics, to review the submission of Impact Case Studies (ICS) in Panel B UoA 9, and Environment statements made by the physics departments / schools / faculties of UK Higher Education Institutions (HEI) to the 2021 Research Excellence Framework. Noting that some physics researchers choose to submit to other UoA, the project was later expanded to extend the review to ICS submitted to Engineering (Panel B UoA 12).

Our aim was to show what the submissions reveal about the 'state of play' of public engagement policies and practices in physics and engineering at the point when ICS were submitted to REF2021, understand the focuses of activity and identify gaps for future prioritisation.

We conducted the research in three phases:

Phase 1 – a landscape summary of the 'state of play' in public engagement policy and practice in physics at the time of submissions to REF 2021. The landscape summary laid out the context against which HEI submitted their REF2021 returns.

Phase 2 – an in-depth critical review of the ICS, building on the rapid analysis conducted in phase 1

Phase 3 – focus groups with members of physics departments and informal conversations with a small number of panel reviewers to derive experiences of the REF process.

Summary

Based on an in-depth critical review of the Impact Case Studies (ICS) and Unit-level Environment Statements (ES):

- Almost half (77/169 or 46%) of the physics ICS produced for REF 2021 mention public engagement activity. While a direct comparison is not possible, due to changes in the reporting approach, this represents a significant increase from REF2014 when 18% of the ICS mentioned public engagement.
- Of the 44 institutions that submitted physics ICS, 31 included at least one public engagement-focused ICS. While this represents majority 'take up' of public engagement in physics departments, it leaves room for growth.
- In engineering, public engagement is mentioned in very few ICS (22/391 or 5%). Of those 22, only two ICS are primarily about public engagement
- There appear to be few differences in approach among the four home nations.
- Key priorities for public engagement in physics are raising awareness and understanding of physics, supporting school-level physics teachers to address low participation in science and influencing policy (UK and elsewhere). This shows little change between REF2014 and REF2021.
- Key priorities for public engagement in engineering are influencing government policy and contributing to the development of professional standards
- Not all physics ICS or ES define their target audiences for public engagement activity (albeit the format of the templates does not require this). Those that do focus on students with lower educational attainment, schools in deprived areas, 'widening participation' schools and communities that are under-represented in STEM subjects (such as students living in socio-economically deprived areas and people who identify as female)
- Very few engineering ICS define a target audience, however it is clear from context that the main target audiences are policy-makers, professional bodies and the 'general' public
- Public engagement activity in physics is often about broadening access to equipment (e.g. mobile planetariums, telescopes) and sharing knowledge, rather than engaging specific publics in specific academic research projects
- Common modes of public engagement are mass public events, media appearances, involvement in science festivals, teacher training events/workshops, public exhibitions and in engineering, policy engagement
- Less common modes are digital engagement (although the COVID pandemic increased this), partnership projects (e.g. with third sector organisations and public libraries), arts and cultural projects, citizen science and long-term engagement with schools
- A handful of examples of ICS used robust evidence to demonstrate the contribution of public engagement – in physics we identified six examples which we felt were strong examples of evidenced engagement and in engineering, one example. However, this is a small minority; most ICS either don't mention evaluation or contain very brief summaries which makes it difficult for a reader to judge the robustness and validity of the evidence.
- The use of evidence/and the role of evaluation is an area that could be developed within ICS – at present the focus is on evidencing positive outcomes rather than reflection on what might be improved. Evaluation also takes place at the department-level and we wonder about the potential of group/network evaluation approaches.

Public engagement in physics and engineering in REF2021

We used NVivo (version 14) to qualitatively analyse the 169 physics ICS, 38 institutional-level environment statements and 44 unit-level environment statements submitted to REF 2021 and 391 ICS submitted to the engineering UoA. There was minimal mention of physics public engagement in the institutional-level statements, so our analysis focuses on unit-level ES for physics.

Information on impact is integrated into the **unit-level environment statements**. We have looked in detail at 'Section 1: Unit context and structure, research and impact strategy', 'Section 3: Income, infrastructure and facilities' and 'Section 4: Collaboration and contribution to the research base, economy and society'.

In the REF2021 unit-level environment statements there are substantial differences in the attention given to public engagement. In some ES, a public engagement narrative is offered in a discrete section, with clear aims and objectives, examples and assessments of impact. In others, public engagement is covered in a couple of sentences spread across the document, making it difficult to make concrete statements about the context for public engagement in those settings.

To understand the extent of **public engagement in physics and engineering ICS** in REF2021, we searched for evidence of the following terms in the ICS:

> 'public engagement' OR 'outreach' OR 'communicat*' OR 'disseminat*' OR 'science engagement' OR 'science education' OR 'educat*' OR 'citizen scien*' OR 'communit*' OR 'community science' OR 'schools' OR 'policy' OR 'policy makers' OR 'public understanding' OR 'public awareness' OR 'consult*' OR 'advis*' OR 'advic*' OR 'co-production'

This search string aims to capture the three broad types of public engagement universities engage in, as outlined by NCCPE: inspiring and informing, consulting and collaborating.

For physics, this query returned 93 items. We screened these to exclude any that were not about public engagement activity, resulting in the removal of 16 ICS from the sample. For engineering, this query returned 34 ICS. We screened these to exclude any that were not about public engagement activity, resulting in the removal of 12 ICS.

Physics

Almost half (77, or 46%) of the ICS produced for REF2021 mention public engagement activity. In about a third of these, public engagement was included as a 'bolt-on' activity (for example creation of an exhibition) that formed one of the pathways for impact for the research. Thirty-one of the 44 institutions that submitted ICS included at least one ICS entirely focussed on public engagement as the pathway to impact.

While the difference in reporting approach prevents direct comparison, this suggests a substantial increase from REF2014 when 18% of the ICS mentioned public engagement activity.

Judged on their titles, 49 ICS were focused on public engagement e.g.:

> *Universe in the classroom: transforming perceptions, teaching practice and public awareness of astronomy*
>
> *Oriel Science: changing lives through public engagement*
>
> *Jodrell Bank astronomy research inspires millions of people from a wide range of backgrounds to be more engaged with science*

Twenty ICS focused on impact on policy, mostly on influencing national and international government policies, including environmental, health, research and education policies. In a few examples, the policy influence was on non-governmental organisations, including humanitarian response, recruitment and research culture.

Engineering

Twenty-two of the ICS mention public engagement activity. Reading across the 22 ICS, there appears to be limited engagement with the objective of connecting and engaging with a broad public and/or specific publics such as schools who stand to benefit from engagement with STEM.

Only two ICS are primarily about public engagement: *Utilising engineering research to transform STEM aspirations* and *The "Hive" installation, an immersive, multi-sensory experience that educates visitors about the vital role of bees in feeding the planet*.

The emphasis, in this sample at least, is on influencing government policy and contributing to the development of professional standards. Nine ICS focus on policy engagement, six on engagement with professional bodies and five on commercial engagement.

WHY

How were departments describing their purposes for undertaking public engagement?

Environment statements

Thirty-three of the 44 physics ES mention their purposes for undertaking public engagement (NB: the term 'outreach' is commonly used interchangeably with 'public engagement'). Eighteen of the 33 ES mentioning their purposes do so in one sentence. Most of these short statements communicate a clear goal for undertaking public engagement but eight of the 18 one-sentence statements could be described as vague, in that it was difficult to identify a clear set of purposes. For example:

> *'to disseminate our research to a general audience we have carried out a range of outreach activities' (HEI 4)*
>
> *'we seek to contribute to the wider cultural benefit of society' (HEI 5)*
>
> *'outreach activities play an important role in widening participation in science and are strongly encouraged' (HEI 6)*
>
> *'we have a strong ethos of engaging public audiences with research' (HEI 7)*
>
> *'our engagement activity has been strategically refocussed to engage larger audiences with our research' (HEI 8)*

Overall, the ESs don't give sufficient detail to allow us to comment on the nature of the relationships being sought with publics. However, looking across the ES, common rationales for engagement are, in order of prevalence:

- widening participation in physics teaching and research (14)
- inspiring school-age students and their teachers (8)
- equality, diversity and inclusion (5, with 4 ES mentioning engagement of visually impaired communities)
- policy engagement (2)
- engaging the public in physics research/citizen science (2)

A general aim of 'inspiring and informing the public' was also very common (8), although different terms were used (e.g. 'inform', 'engage', 'inspire'). It is not clear whether the use of different terms signifies differences in actual approach. HEI 9's ES contains an interesting statement in this regard:

> *'we aim not just to do excellent physics but to ensure that we connect both with wider society and with users of our research … HEI 9 is a public institution and the bulk of our research is publicly funded; therefore, we see a responsibility to maintain a dialogue with the public (not just to 'inform' or 'educate' them) (HEI 9)*

However, ascertaining the substance behind this statement is challenging, at least within the ES. Looking at the ICS for HEI 9, the approaches they describe for their public engagement are similar to several other institutions that do not explicitly frame their work in this way.

The low frequency of policy engagement does not mean that unit-level templates did not mention policy engagement as an aim or policy-makers as one of their 'publics' but simply that it wasn't common to describe such work as 'public engagement'. Policy engagement more often had its own heading or was integrated into the main text.

