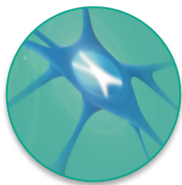# Family Science Engagement and Learning through Storytelling and Children's Media

WINSTON
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2016 Fellowship Report
Country visited: U.S.A.

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Contents

Acknowledgements

2016 was probably the oddest year politically to be travelling to the US, being post-Brexit, and wandering straight into the world of presidential debates. Not to mention having a heated discussion in an airport shuttle bus. (It may have been one of the best pieces of outreach in my career, engaging with a *very* diverse audience!). However it was a fascinating year for me, because of this Fellowship.

We often say that the world is such a small place, but the wonderful thing about working in informal science education is just how small a place it is, and how extraordinarily generous and genuinely kind and caring the people in it are. A series of little coincidences where someone knew someone else, made for my very successful and rewarding Fellowship.

Although I have travelled quite extensively already, this experience was truly memorable. From being serenaded on a coach ride and wandering around inside a submarine to walking across a bridge that pedestrians were meant to steer clear of, and from living in a 'treehouse' and eating cannolis on a boat, to making a sugar skull cookie for a homeless man....

I would like to thank everyone who met with me on the Fellowship (too many to mention), but in particular Amy Kamarainen, Kate Pickle, Abby Cheng, Ellen Doherty, Drew Davison, Eric Brown, Bill Shribman, Gregg Behr, Jen Stancil, Susan Timko and Wendy Brenneman who all helped immensely throughout this Fellowship, offering me so many amazing opportunities and ideas to think about.

A very special mention to Valentine Kass who let me know about the SMASH Media Summit, and the wonderful Jamie Bell, whom I met several years ago at a conference, and is probably the most networked person I know in informal science learning. His recommendations for people and places to visit (not just to eat at!) made this a very enjoyable Fellowship. And to Kevin and Jan Morrison (Kevin being a previous Churchill Fellow) for their kindness and catch ups, and Victoria Prizzia for the loveliest last day of my Fellowship trip.

Of course none of this would have been possible without the generous support from the Winston Churchill Memorial Trust and the friendly e-mails from all the staff, in particular Sara Venerus, Tristan Lawrence and Ben Anstis who have had to deal with all my queries and updates.

And finally a huge amount of love to all my family and friends who had to put up with my e-mails and text messages arriving at all random hours...without feeling too jealous, I hope!

There is plenty more to come following this report as I could not fit everything or everyone in, so please do watch this space.

Abbreviations and Glossary

AR: Augmented reality
STEAM: Science, Technology, Engineering, Arts, Mathematics
STEM: Science, Technology, Engineering, Mathematics
VR: Virtual reality

This report describes what I discovered during my Fellowship and my reflections. I use 'science' interchangeably with STEM (only because my background is natural sciences and this is usually in the forefront of my mind).

I also use various terms to mean the following:

'Public engagement' refers to all subjects delivered by academics to lay audiences.

'Science communication' encompasses everything in the communication of science (and often STEM), from science writing to museum outreach, and therefore includes the public engagement of science and informal science education. This term is most often used to describe science engagement with adults.

'Informal science education' refers to all science learning outside of school, and outside of the curriculum even if participants are physically on-site at a school, and therefore includes public engagement and science communication. This term is most often used to describe science engagement with young people.
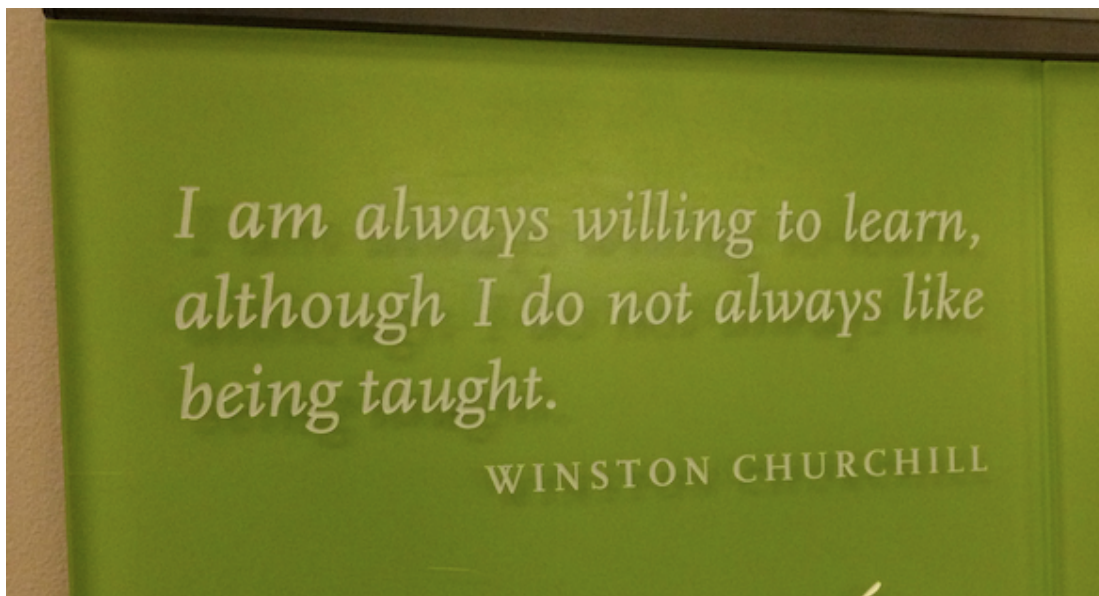
'Formal science education' refers to all science learning within school (or an educational institution) and is curriculum-based.

My Background

As a former neuroscientist, I became interested in science communication as a result of attending public events and schools to speak about my research. I have worked in science education at The Physiological Society, Nesta (known back then as the National Endowment for Science, Technology and the Arts), Planet Science, Science in School, Ignite! and Queen Mary University of London. My Masters research, studying how young people learn accurate science from the entertainment media, led to taking up an International Fellowship at the National Science Foundation, Washington, D.C. in 2011.

Over the years my interests have moved from high school education and training postdoctoral researchers and doctoral students to working with younger students in more informal learning environments, through hands-on activities, storytelling and the arts. I have purposely made an effort to work with families in their local communities rather than at events labelled as 'science' or 'STEM' (science, technology, engineering and mathematics), in order to reach diverse audiences.

I am currently a science education consultant and travelled to the USA (Boston, Tampa, Pittsburgh and Philadelphia) to investigate family science engagement and learning through storytelling and children's media, as part of my Winston Churchill Memorial Trust Travel Fellowship[1] (September-November 2016).

Seen on the wall at Simmons College, Boston.

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[1] http://www.wcmt.org.uk

Executive Summary

I have worked in science communication for just over fourteen years now. In the last few years I have run innovative informal science education projects taking science out to the communities. Working after school with families from diverse backgrounds has been the most rewarding work I have done to date and I wanted to learn more about this as part of my Winston Churchill Memorial Trust Travel Fellowship (September-November 2016; visiting Boston, Tampa, Pittsburgh and Philadelphia, USA).

As well as focussing on two 'tools' for engagement: storytelling and children's media in family science engagement, I was also interested in community engagement, creative spaces for engagement and working with different age groups and diverse populations as part of my Fellowship.