Engagement of under-represented/disadvantaged communities was frequently linked to the local or regional context. Many ES identified the issue of the nationwide shortage of physics teachers as part of their rationale for engagement.

The infrequent mention of co-produced engagement work is significant (just two citizen science approaches referenced).

Physics ICS

Raising public awareness and understanding of physics is very prevalent as a rationale:

> *'to raise awareness and understanding of dark matter and theoretical physics (HEI 10 ICS1)*

Supporting school-level physics teachers to address low participation in physics and other STEM subjects is a frequent theme, commonly addressed by supporting teachers to develop their confidence in teaching physics but also through working with them to integrate 'real-world' physics research into the classroom; most commonly this is UK-focused.

Inspiring school-age children to study STEM subjects is a very common aim:

> *'driven by the need to **close the growing STEM skills gap**, the [centre] is using astronomy to cut across age groups, gender and social demographics and inspire school students to consider STEM careers by giving them access to scientific research and instrumentation, and supporting their teachers' (HEI 11 ICS1)*
>
> *'UK physics faces chronic diversity issues, extensive shortfalls in subject-specialist teachers and **20% lower uptake of physics at A-level than in the 1980s**' (HEI 9 ICS3)*
>
> *'We **enhanced the younger generation's educational journeys** and under-represented communities' engagement with science' (HEI 2 ICS1)*
>
> *'One of the most important aspects of any research programme is the impact it can make through **inspiration of school students, acknowledging that they are our next generation of scientists and engineers**. Impact comes from provision of resources to schools to enhance science education - but is greatly increased if*

teachers have confidence in their own skills and knowledge in teaching the material' (HEI 12 ICS1)

The description of school publics is generally broad. HEI 11's rationale for engagement and/or description of a specific public is uncommon:

> *'it is crucial that this research is across age groups as well as demographics. Attitudes and even prejudices to STEM subjects are known to crystallize at a young age, so the participation of **primary schools** is important' (HEI11 ICS1)*

Eight ICS reference science capital as the conceptual underpinning of their approach to public engagement and thus their targeting of young people, although only two of them (HEI 11 and HEI 2) include text and referencing describing the value of this concept.

Addressing the gender imbalance in physics is another common theme:

> *'In a region where girls can be diverted from STEM subjects, we are working with schools to change preconceived images of Physics and to redress the gender balance in the discipline. The national baseline for women entering 1st year Physics programmes is 22%, and the demographics and socio-economics of [city] produced a lower uptake of 10-14% in the pre2016 period.' (HEI 13 ICS1)*

> *'aims to address the fact that [region] had fewer than half the number of female physics academics compared to the UK average' (HEI 1 ICS1)*

> *'The twin goals of the observatories combine cutting edge research in astrophysics with engaging schoolgirls around the world (including South Africa and India) into science. The embedding of these observatories within residential schools, in cultures that do not traditionally think of women as scientists, has resulted in schoolgirls: (i) being eyewitness observers to authentic research, (ii) operating research-grade telescopes themselves, (iii) becoming proficient in operating sophisticated technology and control software and (iv) hearing talks about different aspects of science, engineering and being a scientist.' (HEI 14 ICS6)*

Two ICS focus on participation in physics for developing countries:

> *'Physics training aids sustainable development in African countries, Palestine and Afghanistan' (HEI 10 ICS2)*

> *'Radio astronomy and big data – bringing STEM training to the developing world' (HEI 3 ICS4)*

There is a strong focus on influencing government policy (UK and elsewhere) and government spending priorities through the provision of evidence and/or academic membership of executive boards/AAPGs/select committees. Less common is a desire to influence working practices and policies at institutions with a role in the science communication ecosystem:

> *`Within the UK physics community, [name] expertise in solar physics made her a natural choice to become the first astrophysicist on the advisory board of the Science Museum in 2012. In her position as a board member, [name] has contributed to the strategic direction of the museum's cultural offer by embedding knowledge of cutting-edge solar physics, and space science as a whole in the institution.' (HEI 9 ICS2)*

It is rare for ICS to indicate a reflexive approach to public engagement, except for one:

> *'As outlined above, [institution] activities have engaged and inspired people from many different demographics but has historically struggled to engage people from certain backgrounds. To try and engage people from these groups with science, and with [institution's] research in particular, HEI 3 developed the annual [name] festival.' (HEI 3 ICS3)*

Engineering ICS

Given that most of the ICS feature public engagement as a secondary concern, there is little in the way of an explicit rationale for public engagement across the sample.

The two engagement-focused ICS contain clear aims. For HEI 15, the aim is to inspire school-age children to study STEM subjects:

> *to provide hands-on experience of their engineering research to excite interest and raise awareness of STEM opportunities and careers […] the [region] has a significant engineering-skills challenge with poor progression into Science, Technology, Engineering, and Mathematics (STEM) careers. Children from primary schools in* ***less-affluent areas and/or with protected characteristics*** *are especially disadvantaged and see limited routes into STEM-based careers and little use in studying STEM subjects. (HEI 15 ICS1)*

Notably, this ICS also ties public engagement to specific research projects:

> *since the funding to support [project] came, in part, from EPSRC grants, the proviso was that the public engagement had to be based on the funded research and draw materially and distinctly upon it' (HEI 15 ICS1)*

This is distinctive, as much of the schools-orientated public engagement in the physics ICS draws on 'physics' or 'science' in general rather than specific research findings/projects.

For HEI 16, their collaboration with an artist on an immersive artwork has the explicit aim of communicating a conservation message:

> *highlight[s] the decline of the world's bee population by focusing attention on the importance of pollination for food production (HEI 16 ICS1)*

Across the other ICS, where public engagement was not a central focus, shaping public attitudes and increasing awareness of STEM were common aims:

> *explaining and promoting the relevance of science to millions of viewers, listeners and readers (HEI 17 ICS1)*

> *a further objective of this project was to inspire a new generation of British engineers to tackle the challenges of the 21st century using science, technology, engineering and mathematics (STEM) (HEI 2 ICS1)*

> *enhanced public understanding and interpretation of archaeological objects…as well as engaging new audiences with archaeological and forensic investigation (HEI 18 ICS1)*

> *the shaping of knowledge and public attitudes towards the role of wetlands' HEI 19 ICS1)*

increasing public awareness of space debris as a global concern and understanding of ADR technologies (HEI 20 ICS2)

Although there is a strong focus on influencing government policy in ICS in the sample, there are almost no ICS where the objectives of engagement are described. An exception is HEI 21:

Bioenergy has significant global potential for reducing carbon emissions – but remains controversial…to apply bioenergy effectively, policymakers need access to robust and relevant evidence. HEI 21's research enables this by providing data on the efficiency, costs and carbon reduction potential of bioenergy technologies' (HEI 21 ICS1)

WHO WITH

How were departments defining the publics with which they engaged?

Environment statements

Thirty-five of the 44 Physics ES mention specific publics. Most prominent are schools (teachers and their students) (13) and targeted schools publics (12):

'with local schools (including students and teachers) and the general public.' (HEI 22)

*'targeted schools less likely to engage with science education, specifically those in **rural areas, with more students in poverty, and lower educational attainment'** (HEI 1)*

*'There is comprehensive engagement with children in schools, which forms part of one Impact Case Study (Section 1.4): half the schools are from **deprived areas**, where students are more likely to suffer low science capital.' (HEI 23)*

*'While interaction with pupils is important, longer term impact comes from supporting, training and enthusing teachers. Our activities focus especially in local WP primary and secondary schools, often without physics-trained staff, by e.g. training 20 local science co-ordinators, raising enthusiasm at a **struggling primary school**, providing a framework for primary science projects' (HEI 24)*

*We have carried out repeat interventions with 1,400 school pupils **from 'widening participation' schools** to increase their interest, enjoyment and participation in physics. (HEI 25)*

Also common are mentions of the 'general public' (8):

'The Unit's Outreach and Public Engagement (OPE) strategy seeks to maximise research impact by promoting physics to schools and the general public' (HEI 12)

Specific public audiences – most often publics under-represented in physics or STEM – are mentioned occasionally (6):

*'collaborative projects are developed with groups and organisations that work with particular demographics that are **under-represented in STEM subjects**.' (HEI 11)*

*'We will work together on a further two projects to bring science and the experience of physics research into **under-represented communities**.' (HEI 20)*

Policymakers are also mentioned as a specific audience (7):

> *'We believe in, and are committed to, delivering on the importance of the impact of our diverse research portfolio; from scientific discoveries and their impact on society and technological development leading to commercialisation and input into **government policymaking**.' (HEI 17)*

A handful of projects are targeted towards blind/visually impaired groups:

> *'bringing science to blind and partially sighted people' (HEI 3)*
>
> *we are specifically interested in targeting non-traditional audiences. This includes engaging visually impaired in astronomy by sonifying astronomical data and reaching out to schools with traditionally lower fraction of students from academic households. (HEI 26)*
>
> *'[name] has used the IoA 3D printer to create tactile experiences for blind people.' (HEI 27)*

Other publics occasionally mentioned include: 'local amateurs' (HEI 28), 'astronomy in Africa' (HEI 29), 'prisoners' (HEI 30), 'citizen scientists' (HEI 25, HEI 14), 'cubs and brownies' (HEI 7).

Physics ICS

The ICS largely mirror the ES in their approaches to defining the publics with which they engaged. Publics mentioned in the ICSs which are not mentioned in the ES include artists and creative/cultural practitioners and audiences with learning difficulties:

> *'influenced artists' creative practice to explain complex science' (HEI 23 ICS1)*
>
> *'Importantly, the [project] also reaches audiences with learning difficulties who would often struggle to access space and exoplanet research. Sessions were delivered at all the local SEN (special education needs) schools.' (HEI 31 ICS1)*

One ICS (HEI 32) focussed on translating research into the regional language, to reach new audiences.

The majority of ICS include mention of more than one public; for example that they intend to 'stimulate public interest/awareness' or 'inspire under-represented groups'. 'Schools' are mentioned in approximately half of the ICS but almost always alongside 'general public'. Schools are the exclusive public in 13 (16%) of the ICS.

Despite their frequent appearance, terms such as 'deprived' 'disadvantaged', 'under-represented' or 'struggling' are not defined in either ICS or ES, which increases the challenge of reliably identifying which publics are being targeted.

Engineering ICS

Nine of the 22 ICS are oriented towards policy-makers or specific government departments:

> *PRF (property flood resilience) is strongly advocated in the 2020 Environment Agency Flood and Coastal Erosion Risk Management Strategy, and the **research has informed the UK Climate Change Risk Assessment**. Defra has described this research as 'one of the most influential flood resilience studies of recent times' (HEI 33 ICS1)*

*improved the efficiency and quality of eye care within NHS healthcare contexts, with use in three NHS Health Boards…**informed national policy and planning for teleophthalmology services** (HEI 34 ICS1)*

*the application of [name]'s research and findings are global as evidenced by citations of his research in the **Malaysian Government's Public Works Department new design guidance** for passive buildings' (HEI 35 ICS1)*

*[name] was part of an expert panel that conducted a systematic review on behalf of **the Department for Environment, Food and Rural Affairs (DEFRA)…which has informed its formulation of policies** regarding the benefits of wetland systems to mitigate pollution from agriculture (HEI 19 ICS1)*

*[name]'s research and profile within robot ethics has also led to prolific **engagement with UK government departments and parliament,** and has informed policy debate in multiple Parliamentary Committees and similar bodies' (HEI 36 ICS2)*

*the research was the **sole publication referenced** by the Minister for Energy Connectivity, in a speech to parliament announcing the Government's final policy position to not support unconventional oil and gas development (HEI 37 ICS1)*

*Society is now benefitting from the higher data rates, lower latency and higher reliability afforded by 5G, thanks to research undertaken by HEI 38's [project] Lab. **This research directly influenced government policy**, yielding the £200 million national 5G testbeds and trials programme (HEI 38 ICS2)*

Six of the 22 ICS are directed towards influencing the guidelines or standards of professional bodies:

The research is used by the Royal Institution of Chartered Surveyors as part of its international guidance for professionals (HEI 33 ICS1)

the impacts of the work include adoption in the Chartered Institution of Building Service Engineers (CIBSE) Guide A 'Environmental Design' for buildings, utilised by over 70,000 engineers in 98 countries (HEI 35 ICS1)

this research has led to new good practice guidelines and standards for the heritage and forensic sectors (HEI 18 ICS1)

HEI 36's researchers collaborated with [company], a large independent UK Law firm, and with [company], a major motor insurer… HEI 36 research contributed knowledge on the developing strengths and weaknesses of the technology itself, as well as many human-factor aspects, on driverless cars (HEI 36 ICS1)

the robotics industry and affiliated unions are using [name]'s research to inform their thinking and practice on robot ethics. His research has underpinned the development of organisational standards and helped define best practice (HEI 36 ICS2)

In two of the ICS researchers directed their interventions towards influencing professional practice in terms of setting standards whilst also seeking to encourage discussion of the ethical aspects of technology and/or standards. This criticality was not always part of public engagement activities. Compare, for example, HEI 36 ICS2 (above) to its ICS1, which describes 'get[ting] communities in this region thinking about the benefits of autonomous vehicles' as an aim.

Although we removed ICS that were solely about commercial/industry impact from the query, five ICS featured an element of public engagement alongside more standard commercial engagement. HEI 13's ICS describes a Knowledge Transfer Partnership (KTP) with a commercial company. The partnership achieved some societal impacts in the form of job creation although this was not its central purpose. Similarly, HEI 38 ICS3 mentions a 'stand at the 2019 Royal Society Summer Science Exhibition' but is predominately focussed on commercial impact on an energy company. HEI 20 ICS is mainly about the commercialisation of sound zone technology – it cites a VR experience made available by the BBC based on its research as a component of its public engagement but engagement with the public is not a priority.

The 'general public' is the most prominent 'public' in those ICS where public engagement is not the focus but a component or 'add-on' to another programme of engagement – or outreach – activity:

> *Impact on outreach includes explaining Fire Science at five exhibitions/festivals attended by over 100,000 visitors, over 20 media engagements on TV, on radio or in popular press, explaining and promoting the relevance of science to millions of* ***viewers, listeners and readers*** *(HEI 17 ICS1)*
>
> ***global public engagement*** *including 2,800,000 views of a TED talk (HEI 30 ICS1)*

Audience numbers are frequently used as evidence; the two ICS above offer evidence of large global audiences, whereas others evidence smaller numbers: HEI 36's public engagement is cited as reaching 500 people through festivals and webinars and HEI 19's theatre production, funded by Arts Council England, was 'performed in the UK in 2019 to 64 people (audience members aged between 11 and 62)'. What we rarely see is evidence of the impacts of engagement on those audiences.

Where impact on the public is one of the main aims, it is interesting to consider the social demographics of the audiences being targeted. A good example is HEI 16's art installation which was presented at The Royal Botanic Gardens Kew and Glastonbury Festival – both places where the audience is very likely to be white and middle or upper class. Similarly, 'HEI 36's research has extensively informed public debate on robot ethics through [name]'s wide-ranging engagement with the public…[name] contributed to over 50 public lecturers and panel debates on ethical challenges in robotics and AI' (HEI 36 ICS2). The ICS cites appearances on BBC R4 and lectures at the Institute of Physics; again it would be worth questioning if the 'general public' is not being sufficiently segmented or identified, or opportunities to target new audiences are being missed or simply not considered.

Compared to the physics ICS, in engineering ICS schools (teachers and their students) are less prominent, with just two in the sample mentioning these publics. HEI 15 ICS1 describes engagement with children, teachers, and families from less-affluent areas in its region, with an explicit rationale for engagement with these groups:

> *the Theory of Change approach acknowledged and addressed the issue that children's confidence and interest in STEM is influenced by their experiences of STEM from an early age (primary education level) and the perspectives of people around them (teachers, parents) (HEI 15 ICS1)*

Whereas HEI 2 ICS1 describes 'a large-scale education programme with which over 6,000 schools have engaged' but makes no mention of the types of school or student groups being targeted.

WHEN

When did the engagement happen?

Environment statements

No physics ES templates explicitly specified the point in the research process when the engagement took place. Two of the 33 described citizen science projects, a methodology that (although the ES did not state this) is normally conceived as involving its public throughout the research process.

The data on the modes of engagement used/described in the physics ES templates shows that most units describe their public engagement work in terms which suggest that engagement is about sharing findings of completed projects or sharing general physics knowledge and methodologies; that is, public engagement work may be only indirectly linked to research projects *per se*.

ICS (Physics* and *Engineering)

Although the physics ICSs provide more detail on the nature of public engagement in physics departments, it is apparent is that public engagement work is not always about specific research projects and/or findings. Very often, aspects of a unit's PE are about sharing equipment, methodologies and the scientific method more generally. In engineering, in some cases, impact is built into the research process, for example HEI 39's ICS describes focus groups and online seminars as a mechanism for increasing community engagement and building local capacity in flood resilience. In most other cases, engagement happens after the research is completed, e.g. HEI 38 exhibiting their drive chain technology at various science festivals/exhibitions and HEI 35 mentioning their attendance at [city] Science and Mathematics festivals. Not all the ICS give dates when the engagement activity took place but, in the 40 ICS that specially mention 'public engagement', the most common period for activity to start was in 2016 or 2017, with a range from 2014 to 2019.

HOW

What modes of engagement were used?

Environment statements

It is not common for engagement processes to be described in detail in ES – these documents focus on the 'what' rather than the 'how'. A broad range of modes of engagement is described (see Table 1).