My main findings and associated recommendations going forward are:

- Storytelling and Children's Media:

    o Stories work at all levels and need to be engaging but not necessarily content-driven. Both storytelling and children's media are great 'tools' for inspiring further investigation, alongside hands-on activities, rather than didactic teaching.

    o Storytelling and children's media can take complex science, values, cultural understanding and practical life skills to much wider audiences than other media, because of the associated family engagement.

- Family Science Engagement and Learning:

    o Family members are important gatekeepers in a child's life. Children want to make their parents proud. By supporting families, young people of all backgrounds can aspire to any future they want for themselves.

    o Social learning (families learning together) not only aids memory but helps nurture a general love for learning.

- Early Years, Teens and the Elderly:

    o We need to realise the importance of play in learning (for all age groups).

    o Allowing young people to take a lead wherever possible helps increase their confidence and transferable skills.

    o Some of the most successful engagement initiatives do not have 'science' or 'STEM' in their title, and more activities need to be taken to where the people are.

    o We need to be more inclusive. Befriending communities and winning their trust can lead to rewarding partnerships.

- Makerspaces, Collaboration and Technology:

  o Makerspaces allow for equitable and expansive learning. Informal science activities in such spaces (and in general) need to be more open-ended, promoting creativity and inventiveness with facilitators who understand non-didactic delivery.

  o Increased networking and collaboration can lead to leveraging more resources and expertise resulting in truly innovative initiatives. Training facilitators within the community can help sustain these projects.

  o Engagement activities need not be 'high tech'. 'Low and no tech' are just as valuable.

- Diversity, Equity and Accessibility:

  o The role model effect is extremely powerful, with many individuals benefitting from seeing people like themselves in careers or roles they aspire to. Girls are more empowered when working on STEM projects in single-sex environments.

A major 'take home' message for me was that there is no magic bullet in informal science education. There is no need to scale up initiatives, replicate or produce highly polished resource materials and equipment. High quality, sustained engagement on a small scale is just as important, and likely to be more valued by communities. Even if it means a simple story about frogs and butter. And ultimately it does not matter about the project, tools or materials used; the most successful engagement comes from the inspirational and passionate individuals facilitating the activities.

I look forward to building upon what I have learnt on my Fellowship and to work with others to expand current and new initiatives to wider audiences.

1. Introduction

Having freelanced in informal science education for over a decade, my thoughts were moving towards, 'now that I have done this, how do I replicate it or take this work further?' For me 'informal science education' encompasses everything: public engagement with science, science communication, non-curricular in-school science learning and learning science in out-of-school environments.

Two areas that played a huge part in my childhood were storytelling and children's media. I watched many cartoons growing up and now use animation clips embedded in my workshops to stimulate discussion. Even though I enjoyed reading as a child, I was not very good at listening to stories read out to us by teachers at school. My mind would wander, and then I would be mystified when the teacher asked us to write about or illustrate our favourite part of the story. But when my grandfather told me a story...now that was different. He would narrate in such a mesmerising way with silly facial expressions, interspersed jokes, rhymes and ridiculous voices. This engaging storytelling coupled with humour and emotions is why I use storytelling in outreach.

I have a family that is keen on science, and even those relations without a scientific background gave me presents such as a crystal radio kit or microscope. I had a childhood filled with tinkering and creating. I loved the natural world, catching insects and making my own perfume with flowers. It was inevitable that I would study science. But not all children are so fortunate. Growing up, I never felt the need to see someone like me doing science, for me to want to do it. However I understand the yearning of some young people to see role models with a similar background to them. When I ran a science session in a school assembly and suddenly found all the young, minority ethnic girls signing up for clubs, I realised just how much some girls needed to see someone like me. Someone like them.

With various research studies[2] suggesting the need for such 'science capital' and promotion of diverse, attainable role models, it seems there is a place for greater engagement at the primary school level, bringing in support for primary teachers and parents who may wish to support their STEM-interested children, but feel they cannot. Working in and out of schools, I see that families need to play a bigger part in children's learning: parents, caregivers and other people that children see on a more regular basis than school staff.

Initially I started with in-school workshops, moving onto science clubs. When it appeared that the families knew their children enjoyed science but did not know how to support the interest themselves, I started up afterschool family workshops. This involved storytelling, and in particular cultural, moral stories. Often scientists like to use words that make them sound smarter than they are. In family learning it is about being understood, and helping them feel comfortable and valued. Stories appeal to everyone, and through these workshops I could show families that science is everywhere, even in the stories they know, and how to do simple, accessible experiments at home. The stories also show children how to be better citizens, through values such as empathy, patience and perseverance that parents appreciate[3] too. Parents have given such positive feedback, even sharing their experiences and what they plan on doing next with their children.

With this Fellowship I hoped to 'plug a gap' in my expertise of family science engagement having recognised that family plays a vital role in a child's aspirations, their learning and what pathway they

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[2] http://www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/Index.aspx
[3] http://www.bbc.co.uk/guides/zyvhpv4

choose. There is little family science engagement outside of science museums and festivals in the UK, and families that do attend are likely to be highly scientifically-literate. The US is much more active at working with their local communities and in researching family engagement.

Focussing on the two 'tools' for engagement, storytelling and children's media (visual entertainment in particular), I was also interested in the following areas as part of my Fellowship:

- Creative spaces for family and community engagement;
- Novel approaches to science engagement: the use of entertainment (games, apps, children's media, broadcast); can digital/technology really reach the masses?;
- Diversity: working with different groups, especially families from different backgrounds (cultural, socio-economic) in outreach and engagement;
- Engaging different age groups: how to engage families that have children spanning the teens to early years, as is the case with cultural groups in disadvantaged areas, and working with the elderly or grandparents (as accompanying caregivers);
- Neuroscience and links in education: related to memory and emotions i.e. emotions elicited in engagement can help or hinder learning.

My work is not about turning young people into scientists, and not even pushing them to become more scientifically-literate. If those are the results, that would be great. My aim is to give all young people the chance to 'do' science, to learn with their families, to learn to love learning, exploring and engaging and to not be fearful of science. Which is why working with local communities is where my priorities lie right now.

This is not an academic report, and there are many research papers I could mention that I have not. Much of what I write here may not be new to most readers, but provides further evidence for the importance of creative science engagement with families and communities.

2. Findings

The findings are given here under the various themes I was interested in. Namely:

- Storytelling
- Children's Media
- Family Science Engagement and Learning
- Early Years, Teens and the Elderly
- Makerspaces, Collaboration and Technology
- Diversity, Equity and Accessibility

2.1. Storytelling

Stories are important in everything, whether in proposals, scripts or education. It is about engaging audiences and helping us make meaning of the world around us. As storytelling features strongly in my outreach, it was one of the main themes of my Fellowship, even if the storytelling took many forms.

L-R: Mosaic frog at Tampa Museum of Art shop, Harvard Graduate School of Education, testing out Hood brand heavy cream to make butter, children at Pizzo Elementary School making butter.