High prevalence	*Lower prevalence*
• Working with schools • Public events, science fairs and festivals • Public seminars or lectures • Media appearances • Workshops/ summer schools • Teacher training • Exhibitions • Public visits to facilities/open days	• Policy engagement • Digital engagement • Citizen Science • Partnership projects

Figure 1: Modes of engagement

High prevalence

- Public events linked to major astronomical events (e.g. 2015 eclipse)
- Participation in pre-existing large scale public events (e.g. Pint of Science)
- Organising public seminar series/lectures
- Media appearances – presenting or being interviewed for documentaries is common, particularly when an academic has a media profile
- (e.g. [name] from HEI 5's appearance on BBC's *Astronauts: do you have what it takes?*, [name] from HEI 20 presenting six television documentary series and 170 radio programmes and [name] from HEI 3's wide range of radio and television work. The presence of these figures offers units substantial opportunities for dissemination of the 'broadcast' variety
- One-off presentations/workshops with schools/summer schools
- Teacher training
- Involvement in scientific fairs and festivals, e.g. Cheltenham Science Festival – many departments have developed demonstrations to support engagement at these events (e.g. HEI 40)
- Public exhibitions (e.g. several ES mention participating in the Royal Society Summer Exhibition, also HEI 11's supported an interactive exhibit at the National Science Museum in London)
- Organising public visits to observatories/telescopes/planetariums and taking mobile planetariums to public events

Low prevalence

- Policy engagement (although individual ICS suggest otherwise)
- Digital engagement/social media, although the REF period covering the COVID pandemic means several departments ran digital projects:

  'accessible home-based experiments in lieu of the usual science exhibits…[and] an astronomy-based presentation aimed at children as part of a Christmas 'Advent' series' (HEI 32)

  '[name] leads a project on the propulsion of Leidenfrost droplets on structured surfaces. With MPhys students, he produced videos (released in Autumn 2013) of water droplets travelling uphill and around the 'Leidenfrost maze', a demonstrator designed for public engagement. These were featured on Science Friday's YouTube (2.8M views, >1300 comments) and Facebook channels (6.6M views).' (HEI 42)

  'The Space and Planetary Physics subgroup operate a free service offering members of the public alerts when the aurora borealis might be visible from the UK. Users receive alerts via social media and smartphone apps with the service currently engaging with 103,000 Twitter and 214,000 Facebook followers in addition to 193,000 users of the bespoke app' (HEI 43)

  '[name] and [name] have also contributed to the YouTube astronomy Deep Sky Videos channel, highlighting research results on the Westerlund 1 star cluster (45k views) and runaway stars (38k views).' (HEI 6)

'We have established three MOOCs. Collectively, these have attracted over 200,000 learners and offer a bridge between outreach and traditional education that complements our role as research-led educators' (HEI 30)

'In the [name] series of YouTube videos, a range of topics, including original fundamental, applied and interdisciplinary research, are presented by our staff. The channel has >350 uploaded videos, >800k subscribers and >88M video views. This innovative collaboration won the IOP's 2016 Kelvin Medal, the Digital Media award at the University's 2016 Knowledge Exchange and Impact Awards and was a finalist for the 2018 Times Higher Education Outreach award.' (HEI 37)

'an active Departmental Twitter account (@Physicsat[HEI]) that has grown to over 1,700 followers, and new science page contributions to Wikipedia (one of the top ten websites in the world by traffic). Between the pages edited by staff and those by our BSc students, we estimate that every month, pages substantially edited by members of the Department are read by tens of thousands of visitors. Wikipedia's page on 'Nucleation' alone has over 120,000 page views/year' (HEI 20)

A few ES acknowledge the importance of the institutional website as the first point of call for public interactions with the department but this is rare. Ensuring departmental or institutional websites are easy to find, accessible and information-rich could be a route for extending public engagement with the research happening in physics departments.

There is intensive engagement with schools, often characterised as 'outreach':

'For outreach, the [name] Centre uses its research outputs to train the next generation of students in coding, observation, and teacher training. An example is the ThaiPASS project (see Fig. 2) that delivered two summer schools on Python programming for Astronomy in 2018 and 2019 (with two additional schools, 2021-2022). Our PhDs and PDRAs play crucial roles in these activities via demonstrations and contributing to guest lectures' (HEI 13, ES)

'HEI 38 leads the UK arm of HiSPARC, delivering cosmic ray detector kits and software to 23 secondary schools allowing students to participate in research.' (ES, HEI 38)

'Our students also take outreach very seriously, and have formed chapters with both the SPIE and OSA, and have frequently undertaken outreach activities with local schools etc. We are now going beyond this and, in conjunction with our College Outreach Officer, we have developed a 'Metabuddies' scheme, where our students are partnered with local schools for long-term outreach activities' (ES, HEI 44)

'Increasing Access: '[project]' supports A-level physics students from less affluent areas to study STEM at university, in partnership with three local schools. It provides after-school physics sessions run by researchers for students and teachers, covering both the A-level curriculum and the researchers' own work. This enables schools to offer enhanced A-level physics, thereby supporting and retaining their brightest students. These schools' catchment areas have less than 20% progressing to higher education; half the students in '[project's]' inaugural year have now applied for STEM courses at university. From 2021, and planned during REF2021, we will partner with the IoP to offer 'Levelling Up', a new

programme for 40 local school students interested in studying physics at university. With philanthropic support, this will provide physics tuition, mentoring by undergraduates, and on-site visits engaging with our research' (ES, HEI 14)

A few ES mention partnership projects. These range from engagement with specific community partners:

[project], a non-profit 'focused on providing STEM education based around the topic of Space Science to refugee and disadvantaged students in the Middle East to help improve their life outcomes' (ES HEI 17)

To partnerships with informal science engagement institutions:

'During the REF period, we set up a new institution-wide collaborative partnership with the [city] Science Centre and Planetarium. Over the next five years, we will build on this new collaboration. We will deliver at least two major joint exhibits promoting HEI 20's physics research, reaching the over 200,000 visitors to the museum a year.' (ES, HEI 20)

There are a few mentions of international partnerships:

'With over £3M support from the Newton Fund and the Global Challenges Research Fund we are leading the training of future generations of radio astronomers in Africa (& South America) to enable their participation in international projects (e.g. SKA) as well as to inspire younger scientists from a range of African countries to consider physics as a career.' (HEI 22)

Partnerships with arts and cultural projects also occur:

'We worked with the [city] Museum and Art Gallery to develop the "Museum of the Moon" exhibition for the 50th anniversary of the Apollo landings. [institute] staff worked closely with museum staff, lent historical documents to create an associated exhibition and gave over twenty public talks, attended by more than 400 people. The exhibition led to unprecedented interest with over 50,000 visitors over the course of the month-long installation.' (HEI 29)

'Astronomy and Geophysics through the Traditional Culture of Wales' involves cultural activities based on scientific themes, HEI 10's Artist in Residence programme for 'the interaction of science with art provides new opportunities to ignite creativity and discovery' and HEI 22's Bragg Centre Creative Labs establishes collaborations between scientists and artists.

As noted above, two ES mention Citizen Science

'A flagship activity that has flourished through the Covid-19 pandemic is [project], an online Citizen Science project that has enabled more than 6,118 budding astronomers to analyse thousands of hours of aurora footage from the Arctic, leading to 205,930 classifications of 22,443 aurora images. This led to a research paper which included five members of the public as co-authors.' (HEI 26)

ES are also used to show how institutions resource or support public engagement:

- Through Widening Participation and civic engagement strategies (HEI 11)
- Funding of public engagement officers, public outreach directors and outreach champions (e.g. HEI 45 has an outreach champion in each research group to advise on engagement and

outreach at the research design stage as well as a Cultural Engagement Leader to develop work at the interface of science and the arts)

'During the 2021 REF period, [institution] staff members, [name] and [name] have been employed full-time on outreach activities for schools and the general public. They lead educational programmes in physics for young people and their teachers. The very extensive schools programme also involves staff members who contribute popular lectures in [city] and throughout the country.' (ES, HEI 27)

- Roles funded by external organisations e.g. Ogden Outreach Fellow, EPSRC public engagement champion fellowship, Royal Society Professorship for Public Engagement, Outreach Officer funded by UKRI:

  'The Access and Engagement Committee Chair [name] supervises 3.5 FTE, who work with the professional public engagement community across the UK […] We are funded through 'pathways to impact' on EPSRC, BBSRC and NERC grants; a £95k direct award from STFC; and significant private funding' (ES, HEI 14)

- Dedicated time in staff workloads to take part in outreach:

  'Research-time allocations are determined in line with faculty guidelines and include time for impact, outreach and public engagement activities' (ES, HEI 25)

- Supporting public engagement/knowledge exchange as part of promotion/pay review:

  'The University places impact and KE activity, including outreach, on an equal basis to academic publications and grant income at all grades of academic appointment, promotion and Professorial re-zoning' (ES, HEI 46)

- Offering guidance and training in public engagement skills:

  'All researchers (including students) are offered guidance and training in PER (e.g. annual Outreach Development Day), while senior academics champion its importance' (ES, HEI 14)

Physics ICS

The ICS offer more detail on the modes of engagement identified in the ES. Of the ICS that mention 'public engagement' most are group projects of between two and twelve members; around a quarter (nine) are single-person projects.

A handful of universities operate or co-operate museums/visitor centres, which is a significant strength in providing vehicles for public engagement activity. These institutions also have dedicated public engagement/outreach professional services staff, so academic departments benefit from their expertise.