The Russian folk tale about two frogs[4] played a prominent part in my Fellowship having discussed the story during my interview (as an anecdote Churchill himself used), in many of my meetings, as well as presenting it to several classes of Pizzo Elementary School as part of Outreach Live! at the

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[4] http://www.scienceinschool.org/content/experimenting-storytelling

Association for Science Centers (ASTC) conference[5], and at Project Zero, Harvard Graduate School of Education[6]. The activity involved participants shaking cream until it turned to butter. The nerve-wracking part of Outreach Live! is having other informal educators from all over the world observe and give feedback. However they were extremely positive and they enjoyed having a go too. By presenting these workshops abroad offered a different perspective, and other ideas for example, the children in one of the groups all stood up and started moving whilst shaking the cream, which added an exercise element to the session. The children were brilliant, even if they were a little more preoccupied by my accent at times (the fact I say 'aluminium' differently to them). A group of boys were so impressed with the activity that they began planning their butter-making empire.

Being based in Boston at the start of my Fellowship, I *had* to visit the Boston Public Library. The children's section was vast, and as I have been collecting stories for my workshops it was as if I had struck gold when I discovered the folktales section. Everything from Aztec legends to Creole poems, and even stories I had been trying to find the source for. These stories are fascinating because although magical and unbelievable they were people's ways to understand the world.

Penny Noyce from Tumblehome Learning[7] described her book series to me, 'The Galactic Academy of Science'[8], where children time travel to visit historical scientists in order to solve problems. She too feels that not all stories need to be completely accurate to engage readers with science. For example, in 'Elizabeth's Constellation Quilt'[9], a little mouse uses embroidered constellations to learn how to navigate by them in order to save her sailor father who is lost at sea. The constellations are not accurate, but the concept encouraging readers to 'look up' and even make up their own constellations, is what the story is for. Penny also runs hands-on workshops linked to her books. To find that many others see the value of combining narratives with hands-on activities as a successful model for engagement was a significant finding of this Fellowship.

As someone who has moved away from using imagery in storytelling (rarely using slides or illustrations), I enjoyed learning more about storytelling sessions within museums and libraries. Timshel Purdum at the Academy of Natural Sciences of Drexel University[10] told me about their preschoolers' story time using a puppet called Marty the Moose to add comedic effect, in the 'Outside-In' part of their museum. Humour is a powerful aid in learning[11] as well as the use of puppets[12]. They use books such as 'Grandmother Fish'[13], to explain evolution to young children, which also provides a compelling narrative for their caregivers too. This was useful, firstly because of my belief in Bruner's words on teaching any child anything[14], even the complexity of evolution, but also in stealthily engaging parents on the topic. Whilst on the subject of evolution, Dan Kahan at the SMASH Media Summit[15] mentioned that people who do not believe in evolution were just as

[5] http://www.astc.org/annual-conference/outreach-live/

[6] http://www.pz.harvard.edu/professional-development/events-institutes/family-science-engagement-and-learning-through

[7] http://tumblehomelearning.com/about-us/the-team

[8] http://tumblehomelearning.com/g-a-s-products

[9] http://tumblehomelearning.com/product/elizabeths-constellation-quilt-book

[10] http://www.ansp.org

[11] http://www.doc.gold.ac.uk/ephraim/Humor-E-Journals/IntStudiesHumour/Vol2014-1/Articles/PathmanathanLearningScienceThroughHumour.pdf

[12] http://www.nuffieldfoundation.org/puppets-project

[13] http://www.grandmotherfish.com

[14] http://infed.org/mobi/jerome-bruner-and-the-process-of-education

[15] http://www.sciencemediasummit.org/summit.html

engaged as believers with programmes such as 'Your Inner Fish'[16], proving the power of great storytelling.

Adrianne Sethi at the Senator John Heinz History Center[17] also used picture books in her Storyburgh session, 'Pittsburgh: A Tradition of Innovation', which I attended. She used 'What do you do with an idea?'[18]. Although the book was about ideas in general, Adrianne related it well to the surroundings within the museum, about Henry Heinz. Speaking with Adrianne afterwards she mentioned that for some of the younger children the abstract image of the idea in the book (it looked like a potato to me) was difficult to comprehend. She would normally run hands-on invention activities too, but this depended on the audience, the age of the children (and their fidgetiness) and engagement of the parents. Adrianne did however have a set of vegetable models and other props to encourage audience participation during the story, and to promote young children's fine motor skills.

Chris Loggins from the Fred Rogers Company[19] runs sessions at the Carnegie Library of Pittsburgh (Oakland)[20] called 'Snugglebug Storytime: oral storytelling for children' (from birth to 18 months). He uses high contrast black and white illustrations for younger children and includes songs, finger puppet plays and nursery rhymes. There are two stories per highly-attended half-hour session, held on Wednesdays and Saturdays. What interested me was when Chris said that a lot more fathers said they felt more inspired to read and sing to their children having seen a male storyteller do it. I had no idea there was a perception amongst some that only women read stories to children.

Naturally many of the live shows in museums involved some form of storytelling whether historical stories (for example, the history of the world's largest Van der Graaff generator[21] in the Theatre of Electricity or 'Animation Magic'[22] and Live Animal Story Time at the Museum of Science, Boston[23]), or the interactive sessions at ASTC where museum professionals often set the scene of their demonstration by narrating a humorous anecdote (for example, Elin Roberts' Jenga story[24]).

I visited the Mütter Museum[25] purely out of interest, but was pleasantly surprised to find an exhibit on the gruesome original versions of fairy tales, which included monstrous births and animal human hybrids. Folklore and storytelling here was used to communicate medical sciences: everything from cannabalism in Hansel and Gretel to animal comparative anatomy in Snow White (the woodsman bringing back a boar's heart), and from the dangers of childbirth (many mothers of fairy tale heroes and heroines died giving birth) to the naming of a hair-eating disease as Rapunzel syndrome. Having read about links between fairytales and science[26], it was even more evident through watching visitors captivated by the morbid stories and associated health conditions, that fairytales can aid science engagement.

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[16] http://www.pbs.org/show/your-inner-fish
[17] http://www.heinzhistorycenter.org
[18] https://www.amazon.co.uk/What-Do-You-Idea/dp/1938298071
[19] http://www.fredrogers.org
[20] https://www.carnegielibrary.org/events
[21] https://www.mos.org/live-presentations/lightning
[22] https://www.mos.org/live-presentations/animation-magic
[23] https://www.mos.org/live-presentations/live-animal-story-time-for-preschoolers
[24] http://www.astc.org/annual-conference/live-demo-hour-2016
[25] http://muttermuseum.org
[26] https://global.oup.com/academic/product/science-in-wonderland-9780199662654

Meredith Thompson's work on drawing an engineer[27] (similar to 'Draw a scientist'[28]) demonstrated what young people thought engineers did (fixing cars and operating trains). To help combat these misconceptions, there were a variety of story-based engagement activities that Meredith and others pointed me in the direction of.

The first being Museum of Science, Boston's 'Engineering is Elementary'[29]. Described as a 'flexible curriculum', the resources contain a story, background on what engineers do, what engineering design is, and a challenge. There is assistance for English language learners, teacher tips and worksheets with case studies of diverse role models. I enjoyed reading through 'Sounds Like Fun', all about acoustic engineering, and the story of Kwame, a blind Ghanaian drummer.

L-R: Van der Graff generator (Museum of Science, Boston), American folktales, Heinz History Center, Tufts' CEEO, various storybooks, Boston Public Library staircase.

I spoke with Darryl Williams at Tufts University[30], Elissa Milto and Jessica Watkins from CEEO (Center for Engineering Education and Outreach[31], Tufts) to discuss engineering outreach, as in the UK it is difficult to get young people thinking about engineering and what it entails when it is not a curricular subject. Massachussetts on the other hand has engineering in their state standards, so children in Boston understand engineering better. Engineering outreach is so prevalent in Boston,

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[27]

http://www.academia.edu/982600/Draw_an_Engineer_Test_DAET_Development_of_a_tool_to_investigate_students_ideas_about_engineers_and_engineering

[28] http://science.sciencemag.org/content/126/3270/384

[29] http://www.eie.org

[30] https://www.tufts.edu

[31] http://ceeo.tufts.edu

that a publication mapping all the different engagements is almost never-ending[32]. However outreach is still required because teachers still struggle with engineering having never studied it at school themselves, as well as dealing with the feeling of 'not knowing the answer' and how to encourage exploratory skills.

One of CEEO's projects, 'Novel Engineering'[33], uses books that children are already reading in school and allowing them to find the problems within those stories. This project brings together literacy, engineering design and problem-solving thereby being truly cross-curricular. Elissa gave an example from 'The Mixed-up Files of Mrs. Basil E. Frankweiler' by E.L. Konigsburg[34] where the characters needed to create a backpack with certain features to carry their essentials. When the readers reach this part in the book, they need to plan and actually make their own backpack using provided materials. Depending on the age and ability of the readers, they can identify the problems themselves in *any* book they are reading, and try to fix them. Many engineering activities I have seen in the UK and abroad are quite prescriptive. Knowing that such cross-curricular exploratory sessions work so well was refreshing to see.

Irene Porro from the Christa Corrigan McAuliffe Center for Integrated Science Learning at Framingham State University[35] has previously done much work bringing together the arts and sciences, mainly through The Catalyst Collaborative at MIT[36]. She recommended a newly released play, 'Marjorie Prime'[37], at Central Square Theater in Boston. It was based on the topic of Alzheimer's Disease, but through a futuristic look at how we would have humanoid robots (primes), that can keep our memories alive. A very touching story, weaving complex science cleverly into the narrative. Artistic directors and scientists came together to produce this play, which was not only poignant but raised many ethical questions. One of which was whether we should be able to manipulate our memories? Memory plays a huge part in storytelling and learning, and makes us who we are. Steve Ramirez[38] at the SMASH Media Summit said how they can manipulate memories in mice now, and while it could be widely available in the future it would be like antidepressants: you would only prescribe it for say, veterans suffering post traumatic stress disorder, as opposed to a high school student whose heart has been broken. One of the PBS Nova films, 'Memory Hackers'[39], that I judged for the Summit, also featured Steve's work, and contained some thought-provoking questions about memory too. Are we meant to remember everything? Perhaps one of the best functions of the brain is its ability to forget. People who remember everything ('autobiographical recollection') remember *absolutely* everything, including all their bad experiences. In learning, if we remembered everything, and knowing that the brain has a limited capacity, would this impact our ability to link new experiences to past memories, therefore making social (and family) learning difficult? Or easier? I have no idea.

From the technology side, virtual reality (VR) seemed to be everywhere. This 30-year-old technology is experiencing a huge resurgence as a result of creators' desires to use it in storytelling. Not to mention the significant price drop in headsets making it more commercially accessible for households and schools. Alex McDowell, keynote speaker at the ASTC conference described USC's World Building Institute[40] (responsible for emotional and haptic interventions such as the giant

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[32] http://ceeo.tufts.edu/documents/researchMEIDCreport.pdf
[33] http://www.novelengineering.org
[34] http://www.novelengineering.org/what-is-novel-engineering/get-started/book-ideas
[35] http://christa.org
[36] http://arts.mit.edu/welcome/overview/partners/catalyst-collaborative-at-mit
[37] https://www.centralsquaretheater.org/shows/marjorie-prime
[38] http://theramirezgroup.org/team/steve-ramirez
[39] http://www.pbs.org/wgbh/nova/body/memory-hackers.html
[40] http://worldbuilding.institute/people/alex-mcdowell

flying whale[41]) and how they are using technology and storytelling to help people visualise spaces. Storytelling is our way of making sense of the world and VR offers the option to help citizens understand what the future could look like. For example to visualise if water was unavailable in the world or to see coral bleaching and pollution in the oceans, or even what communities would look like in built up areas.

In the 'Immersive Storytelling' session at the SMASH Media Summit, Albert Yu-Min Lin, National Geographic Fellow[42] discussed how emotion plays a key part in storytelling and that 'learning happens around a-ha moments'. As there is not much for children to do outside, how can they have those moments of discovery? And how do kids in Nevada for example, care about oceans if they have never been there? Albert says, get them to wear a headset to have that a-ha moment. VR and AR (augmented reality) may be some of the many new tools for learning. He also mentioned 'Pokémon Go'[43], and how it is all about story. The main character is the hero in the story and a part of the story. If we can make the user a part of the narrative, we can use these tools for raising awareness of global issues, climate change and encourage users to participate in citizen science. Interestingly, 'Pokémon Go' came up a few times during my Fellowship. Amy Kamarainen from Project Zero[44] who works on EcoLearn[45] said that since 'Pokémon Go' has taken off she no longer needs to explain what AR is.

While I see the benefits of VR, I still worry about the isolation aspect. How can it be truly collaborative if everyone is wearing a headset and experiencing different 'stories'? And if a class is meant to use it in the way Google Expeditions[46] expects it to be used (where a teacher can see where each individual is looking and direct them to a specific place), why does a headset need to be used at all? Is it purely for novelty? Novelty may hook learners, but could lead to the 'chocolate-covered broccoli' effect, i.e. covering up something perceived as dull (the science) with something exciting (the equipment).

Daniel Pillis from Carnegie Mellon University[47] set up 'Tilt Brush'[48] for me using the HTC VIVE[49] allowing me to draw on a 3D canvas, and teleport myself anywhere on the canvas to look back at my creations. As fun as it was, I was not sure how it could be used in education. Until I met Tyler Samstag from the Allegheny Intermediate Unit[50] (which provides professional development and educational services for all 42 school districts in Allegheny County). He said that the potential to use 'Tilt Brush' with dyslexic children was immense. Children could write letters within the programme and view their writing from all different positions enabling them to recognise the shapes of letters and words.

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[41] https://vimeo.com/90192951
[42] http://www.nationalgeographic.com/explorers/bios/albert-lin
[43] http://www.pokemongo.com
[44] http://www.pz.harvard.edu
[45] http://www.pz.harvard.edu/projects/ecolearn-projects
[46] https://www.google.co.uk/edu/expeditions
[47] http://www.cmu.edu
[48] https://www.tiltbrush.com
[49] https://www.vive.com/uk
[50] http://www.aiu3.net

2.2. Children's Media

One area that has always fascinated me (which led to my Masters research[51]) is the ability of entertaining children's media to convey science learning to young people. I have since found that bringing entertainment together with hands-on activities helps young children understand complex science (such as climate change)[52]. However I still feel that much of the media engagement here in the UK is with educational media, 'edutainment' (purposely-made entertaining educational content) or challenging the inaccuracies in pure entertainment. Or again as a quick novelty hook prior to launching into heavily curriculum-focussed content. There is little informal science engagement embedding children's entertainment. But what power does such entertainment have in public engagement and informal learning?