There is an interesting distinction in audience demographics between those units who choose to exhibit at established physics/science exhibitions (the Royal Society exhibition is frequently mentioned) and those who pursue relationships with local cultural institutions. One of HEI 9's ICS mentions a presence at music festivals to engage teenagers and young people, suggesting a proactive approach to audience development that raises questions about how institutions decide where to engage:

'packaging our University's research into exciting exhibits and visceral interactions and putting these in places people go' (HEI 2 ICS1)

Some ICSs go into useful depth on the rationale and approach to long-term school engagement, compared to others which talk in general terms about school workshops. For example, HEI 9 ICS3 identifies the importance of role models:

> *[project] partners researchers with schools to involve children in HEI 9-based scientific research related to the [name] Spacecraft (to launch in 2023). Over the past four years, [project] has grown to 30 school-researcher partnerships (involving approximately 1,000 pupils) with 100% retention of schools on the programme. It has enabled more than 150 school students to author 10 scientific publications.' (HEI 9 ICS3)*

HEI 30 ICS4 highlights the need for long-term engagement with targeted schools:

> *'Researchers and students from our research group supported school pupils to deliver activities for the festival, led a weekly science club for 18 p4-p5 pupils in [name] Primary School … [a] teacher commented "By working with and, perhaps most importantly, getting to know [name] and his team, our pupils were able to build relationships with real scientists ... they began to see that anyone can become a scientist and that 'scientist' can mean a lot of things"' HEI 30 ICS4)*

Although several ICS mention collaborations with cultural institutions, there is a surprising lack of engagement with libraries. HEI 30 is an exception; a partnership with the city's libraries provides a means to deliver a Harry Potter-based schools engagement programme.

Individual ICSs are particularly useful for understanding the myriad ways that policy engagement works. Long-term relationships are key. For example, HEI 17 ICS4 contains a useful description of how the resulting impact on legislation was achieved through a long-term process involving extensive relationship-building and lobbying.

Policy impact may be indirect, with an academic establishing a relationship with a lobbying organisation, who then facilitates policy impact. One ICS showed citizen science having a policy impact:

> *Zooniverse projects, directly supported by HEI 25, are making an international impact on policy and practice. (HEI 25 ICS1)*

HEI 45 ICS4 describes an academics' research used by UK, US and international organisations to support their own work, which then had a policy impact.

Engineering ICS

As noted above, there is a stronger focus on policy, organisational and commercial engagement in the engineering ICS. The ICS offer detail on the 'how' of policy engagement/influence. There are various routes to this; the main ones being:

- Commissioned research

For example, all the impacts described in HEI 33's ICS resulted, at least in part, from projects commissioned by the government agencies/bodies who would then go on to implement changes linked to the research, e.g. DEFRA, the Brazilian National Council for Scientific and Technological Development and the Royal Institute for Chartered Surveyors. Likewise, HEI 21's ICS details a policy briefing which led BEIS to commission further research.

- Partnerships

For example, HEI 34's partnership with an NHS Trust allowed researchers to implement their system in an NHS setting; HEI 21 led the Supergen Bioenergy Hub, a partnership between universities, industry and policy stakeholders and thus a vehicle for policy engagement; HEI 18's Museums and Universities Partnership Initiative grant supported collaboration to develop models that were displayed in an exhibition, enabling impacts on visitors and staff. HEI 18 also collaborated with the International Committee of the Red Cross on the development of a 'unique online resource for forensic practitioners … collaboratively developed a six-week online course which is delivered via FutureLearn and relies heavily on 3D models generated with the methods we developed'.

- Policy briefings

HEI 21 ICS1 offers an unusual level of detail on how its relationship with policy-makers has:

> *helped inform government-commissioned research and studies by working with government departments to synthesise existing knowledge and identify future prospects and gaps/innovation needs that are impeding progress. It is a collaborative process whereby these beneficiaries help to drive the research agenda. Our research provides policymakers with initial performance data sets (HEI 21 ICS1)*

It describes how research was developed by the HEI and [company] but HEI 21 collates, synthesizes and communicates the outputs, transforming them into 'policy-maker friendly' material addressing the UK government's key bioenergy questions.

- Co-authorship of government directives and policy

For example, '[name] was invited to help co-author the UK Climate Change Risk Assessment 2017' (HEI 33 ICS1) and 'policy impact has occurred via authorship of sector strategies, leadership of collaborative research efforts and increasing awareness amongst decision makers' (HEI 47 ICS1)

- Government appointments

For example, 'the NHS Consultant Ophthalmologist who collaborated with [name] in the research projects was appointed National Lead for Teleophthalmology in March 2020 and called as a member of the Expert Working Committee writing the National Eye Health Framework for the Coronavirus Pandemic' (HEI 34 ICS1) and 'in 2019, [name] also chaired the advisory board for the Committee on Climate Change's Biomass Report … [the] recommendations … are now being picked up in the forthcoming Biomass Strategy' (HEI 21 ICS1)

- Professional bodies

Where professional bodies and the creation of standards are concerned, seminars and membership of relevant bodies/advisory boards are the most common.

- Festivals, exhibitions and media

In those ICS where public engagement is an add-on, participation in science exhibitions and festivals is common, as are media appearances. For example, HEI 38 ICS1 mentions exhibits at the Royal Society Summer Science Exhibition and Colchester Science Festival; HEI 21 ICS1 notes articles in *The Conversation* and appearances on BBC Farming Today and HEI 36 ICS1 notes appearances on BBC R4.

Less common were theatre productions (HEI 19 ICS1), public engagement workshops (HEI 15 ICS1), art installations (HEI 16 ICS1), immersive experiences (HEI 38 ICS2) and school visits (HEI 2 ICS1).

Unusually, HEI 15's ICS describes how their engagement efforts were funded. In this ICS, HEFCE funding allowed for the creation of a team of specialist public engagement staff to work with primary schools and staff built public engagement into their EPSRC grants to ensure the work could be sustained in the long-term term. This ICS also describes the development of a Theory of Change model to inform their public engagement work; a model that has been adopted by other organisations, such as Museums [region], the Combined Authority and other FE colleges and schools in the UK and Nigeria. This shows that ICS can evidence ways of doing engagement as well as engagement activities themselves.

WITH WHAT IMPACT

What types of impact were claimed and how convincingly were they being evidenced?

Environment statements

The most common claims focus on numbers of people reached, rather than going into detail regarding the outcomes of these interactions:

> *'audience exposure of approximately 20M (approximately 11M through TV and radio interviews and 9M from online news feeds, events and articles)' (HEI 12)*

> *'We hold circa 10 public evening lectures per year highlighting our research, attracting audiences of up to 400 each, and we engage with the wider public during the Science Open Day (6000 visitors in 2019)' (HEI 48)*

External recognition is also commonly mentioned:

- Awards
  - NCCPE's Gold Engage Watermark (HEI 45)
  - Times Higher Education award (HEI 45)
  - 'The Head of [project] was named the widening access practitioner of the year at the 2020 NEON Awards, further demonstrating the success of our engagement programme.' (HEI 31)
- Indicators of esteem
  - '[name] was recognised by the US State Department for his innovative outreach and engagement and toured the USA studying initiatives that supported minority students. Both [name] and [name] (RA) were selected for the US International Visitor Leadership Programme, the latter for engaging women in science. In 2019, [name] was formally elected a Fellow of the City & Guilds Institute of London in recognition of 'unwavering support to education and training of young people' (HEI 17)
  - 'As indication of the quality of the PE work carried out by the [institution] during the assessment period, [name] was awarded the RAS Annie Maunder Medal for Outreach in January 2021' (HEI 29)

Impact on numbers in specific groups studying physics:

- 'Our "Changing the Face of Physics" initiative doubled the number of women studying Physics at HEI 13, and we supported over 100 schoolteachers and provided over 30 work experience opportunities to under-represented groups. This activity contributes to the UK's Industrial Strategy by inspiring, engaging and, for some, training a STEM- and digitally-literate workforce' (HEI 13)

- ‘We also run a work experience scheme, aimed at students from under-represented groups. Of the students who attended [city] Potential or Sutton Trust Summer Schools, 26 subsequently enrolled on HEI 37 Physics degrees.’ (HEI 37)

More rarely, policy impact is described:

- ‘Besides formal committee work, our staff present at Parliamentary Select Committees ([name], [name]) and influence climate policy through joint positions with the GI. Examples include Prime Minister Theresa May’s decision to announce the UK’s commitment of net zero emissions by 2050 at HEI 17. This followed a letter coordinated by [name] in May 2019. [name] also gave the first expert talk on Climate Science at the Citizens’ Climate Assembly which was requested by six committees of the House of Commons and has since been referenced widely by politicians’ (ES, HEI 17)

Very occasionally, feedback from participants is mentioned:

- ‘Based on the positive feedback received from teachers and students, we aim to expand the scheme’ (HEI 17)
- ‘To date, we have trained several hundred teachers through these courses with more watching the Education [region] YouTube channel. Feedback has been extremely positive.’ (HEI 30)

And even less often, independent evaluations are mentioned:

- ‘As well as statistical data gathered about all PE activities, specific initiatives are individually evaluated, including by independent external evaluators, using an Evaluation Framework which defines a set of Generic Learning Outcomes’ (HEI 11)

Physics ICS

Again, the ICSs offer further detail on the type of impact achieved, along with evidence to support these claims. By far the most common form of public engagement mentioned is school projects, followed by policy engagement.