L-R: Fred Rogers, Fredosaurus Rex, Baymax, Ruff Ruffman, Miles from Tomorrowland, WGBH HQ. Centre: Daniel Tiger.

I wanted to find out more about the impact of pure entertainment, one example being 'Big Hero 6'[53]. I met with Chris Atkeson and Daniel Pillis at Carnegie Mellon University's Robotics Institute[54] to learn about soft robotics and the character of Baymax in the film[55]. Having previously attended a Guardian Masterclass[56] about the animation, I wanted to know more about how movies can lay out a specific future having been informed by current scientific research. Disney animators visited many labs looking for medical robots and landed upon the idea of a robot for good: helping with healthcare. By depicting robots as positive, could this help audiences engage better with robots? In

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[51] https://www.scribd.com/document/61314364/My-MA-Dissertation-Sai-FINAL
[52] https://www.ase.org.uk/journals/primary-science/2015/05/138
[53] http://movies.disney.co.uk/big-hero-6
[54] https://www.ri.cmu.edu
[55] https://www.cs.cmu.edu/~cga/bighero6
[56] https://www.theguardian.com/guardian-masterclasses/video/an-afternoon-with-disneys-big-hero-6-video

Europe (which Atkeson attributes to 'Terminator'[57] films) and the US, the public perception of robots is quite negative. However, the Japanese are not fearful of robots at all. Even 'Astroboy'[58] is a citizen of Japan.

'Big Hero 6' was a great piece of public engagement, as people understand soft robotics and there is a lot more funding for research now. The innovations that the Disney team came up with has also helped. Research and education informing entertainment, and vice versa. Chris said that movies, TV and written materials are a way to educate people on what is in store for us and can prove very important for policy discussions. 'Big Hero 6' had a very positive message showing that technology can make life better for everybody, and portraying an attractive life as a geek. The strong female characters in the film were based on the Girls of Steel First Robotics[59] team, which I will explain later.

Listening to Sascha Paladino (creator and executive producer of Disney Junior's 'Miles from Tomorrowland'[60]), was particularly inspiring. He described finding out he was going to become the father of twins and wanted to create the best possible adventure that a family could go on. Sascha remembered going to the American Museum of Natural History (AMNH)[61] and receiving a planetarium course certificate at the age of 9. He said, 'the adventures you have with your family are better than the ones you can have by yourself.' In the series we follow Miles Callisto and his family on a series of intergalactic adventures as they connect the universe on behalf of the Tomorrowland Transit. Bud Rock, CEO of ASTC, who introduced Sascha's session at ASTC explained my chocolate-coated broccoli analogy better: 'rather than sneaking science into conversation like a pill, how do we make the science content itself a delight?' And this is why I believe that true entertainment can get more science (or enjoyment of science) across than educational material.

It is less about the accuracy as mentioned earlier, it is the story that is important. Science fact inspires science fiction, with the animators taking artistic licence. For example, showing pancakes rocketing across the room, because too much 'propulsion powder' was added, or that tardigrades (which looked physically accurate) could grow to such huge sizes (inaccurate). These little examples can cause excitement and inspire children to want to find out more.

Science centre educators such as Janella Watson from the New York Hall of Science (NYSci)[62] ran activities under the 'Miles' brand, by using clips and leveraging the impact that science centres have to run open-ended activities incorporating the themes in the show. In this way the show has a life outside of the traditional medium, inspiring young people to 'do science'. NYSci is also based in Queens, where over 170 languages are spoken. How can you encourage such diverse audiences to interact with what could seem to many as an unapproachable educational establishment? Answer: by using the show's popularity. The collaboration between Disney and NYSci brought in the local community, enabling young people to meet real astronauts and launch rockets alongside them.

The diversity within the show, going against stereotypes and mirroring families seen in society, was also worth noting. For example, that the father is not depicted as unintelligent and silly as in many other popular cartoon shows, the mother is Chinese-American, although it is never explicitly mentioned, and their friend Miranda is from a single-parent family. Partnering with Google's

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[57] http://www.imdb.com/title/tt0088247
[58] https://en.wikipedia.org/wiki/Astro_Boy
[59] http://www.frc.ri.cmu.edu/girlsofsteel
[60] http://disneyjunior.disney.co.uk/miles-from-tomorrow
[61] http://www.amnh.org
[62] http://nysci.org

campaign, 'If you can't see it, you can't be it'[63], the animation shows Miles' older sister, Loretta, as a brilliant computer coder. For Hallowe'en, Disney neglected to make Loretta costumes available, and as a result children everywhere made their own. Toy and clothes aisles may be about gender[64], but for Paladino, the show is about the whole family. Interestingly, the same scenario was seen when shops ran out of the 'Star Wars'' Rey[65] dolls. Will Macfarlane from Parts and Crafts[66] in Somerville said they received donations of all kinds of dolls (from 'Monster High'[67] to 'Bratz'[68]) and helped young people change them physically (and chemically, using acetone) into their own Rey dolls.

The Fred Rogers Company[69] is an innovative producer of educational media for 2-8 year olds, and is continuing the legacy of Fred Rogers of 'Mister Rogers' Neighborhood'[70] fame. Ellen Doherty, Executive in Charge of Production, organised meetings for me with Cathy Droz, Chris Loggins, Suzanne Masri, Brittany Smith, Jack Rowley and Paul Siefken[71].

'Mister Rogers' Neighborhood' never made it to the UK during my childhood. It was deemed to be too local community focussed and too much of an 'American neighbourhood', so was not sold internationally. However I remember 'Sesame Street'[72] vividly growing up and wondered why, as they were both on television in the US at the same time. Cathy said that 'Sesame' was focussed on diversity and early cognitive skills, aiming to make letters, reading and early mathematics eye-catching and exciting. 'Mister Rogers' Neighborhood''s focus was on socio-emotional skills in a much calmer, slower environment, i.e. much more about values and social learning.

"I give an expression of care to each child to help him realize that he is unique," Fred said. "I end the program by saying, 'You've made this day special by just your being you. There's no person like you, and I like you just the way you are.' And I feel that if we in public television can only make it clear that feelings are mentionable and manageable, we will have done a great service."

Fred talked for several minutes about kindness and dignity and society's responsibility to raise healthy, happy kids. Pastore's face was impassive as Fred finished. He seemed moved, not only by Fred's words but also by the weight of his sincerity. He blinked a few times, then lifted his hand and let it drop to the table.

"That's wonderful," he said quietly. "Just wonderful."

Excerpt from 'Make the Impossible Possible' by Bill Strickland.

Following Fred's passing, a new animation was created called 'Daniel Tiger's Neighborhood', where Daniel is the son of Daniel Striped Tiger from the original 'Mister Rogers' Neighborhood' show. It covers social and emotional skills, families getting on with one another and daily routine training to

[63] http://googleforeducation.blogspot.co.uk/2015/11/google-gallup-research-report.html
[64] http://www.livescience.com/45006-removing-gender-from-toys.html
[65] https://en.wikipedia.org/wiki/Rey_(Star_Wars)
[66] https://www.partsandcrafts.org
[67] http://play.monsterhigh.com/en-gb/index.html
[68] http://www.bratz.com
[69] http://www.fredrogers.org
[70] https://en.wikipedia.org/wiki/Mister_Rogers'_Neighborhood
[71] http://www.fredrogers.org/about/who-we-are
[72] https://en.wikipedia.org/wiki/Sesame_Street

help parents. There are apps to accompany the show, because whatever the socio-economic background of the family, all parents seem to have a smartphone. Apps such as 'Good Morning and Good Night'[73] not only engage children, but help parents teach routines such as brushing teeth.

Paul's insight into children's media was particularly enlightening. He said that 'Daniel Tiger' is very different to other children's shows as there are more adult characters than child characters. This is so that the adult characters lead the behavioural strategy and help the viewing parents to model those behaviours with their own children. Some parents have even been in touch to say, 'thank you for making me a better parent'.

Chris works on 'Peg + Cat'[74], a fun maths skills television programme for 4-6 year olds, and they also run sessions to train teachers and parents at the Allegheny Intermediate Unit and childcare centres, using 'low and no technology' activities (i.e. dice and cards). He said that the feedback they get from families in person and through social media tells them what their viewers are learning, such as noticing trapezoids on their day out. While these shows are what I would term 'edutainment', in that they have a significant educational aim, are entertaining to watch but not curricular or pure entertainment, it is the added value of outreach that I found fascinating.

Suzanne, Brittany and Jack talked me through 'Be My Neighbor Day'[75] based on the 'Daniel Tiger' episode, 'Neighbor Day' bringing families together and encouraging them to take part in community-focussed acts of kindness. These acts included making and decorating placemats and greeting cards for the elderly, organising clothes and food donations, and packing snack bags for young people about to take their exams. The team mentioned research where children who take part in voluntary work with their parents are more likely to continue doing voluntary work when they are older. The Fred Rogers Company provided a pack of promotional materials also available in Spanish. Each of the days run by different PBS stations around the country recorded high-family turnouts, with thousands of individuals pledging service hours. It encouraged multigenerational collaboration, community action and partnerships, such as growing community gardens.

Wendy Brenneman and Jessica Lausch from Carnegie Science Center[76] told me about how they integrated another children's programme from the Fred Rogers Company into skill-based summer camps. 'Odd Squad'[77] focuses on problem-solving, teamwork and perseverance following odd mathematical mishaps (such as all the zeros have disappeared and the 'Odd Squad' need to reach out to the community and solve this issue with maths). Both the Company and Center worked together to produce week-long summer camps using engaging developmentally-appropriate activities incorporating the media (10-15 minute clips), with participants all becoming 'Odd Squad' agents. The Center has approximately 2200 children over the summer taking part in such camps.

Bill Shribman from WGBH[78] met with me to discuss the digital and outreach side of WGBH Kids media, and about the use of 'low tech'[79] by children. Bill organised some meetings for me with the digital team at WGBH. Louise Flannery, Mollie Elkin (Digital Children's Media department) and Mary Haggerty (Education department) talked me through the 'Plum Landing'[80] app aimed at 6-9 year

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[73] https://www.youtube.com/watch?v=HaUDGV4aAH8
[74] http://pbskids.org/peg
[75] http://www.WontYouBeMyNeighbour.org
[76] http://www.carnegiesciencecenter.org
[77] http://pbskids.org/oddsquad
[78] http://www.wgbh.org
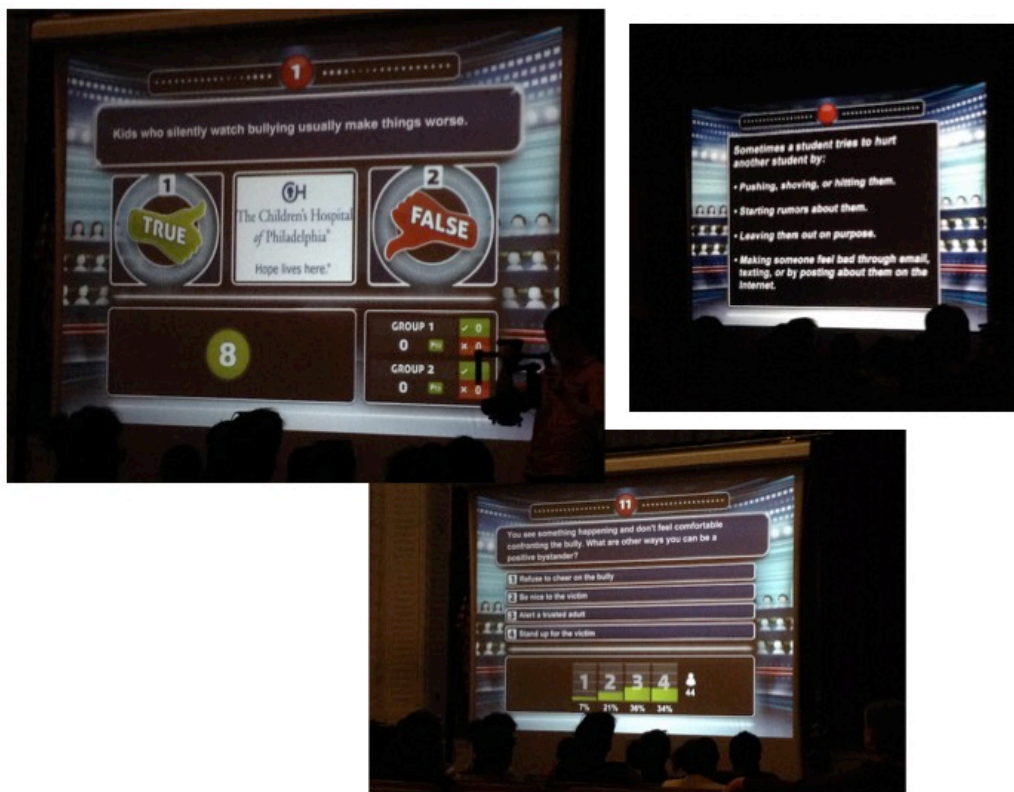[79] https://www.youtube.com/watch?v=JchSOwNa4FM
[80] http://pbskids.org/plumlanding

olds, getting them outside and investigating the environment. Especially as doctors have been *prescribing* more outdoors time to help obese children exercise, and to alleviate 'Nature Deficit Disorder'[81] amongst urban children. Parents are naturally concerned about excessive screen time so the technology here is not passive, it is there to leverage action. Children can grow their own plants, upload photos, collect data, superimpose their photos on a timeline and submit them to a gallery. Educators can use the resource and WGBH is part of the 100Kin10[82] initiative to train and retain 100,000 more STEM teachers by 2021. As I was also interested in preschool apps, Louise demonstrated 'First 8 Studios'[83] for me, full of hands-on activities and materials for teachers and caregivers of those aged birth to 8 years old.