In school projects, impact on teachers is mostly evidenced through testimonials and (more rarely) post-project surveys. Impact on students is again mostly evidenced through short testimonials, often from teachers, as well as statistics or commentary on intake to physics programmes at the institution. Unusually, HEI 1 ICS2 highlights impact on school-age students’ interest in studying physics at higher level by including quotes from UCAS personal statements

There are some impressive examples of policy impact, e.g. the ban on microplastics (HEI 17 ICS, HEI 44 ICS1) and impact on greenhouse gas emissions mitigation measures (HEI 17 ICS7). There are a few crossovers between ICS with policy impacts (as in the above examples both citing influence on microplastics policy). In policy engagement, impact on policy/legislation is mostly evidenced through testimonials and/or letters. Occasional reference is made to the citation of evidence in government reports.

Other forms of impact mentioned in ICS:

- Impact on outreach/PE strategy

  ‘SEPnet, a network of nine universities in [region] was directly influenced by [project] to change their Outreach and Public Engagement strategy…the success of this research-based engagement with schools has prompted SEPnet to include a ‘Research in Schools’ theme for its Outreach and Public Engagement strategy for 2017-2024’ (HEI 45 ICS1)

- Impact on culture

  'discovery of Proxima b "inspired the creation of numerous valuable cultural artefacts, including documentary films, literature, music and video games"' (HEI 45 ICS3)

- Impact on school curriculum

  HEI 1 ICS 1 highlights their involvement in revising the AS and A-level physics curriculum to include topics researched by HEI 1 researchers, evidenced by a testimonial

Engineering ICS

The most common claims focus on numbers of people reached, rather than any detail of the outcome of engagement. For example:

> *The mission received global media coverage, leading to increased public awareness of space debris as a global concern … national and international news organisations with a combined total of 3.5 billion viewers (HEI 20 ICS2)*

- Policy engagement

Although numbers are not mentioned specifically, some of the ICS are about engagement with government departments or national bodies that will ultimately be hugely impactful on publics, albeit involving limited actual public engagement with scientific research/knowledge. Societal impacts are tied to specific collaborations, through job creation and climate impacts: For example:

> *there have also been important social impacts from the University/[company] collaboration, including creation of a significant number of well-paid, high-tech jobs in [city], which is one of the twenty most deprived socio-economic regions in the UK (HEI 13 ICS1)*
>
> *increased efficiency of screening and a reduction in unnecessary travel by doctors and patients will help to reduce carbon emissions associated with healthcare, particularly in remote areas (HEI 34 ICS1)*
>
> *the Environment Agency has committed to protecting thousands of households from flooding using PFR measures with the potential for at least 150,000 households to benefit from PFR, rising to over 200,000 in 2023 (HEI 33 ICS1)*
>
> *By 31st December 2020, the technology had been adopted in 12 emergency eye treatment centres across 4 Health Boards in [region]… the NHS received a request during the pandemic to share the slit lamp technology with [company] a company from New Zealand…the technology also influenced the design of [product], the leading electronic patient record platform for eye care in [region] (HEI 34 ICS1)*
>
> *HEI 36 research has helped shape the NHS strategy for preparing the healthcare workforce to deliver digital healthcare technologies in the future (HEI 36 ICS2)*

Where policy impact is the focus, as it is across most of the sample, the impact claimed is on specific policies and government spending:

> *research and industrial collaboration, led by Prof [name] and the team…has guided UK national and EU level marine policy. Without these efforts it is unlikely that the sector would be where it is today (HEI 47 ICS1)*

researchers maintain regular contact with UK government to understand their policy needs and provide scientific information so that policies are based on the latest evidence (HEI 21 ICS1)

Due to the nature of the impact being claimed in these ICS, which is most often some form of policy impact or impact on professional standards, it is quite straightforward for the author to evidence their contribution: if the work of an academic is cited in a policy document, for example, or if they are a member of an advisory panel. What is more difficult is to evidence the contribution of an academic attempting to push discussion of, for example, the ethics of a technological development.

- Schools' engagement

The ICS that contain some mention of schools engagement are largely focused on impact on career choices and the teaching of science:

"the year 10's have been energised and enthused for their future choices and this has been ignited with your help" (HEI 2 ICS1)

using more family workshops and more practical teaching of science to stimulate and sustain interest in STEM subjects and careers (HEI 15 ICS1)

One ICS mentioned impact on other HE institutions public engagement approaches:

HEI 15's specific public engagement approach has been adopted by [city] and [city] Further Education Colleges to increase women's enrolment on their construction apprenticeship programmes (HEI 15 ICS1)

- Public engagement

Given that there were only two ICS predominately about public engagement, it was interesting that one of those (HEI 16), focused attention on the economic impacts of the art installation rather than the impact of the installation on the public.

WHAT DOES GOOD PRACTICE IN PUBLIC ENGAGEMENT LOOK LIKE?
• Long-term support for strategic planning of engagement and evaluation • Draws on insights from previous practice • Sustained funding • Adequate resources • Stable and secure staff • Takes place throughout the research process • Aims, purposes and publics for engagement are clearly identified

Figure 2: Attributes of good practice in public engagement

Challenges in evidencing the contribution of public engagement to ICS

It is well understood that evidencing the impact of public engagement is challenging. This was recognised in the Overview Report from Main Panel B,[1] which noted that while the large number of public engagement cases demonstrated the importance of the subject in capturing people's imagination – especially younger people – some of the cases would have benefited from evaluation design earlier in the process, so that the evidence was more tightly linked to the impact of the engagement on the targeted audience.

Looking at the ICS that are at least 60% likely to have achieved 4* and that mention public engagement (19), we identified a small number as showing good evidence of impact. These included Tactile Universe (Portsmouth), Physics Research in School Environments (QMUL), Binding Blocks (York) and Jodrell Bank (Manchester) (physics) and Using engineering to influence STEM aspirations (Northumbria) (engineering).

Looking briefly across the ICS likely to have achieved 4*, the majority contain a believable narrative of *multidimensional* impact. This is rarely substantiated by external or internal evaluation but rather tends to rely on testimonials. Without input from the REF panels, it is difficult to make any definitive statements on this question but it could suggest panels are responding to strong narratives.

WHAT DOES A 'ROBUSTLY-EVIDENCED' IMPACT CASE STUDY LOOK LIKE?

- The contribution of public engagement activities is categorised (e.g. 'widening access to higher education'
- The publics for the engagement are identified
- The relationship between the timing of engagement activities and the underpinning research is clear
- Aims and objectives of any evaluation are stated
- Evaluation methods are described
- Evaluation results are included
- Qualitative data are attributed
- The claimed impact of the engagement is identified or referenced

Figure 3: Attributes of robustly-evidenced impact case studies

The ICS include several examples of robust evidence and clear identification of impact but there are also many where this is not the case; particularly in instances when an individual ICS is attempting to claim impact across multiple areas, meaning space is limited.

Although the impact claims are believable, they tend to be un-referenced:

> *'the proportion of female participants is higher than the ratio in comparable graduate schools in Europe or the US' (HEI 10 ICS2)*
>
> *'visitor feedback has been overwhelmingly positive' (HEI 32 ICS2)*

[1] REF2021 *Overview Report by Main Panel B and Sub-panels 7–12* Available from: 2021.ref.ac.uk/media/1911/mp-b-overview-report-final-updated-september-2022.pdf

This lack of references means readers cannot follow up the claims. However, this issue might be because the template's 'indicative maximum' of 10 references means institutions must prioritise their evidence.

ICS can lack detail on the nature of the impact and who was involved, e.g. HEI 39's ICS (engineering) describes 1000 participants attending an online workshop, 50 stakeholders attending an education workshop and 40 discussions and seminars with local council teams and community leaders. However, the ICS does not detail who these people were or in what ways they were impacted by their engagement in these activities.

However there are some excellent and detailed examples, for example HEI 15's ICS (engineering) which describes how:

> *researchers tracked the specific effect on a sample size of 372 students by comparing 2017 data with a 2015 baseline. Data show children became more willing to pursue engineering careers (increasing from 25.6% to 33.1%) with the biggest effect on young girls (70.6% expressed an aversion to engineering careers before the interventions, 47.1% afterwards) (HEI 15 ICS1)*

HEI 3 ICS3 (physics) showed there is scope for more reflexive practice:

> *'In 2016/2017, [centre] commissioned a major external survey conducted by marketing consultants Morris Hargreaves McIntyre (MHM). The survey found that, excluding school visits, nearly half of all visits to [centre] (47%) are family groups, and nearly one-third of all visitors are children (just under one in five are aged between 5 and 11 years old). This significant proportion of family-group and under-18 visitors shows that [centre] is succeeding in engaging with young audiences, and works towards our goal of inspiring the next generation of scientists and engineers. There is an even gender split, and 37% visit from outside the region. However, [centre] has historically struggled to engage certain demographic groups; the 16-24 age group were under-represented in the visitor profile, making the fewest visits at just 3%, whilst 97% of visitors were from white ethnic groups.' (HEI 3 ICS3)*

While we should be wary of suggesting that external evaluation is necessarily 'better' than self-evaluation or formative learning activities, independent evaluations are occasionally mentioned (in ~5% of the physics ICS and ~10% of the engineering ICS) as evidence of impact. The value of external evaluation was a point of discussion in the focus groups (below). Nevertheless, the evidence given is almost always limited, making it difficult for a reader to assess the claims. For example:

> *'Evaluation comprised comparison of pre- and post-intervention data and showed an increase in knowledge about the Moon among the pupils and an increase in the number of students discussing lunar research with their families. In particular, feedback from teachers suggested marked changes in pupils' aspirations, engagement, and awareness of STEM careers and of what is possible by studying science and mathematics.' (HEI 12 ICS1)*

This is typical of the lack of detail, with no evidence of the kind of evaluation, who conducted it, what methods were used and where the full findings could be seen. However, there are a few exceptions to this trend, such as HEI 11 ICS1, which goes into detail on the evaluation methodology.

Many ICS include quotes from one-off post-event surveys. Such surveys are useful to capture initial impact but longer-term approaches are needed to understand substantive impact. There are notable exceptions, e.g. HEI 45 ICS1 describes the use of before and after surveys, as well as follow-up surveys three years after the project. However, reporting of findings could be more specific. For example, this ICS contains several quotes from interviews with project participants, but all the quotes are attributed to 'students from deprived areas', making it difficult to know how representative they are of the whole participant group. Moreover, quotes from survey responses and testimonials are almost always positive, suggesting institutions have little incentive to identify areas for improvement.

Policy impact can be more straightforward to claim, e.g. HEI 33 (engineering) cites relevant documents from the Environment Agency and Defra, as does HEI 47. However, we do have to rely on the claims being made as there is no actual evidence of impact. Using HEI 47's ICS (engineering) as an example, the claimed impact is that:

> *Prof [name]'s roadmap and innovation report were also carried forward into the September 2020 call for evidence on the potential of marine energy projects in Great Britain and in turn into the Energy white paper (HEI 47 ICS1)*

The main source to corroborate this policy impact is the 2020 energy white paper. However, this document contains no reference to [name]'s work or HEI 47. This is not to say that the claims made are false, but it does raise questions about how reviewers can assess the validity of the claimed impacts. It also relies on reviewers having time to investigate the claims being made.

When the mode of engagement is an exhibition or media appearance, it is often the output that is referenced rather than any named outcomes, e.g. HEI 17's ICS (engineering) ends with a paragraph on outreach activities but does not specify how these interventions impacted audiences; HEI 36 ICS2 (engineering) is similar in that it cites only that the appearances happened.

An outcome of public engagement being a secondary concern is that the impacts are not that convincing simply because of the lack of space for authors to support their claims. For example, HEI 2's ICS (engineering) features one testimonial from a teacher as evidence of the impact. HEI 19's ICS (engineering) contains a generic quote from the director of the theatre company with whom they collaborated on a production:

> *it generates impacts in terms of public engagement, changing perceptions and building understanding and enthusiasm around science and engineering (HEI 19 ICS1)*

This is a statement of intent rather than tangible evidence of impact, thus doesn't allow a reader to make a judgement on the actual impact of the project:

Focus groups

In phase 3, we conducted two online focus groups and one interview to allow us to derive richer intelligence about the REF process, and to test our interim findings.

Focus group 1 had six participants, focus group 2 had eight participants and the interview had one participant. The participants were drawn from physics departments in thirteen universities in nations and regions across the UK (except for Northern Ireland). The participants were a mix of physics researchers with an interest in public engagement, academics, academics with public engagement-focussed roles and public engagement professionals. *NB: the focus groups were set up before the project was extended to include engineering, so all participants were linked to physics departments*.

The focus groups and interview were recorded. AG created de-identified transcripts from the recordings which she shared with the participants for review and correction before analysis.

AG also held informal conversations with three REF2021 panel assessors to gain contextual insight into the assessment process and the challenges faced in assessing the contribution of public engagement; she took written notes of these conversations.

Focus group discussion points

Drawing on the outcomes of the landscape survey and this interim report, the focus groups and interview addressed four topics:

- Reflections on the experience of submitting case studies / writing environment statements
  - What have been their experiences?
  - What enabled or hindered them in this work?
- Frameworks for evidencing the contribution of public engagement
  - What approaches to evidencing the impacts of engagement do departments use and why?
  - What support do departments draw on?
  - Is more support needed to strengthen this aspect of their work? What kind?
  - Could departments draw on existing frameworks (such as the STFC's evaluation framework) to enhance the robustness of their evidence in REF2029?
- Evidencing the quality of engagement
- How do people interpret the term 'rigour'?
- How do we enable and underpin 'rigour'?
- Priorities for engagement
- How are departments formulating their priorities for engagement?
- To what extent do departments take funders' strategic priorities into account when formulating their own strategies?
- Looking to the future, how would they like future-REFs to look?

Reflections on the experience of submitting case studies / writing environment statements

Many of the participants had been directly involved in writing case studies and all had engaged with the process in some way. For everyone, REF was a stressful experience.

However, participants noted that the presence of public engagement in case studies gave public engagement visibility and importance and supported efforts to embed public engagement in departments:

> *there is a huge wealth of data … which is a mine of information about the fantastic work that's done in public engagement. Using that to our advantage to showcase why doing public engagement is important is one of the massive benefits of REF (Participant Z)*

Additionally, two participants described how they had made strategic use of the REF outcomes to leverage increases in staffing and spending on public engagement in their department.

Two issues in particular were highlighted: the first relates to internal review process for potential ICS. All the universities represented had central teams supporting REF submission. However, there was a feeling that REF support teams lacked understanding of public engagement and how to evidence the impacts coming from public engagement:

> *It felt like I and to an extent my colleague who leads the project had a better understanding of public engagement impact in REF than our impact officers which was quite frustrating (Participant L)*

> *particularly staff in the review process […] had really unrealistic expectations about what is even achievable in public engagement impact because they think that when they give a talk to 10,000 people they fundamentally change all of those people's lives when they haven't (Participant F)*

Participants described drafts going back and forth several times, often receiving conflicting feedback in each cycle:

> *they would write the draft and they would send it to the university central team for feedback and they would make changes and send it off again and they would get completely conflicting advice from more or less the same group of people about what should and shouldn't be in and how it should and shouldn't be written or evidenced (Participant K)*

To support people writing case studies, participants suggested what was needed was specific REF guidance for public engagement with physics, which would enable them to 'push back' against conflicting feedback and increase their confidence in the case studies they are writing.

This links with another highlighted issue: the lack of feedback from panel reviewers on submitted ICS. This related not just to the lack of concrete information about the ICS score but – and more strongly – to the lack of feedback on the strengths and weaknesses of the ICS:

> *I don't know, and I still don't know, because of the lack of feedback […] it's quite hard to judge. Was that good? Was that bad? What happened in that process? Was our original draft better than the one that came out of the process? It's a bit of a black box. (Participant X)*

Given the amount of effort and time spent on creating ICS, participants felt they deserved some feedback.

Frameworks for evidencing the contribution of public engagement

Participants agreed that having a robust and convincing system to collect and demonstrate evidence of impact is extremely important. As noted in the analysis of the ICS, almost all the ICS that cite evaluations (whether in-house or external) could have used the evidence at their disposal to better effect (depending on the methodologies used) to demonstrate how the processes of public engagement lead to outcomes and impacts. For example, evidence from evaluations often refers to participants in general. Given funders' interests in engaging with specific demographic groups, evidence could usefully focus on the impacts on those specific communities.

In the discussions, there was a shared sense among the participants that as physicists, or people who had come into public engagement from physics, they lacked the skills to gather the evidence and to analyse the resulting data most effectively:

> *maybe as physicists we're not quite so well geared up at collecting the kinds of evidence we want for this kind of impact case study (Participant Q)*
>
> *my pain point at the moment is feeling I need to be super-careful about how I'm collecting information, but also not necessarily feeling I'm qualified to do that (Participant H)*

Despite this acknowledged weakness, very few had drawn on existing approaches or frameworks, with only two participants mentioning a framework by name:

> *In terms of documents or frameworks we found useful, I think certainly the STFC public engagement evaluation strategy is helpful (Participant Q)*
>
> *we do have our evaluation toolkit from the Ogden Trust, which is really useful (Participant S)*

Most participants would welcome more support with evidence-gathering from their department or institution.