I also spoke with Saranya Sathananthan (Education department) about 'Design Squad Global'[84] aimed at 10-13 year olds. Slightly above the age range I currently work with it was good to learn about motivating STEM clubs across the globe to collaborate. There are two versions of the club (6-week or 12-week) and they are paired with a club in another country to run engineering design challenges with recycled and commonly found materials. Most are community-run and it depends on who is championing these clubs to sustain them. The biggest issue they have is the time zone, so some clubs are run asynchronously, catching up about design processes, successes and failures via e-mails and video clips. This initiative celebrates engineering, cross-cultural understanding and having fun all at the same time.

From the CHOP interactive presentation at G.W. Childs Elementary School.

[81] http://www.bbc.co.uk/news/science-environment-38094186

[82] https://100kin10.org

[83] http://first8studios.org

[84] http://pbskids.org/designsquad

Bill introduced me to Flaura Winston from the Children's Hospital of Philadelphia (CHOP)[85], who invited me to an interactive session, 'Free2B: Multimedia Bullying Prevention Show' at George W. Childs Elementary School in Philadelphia. It was sponsored by CHOP's Violence Prevention Initiative and consisted of multiple choice pre- and post- questions (assessed by interactive voting controls given to each child in the audience), a 3D film about bullying, real life bullying stories inspired by messages on YouTube, and the bullying experiences of people who worked on the 3D film (including the actors).

The initial film was clever and set the scene, but it was the emotions conveyed in the true stories that affected many members of the audience. When the viewers (9-11 year olds) had finished watching these films they were asked school-specific questions, such as where do they feel that bullying happens within the school. The answers to these questions formed the basis of a report for the school management team to address.

For one and a half hours these children took part in an interactive session without losing their attention, learning skills that they can implement to prevent bullying.

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[85] http://www.chop.edu

2.3. Family Science Engagement and Learning

Although storytelling and children's media play a huge part in my work with young people, these are simply the tools. My main focus is family learning and community engagement. How can I engage with communities better in order to run successful family engagement activities that suit their needs? If families and communities are the gatekeepers to young people, they can influence and encourage their children to learn and to achieve, much more than any informal or formal educator can. As part of this Fellowship I also looked at creative spaces for family and community engagement and working with different age groups and diverse communities, which I will discuss in this section.

The Foundation for Family Science and Engineering[86] is a non-profit based in Oregon dedicated to increasing public engagement and appreciation of science and engineering. They run the SEEDS (Supporting Early Engagement and Development in STEM) afterschool programme and evening community events (in both Spanish and English) bringing young children and their families together to do hands-on activities in accessible, non-threatening environments. This last part is key. I have found it much easier to get families to come to a place they are comfortable with, than a hired venue deemed suitable by funders. And this is not about the SEEDS team doing everything (which many of us freelancers feel the need to do) as David Heil from the Foundation told me. It is about helping communities develop and take ownership of running these STEM-focussed family learning events themselves. They help identify community-based resources: who are the local education community, STEM providers, schools and community stakeholders that need to be involved. David said that if children ask questions and the parents say they have no idea and do not support the children to find out, the children stop asking. How do we find these caregivers within the community and help them feel comfortable to support their children?

David Heil talked about finding families in places of religion, hospitals, through putting information in goody bags for newborns (when talking about readiness for Kindergarten), or going to homes with activity bags (with information in different languages), family resource centres, fleamarkets: anywhere where the communities and families are. Having received an NSF[87] grant for the initial work, David's team now provide materials and manuals for the communities to run activities themselves. They also sell some kit that communities find difficult to create or source.

I had an interesting conversation with Kevin Crowley from the University of Pittsburgh[88] about science communication, public engagement and informal science learning in the UK and US, but also about materials used in engagement. As part of the Climate and Urban Systems Partnership (CUSP)[89] project, which I will describe later, Kevin mentioned that turning up with polished kits in a community setting does not engage people. Communities need to see every day materials and to imagine doing it themselves in order to feel at ease with deeper conversations. Kevin also mentioned some organisations that still promote a deficit view: going into communities, showing them what they are researching and leaving without any follow up to help individuals take ideas further. I feel the same way about science shows in schools by external presenters. Katie Baur, Coordinator at the National Living Laboratory[90], Museum of Science Boston, put it perfectly: 'Avoid being the sage on the stage.' Outreach should not be about marketing or fame. Those

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[86] http://www.familyscience.org
[87] https://www.nsf.gov
[88] https://www.education.pitt.edu
[89] http://www.cuspproject.org
[90] http://www.livinglab.org

organisations that listen to their communities and are honest and transparent about their intentions, will facilitate better conversations so both parties can benefit.

David Sanchez from the Swanson School of Engineering[91] met with me to discuss community and family engagement. He was very positive about my work and emphasised that parents are the most crucial teachers. As an engineer he uses the term 'design-build challenges' rather than using 'engineering', and works with schools and communities long-term (over several years) to build a strong rapport with individuals in various neighbourhoods. David told me about motivating families, giving them the confidence to continue the work, for example in hydroponics[92], saying 'once the family is taken care of, society will get along'. Working in communities you can find the talents of everyone and who is willing to do what. People learn from each other's expertise and it becomes civic and social engagement. Being part of a community is amazing, and motivates others to join in. He mentioned how young people yearn for an expert-apprentice model, a real relationship that you can achieve with smaller student:educator ratios, just as in clubs. David told me of a child who said, 'I wish I was a phone, so my parents would play with me more.' The attention young people get from a caregiver or educator is what they value most.

Visiting the Phipps Conservatory, I met Sarah States and Maria Wheeler-Dubas in the science education and research team to tell me about their work. Apart from the air quality issues in Pittsburgh, a huge problem is the lead contamination in soils. They have a raised bed scheme to help several neighbourhoods grow their own vegetables and enjoy their produce safely. Much of their outreach is on sustainability issues and climate change, and they have internships for high school students to help them into environmental careers. With only 6-8 students accepted onto the scheme a year, this ensures the close expert-apprentice model David mentioned.

A fascinating discussion with Sameer Honwad from the University of New Hampshire[93], helped me understand the true need for local community groups like clubs and afterschool activities. Young people have a need for a cultural identity, and to belong to a community. If the parents cannot instil it, young people need to find it from elsewhere.

There was a panel discussion about various platforms at the SMASH Media Summit, and a question was posed referring to Snapchat[94]: how do you engage with an audience if they do not communicate like you (i.e. if you are not on Snapchat too)? This could easily apply to communicating with diverse audiences. Why do we not go to where they are? Speaking with John Durant and Ben Wiehe from the MIT Museum[95] it was great to hear how they value going to where the people are.

Ben mentioned a Native American reservation in rural Montana, which has now embraced science into their community, as SciNation[96]. But it was not plain sailing at the start. Staff had to understand the community's culture, for example not running science engagement activities during silent prayer times. Ben said that initiatives like this, just as the MIT Museum takes their outreach van to places with no access to museums or festivals, all help with institutional change. When science centre staff venture out into the community they become better communicators. Many other colleagues I met during the Fellowship agreed with this. Staff enjoy communicating with children and adults at the

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[91] http://www.engineering.pitt.edu
[92] https://en.wikipedia.org/wiki/Hydroponics
[93] https://cola.unh.edu
[94] https://www.snapchat.com
[95] https://mitmuseum.mit.edu
[96] http://spectrum.umt.edu/education/outreach/mosse_k12/CommunityInitiatives/FlatheadIndRes.php

same time. It may be the same information but no one feels like they are being talked down to and adults feel safe asking more complex questions.