> *We do have support. I'd like there to be more. I think a lot about this. […] be more organised so there'd be somebody else acquiring the evidence so that we could detach the doing and the organising and the delivery which is tough enough. (Participant M)*

There are two elements to this discussion of support. The first is the institutional recognition of the importance of building an effective evaluation framework:

> *I almost feel like it's down to me pushing it at the moment, like there's no one … no one seems to be taking it particularly seriously that we need to have a framework to measure these things. And so I'm shouting loudly that we need this and I'm trying to put forward examples and I'm not sure there's a receptive audience. (Participant Q)*

Linked to this is the importance of embedding the evaluation of impact in the research underpinning the ICS:

> *we're trying to make a concerted effort to embed impact into all of our different programmes but there's sort of a resistance […] I think other people think they don't always need to know, don't feel that they need to do it until after it's too late and think "maybe we should have done this earlier". I think there's always that problem of making sure we embed it early enough (Participant W)*

The second point is, that given the importance placed on evaluation, that there should be institutional support for embedding researchers with the necessary public engagement expertise:

> *… there are experts that do it and they've got PhDs in it and it's their research area. Why should me, as a public engagement professional in a physics department do it? I'm never going to be at their level […] I would much prefer to bring in the experts and have the money to do that, then try to kind of half *** it and not do such a good job. (Participant L)*

Institutional support was seen as particularly important for the kind of longitudinal data-gathering needed to be able to attribute any change or impacts to engagement, rather than to other factors, for example in the many physics engagement ICS aimed at increasing take-up of physics by young people, which is necessarily a long-term endeavour.

Several participants had used the services of professional evaluators, which they felt had been really valuable:

> *That for us was really key, to have someone else coming in to help us with that gathering of the evidence and also to be able to put that in as an expert report (Participant L)*

There was general agreement that it would be valuable to have the resources to involve external evaluators but funds did not always allow. Others drew on the support of colleagues with specialist skills:

> *We leaned on the educational researchers to help us with the thematic analysis to make sure that we were doing it correctly and that we were getting the right sorts of things out to paint that narrative and contextualise the quantitative stuff. (Participant F)*

Given that all institutions are under financial pressure, participants especially valued the funding for specialist support offered by funders such as the STFC and Ogden Trust, and occasionally by government departments.

Evidencing the quality of engagement

Participants agreed that experience allows them to judge what 'good quality' engagement looks like:

> *… when you've done it for a while, you watch something and you think 'OK, that's worked really well. That's worked really badly. We'll change this. We'll change that' [*but*] it's really difficult to capture that. (Participant D)*

But as Participant D suggested, people found it less easy to identify impartial standards that evidence the quality of that engagement:

> *It's raising some questions for me at the moment about quality and about rigour and about how we should structure things in order to make the engagement worthwhile (Participant K)*

In terms of evidencing quality, the guidelines provided by REF weren't regarded as particularly helpful:

> *The guidelines from REF … generally it's not very good in terms of helping. They have stuff on how to present evidence. But it was 'if you're doing a percentage show a percentage sign'. It was more about formatting than it was about what quality evidence looks like. (Participant F)*

Panel members also agreed that it was difficult to assess evidence of impact from engagement, compounded by the format of the ICS, which did not offer a route to evidence the quality of the engagement.

This meant participants found it hard to be sure if the public engagement work they were doing, and the evidence of impact that they were presenting, was of the same quality across the sector. Panel members were sympathetic to this quandary, agreeing that the nature of the impact of public engagement makes it difficult to evidence; however, where there was evidence that the evaluation of impact had been well-planned, they were much more likely to believe the claims of impact. This difficulty could well be linked to the expectation that engagement is something that happens after the physics or engineering research has been completed, rather than be integrated throughout the research, as noted in the analysis of the ICS above.

There were also lots of questions around the conflict between the reach of an activity and the significance of its impact. As noted above, it is relatively easy to show that three thousand people have visited an exhibition but less easy to evidence the impact that engagement has had on those visitors. This was a particularly thorny issue for projects that engaged with quite small numbers of participants but perhaps over a very long duration, with specific communities or in a particular region:

> *For our [ICS], one of our concerns was that it has quite small numbers [of participants], so in terms of reach, it didn't seem that great. But the significance was really there. A lot of the conversations we were having in the build up to submission were about how would the panel view something that placed a lot more emphasis on the reach over the significance. (Participant L)*

That difficulty led to discussions about the quality of the reviews of public engagement ICS and who was undertaking those reviews; what level of public engagement experience and expertise was 'in the room':

> *it's somebody who's not a public engagement professional, assessing a public engagement case study for its rigour. I think we have a quite a different view. When we read something, we look at it and go 'oh, but why didn't they do that' or 'that doesn't make any sense because they already were all going to university'. And therefore actually acknowledging professionals, also bringing more people into the assessment process would help with rigour and quality (Participant D)*

In conversation, panel members believed that, generally speaking, assessors felt comfortable with and competent to review engagement-focussed ICS, although some would have welcomed more of a 'steer' on how to evaluate evidence of impact from engagement. In fact, there had been considerable discussions across panels about what constituted evidence; evaluation was too often limited to numbers attending, unsupported by narrative evidence of change.

A few participants felt there had been inconsistencies across panels on assessing the quality of evidence of impact from engagement and that physics was assessed more harshly than other subjects. Some thought this was because expectations of physics were too high, others that it was because engagement with physics was perceived to be a difficult area in which to succeed. One panel member agreed with this view to an extent; the panel had questioned whether they were being ungenerous, or more rigorous, in physics. Another noted that expertise in the impact of engagement, both on publics and in policy, resides in a very small number of people. However, they pointed out that scores had been calibrated across panels and in most cases, ICS at the 4* end were scored very similarly.

Priorities for engagement

A few participants were in the midst of writing or reviewing departmental strategies for engagement. They drew on a range of support: input from academics and researchers, support from funders and university strategy and public engagement strategy documents. These departmental strategies were aimed at creating a vision for public engagement within the department and being able to use the strategy as a lever for change in the institution:

> *[*the strategy*] will be signed off by the heads of the research groups and the Head of the School of Physics here, who fortunately is very supportive … Whether that will translate into any meaningful change, I don't know. But it is at least starting to make people think about it, and my ultimate hope is that it will give us something to wave at the university (Participant K)*

Participants were less clear about funders' strategic priorities; many felt that they didn't know enough about what these were to be able to build them into their proposals. However, there was a strong feeling that the STFC:

> *… should be rightfully proud of the amount of effort they put into public engagement and the public engagement grants that are available. It's much better than all the other research councils (Participant X)*

Looking to the future, participants wanted to see more crossover and collaboration between the three elements of REF in future-REFs; to become a more 'joined-up' process that can more effectively capture what an institution is good at (and what it is not) and that engagement has a role to play in evidencing this.

Another change participants would like to see is to acknowledge the contribution of everyone involved in a project. Public engagement professionals are often integral and valued members of projects but as professional services staff, rather than researchers, they are often not named in ICS:

> *I feel my name's written on so many grants, my time costed to do engagement activities but I'll never see kudos for any of that. It's more 'oh, thanks [S] for helping out'. […] You're the silent cheerleader in the background (Participant S)*

There was also a strong feeling – as noted above – that implementing feedback from panels would mean that REF:

> *… would go from being something that was just tiring to something that was actually useful, where you'd have an expert look at your thing […] it would be like an advisory panel, that would be brilliant. (Participant Q)*

Panel members agreed that the process needed to be simpler, less bureaucratic and therefore less stressful but felt change should be evolutionary, not revolutionary, by clarifying definitions and criteria, training panel members in using criteria and making expectations clear. Also, they felt that to help people writing and submitting ICS, the sooner this clarification and decision comes, the better, to avoid uncertainty.

Implications for REF2029

There are some significant changes proposed for REF 2029.

- The Impact profile will be renamed 'Engagement and Impact', recognising the important contribution of the 'process' of engagement to the 'outcomes' realised. This aligns with the point made earlier in this report, that case studies with a strong and well-developed story line describing the pathway to impact tended to score well
- There is in principle support for a third criterion of 'rigour' to be introduced with further development work on this being undertaken by the panels when they are appointed later in 2024.
- The Environment profile is undergoing a radical overhaul. It will be renamed 'People, Culture and Environment' and it is proposed that the weighting is increased from 15% to 25% (although there has been strong push back from the sector about this). The new PCE profile is likely to set higher expectations about how institutions and units support inclusive, reflective and engaged practice.

These developments will put pressure on units to strengthen their approach to planning, evaluation and evidencing the impact of public engagement. Broad questions remain about the role of evaluation. Earlier REFs could be said to have encouraged institutions to articulate the perceived benefits of what they do, rather than reflect on what might be improved, which is an important element of rigour. Can departments be encouraged to use evaluation to demonstrate learning as well as for 'evidencing' success/positive outcomes?

We outline below some ways in which the sector might build on the findings from this review and the likely evolution of REF in our preparation for REF2029.

Consider:

Departments

- Long-term strategic approaches to planning, evaluating and evidencing the impact of public engagement

Sector

- Contributions to the development of the Engagement and Impact profile
- Advocate for increased funding for specialist support for effective planning and implementation of evidence-gathering in readiness for the REF
- Advocate for greater inclusion of experts in public engagement with research on REF panels

NCCPE

- Developing resources and training aimed at physics and engineering departments to provide guidance for evidencing impacts from public engagement and creating an effective supportive culture and strategy,
- Using insights from this review to inform the Centre's contribution to the development of 'rigour' as a criterion in REF 2029

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