I mentioned not wanting to work at festivals labelled as science anymore, because of the already scientifically-literate audience, and the fearfulness surrounding science amongst certain communities that do not attend. John asked whether we even need to use the word, 'science', just as David Sanchez mentioned earlier rarely uses the word 'engineering'? Does it matter if people engage with an activity and do not know it is science? Institutions such as the MIT Museum, Exploratorium[97] and others do not have the word 'science' or STEM in their titles, confident enough in promoting exploration, wonder and curiosity without labelling themselves with specific subjects.

However another issue that I have found is trying to work with non-science festivals that see the activities as too 'sciencey', despite how they are branded. This results in the festival staff either declining the offer or adding it into a science area within their festival. Ben agreed and mentioned that once you manage to win over a non-science festival, a science microcosm develops within that festival which can be just as audience-segregating as a science festival.

Since arriving back in the UK I have been telling colleagues about the Remake Learning Network[98]: over 250 organisations and thousands of individuals working together to shape teaching and learning in southwest Pennsylvania, West Virginia and beyond. Pittsburgh was a steel town, a rust belt[99] community that needed to change or die. There was something almost magical about the place and the humility of the people there, striving to reinvent education.

Rather than education for the sake of getting a job, the network is helping young people gain skills and the mindset to succeed through making, playing and inventing in collaboration with others. The real challenge is not the innovations, but the spread, scale and accessibility for all. And as each member focuses on their own communities these learning opportunities are reaching everyone, making the offerings truly equitable.

The Sprout Fund[100] steward the network and I was pleased to meet with Patricia Monticello Kievlan and Ani Martinez. They told me of four other places running similar networks: Chicago, New York, Toronto and the San Francisco Bay Area. The Sprout Fund offers catalytic grants (typically $1000-$5000), and run the Remake Learning website and blog as well as providing community-building capacity. There are always challenges getting people together, but the success of the network is down to its committed champions.

Gregg Behr of The Grable Foundation[101] is one such champion. Gregg told me that teachers said they were not connecting with children the way they used to, that the classroom is wired differently now so children are learning differently. Gregg thought, 'if our goal is to make Pittsburgh great again i.e. a better place to live, work and play, we cannot overlook learning.' And for children at an economic disadvantage (45% of children in the USA are on free school meals), they simply need more encouragement and opportunities.

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[97] https://www.exploratorium.edu
[98] http://remakelearning.org
[99] https://en.wikipedia.org/wiki/Rust_Belt
[100] http://www.sproutfund.org
[101] http://grable.org

The network have held hugely successful Remake Learning Days[102]: a week of hundreds of free (or low cost) events such as coding, community art projects, careers fairs, language learning, kite flying and LEGO. Sponsored by local companies and trusted organisations such as churches and hospitals, these pop-up events are for anyone interested in hands-on learning. In 2016, over 270 events took place with over 30,000 people attending. Of the 350 zipcodes (postcodes) of the attendees, the top six were from low income neighbourhoods, showing that there is a huge interest from communities that would not usually have such opportunities. These Remake Learning Days have caught the attention of the World Economic Forum[103] and many more events are planned for 2017.

Minda Borun, formerly of The Franklin Institute[104] and currently consulting, discussed a project with me that has been running for 20 years in various iterations, 'Family Learning in Museums: The PISEC Perspective'[105]. Project partners were the Academy of Natural Sciences of Drexel University, The Franklin Institute, the New Jersey State Aquarium (now Adventure Aquarium[106]) and Philadelphia Zoo[107], hence the Philadelphia-Camden Informal Science Education Collaborative i.e. PISEC.
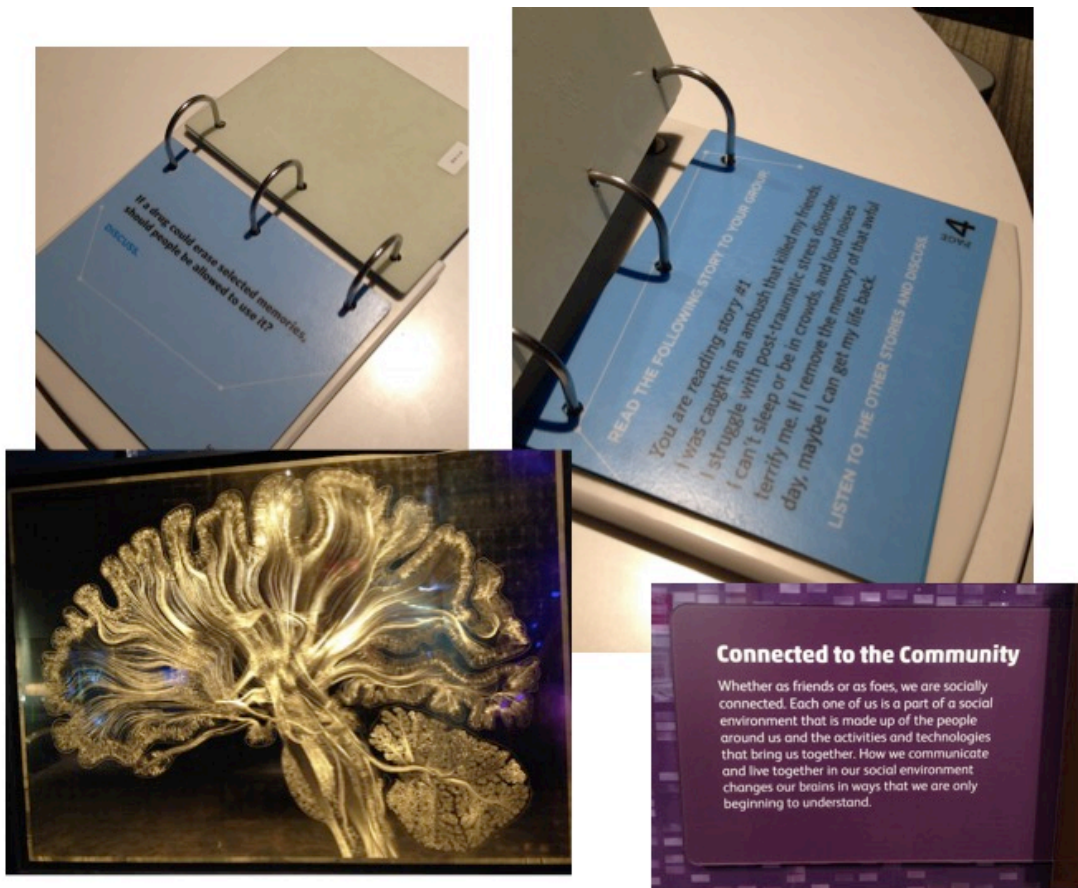
From exhibits at The Franklin Institute and Museum of Science, Boston.

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[102] http://www.remakelearningdays.org
[103] http://www3.weforum.org/docs/WEF_EGW_Whitepaper.pdf
[104] https://www.fi.edu
[105] https://www.fi.edu/sites/default/files/EvaluationReasearch_4FamilyLearning1998.pdf
[106] http://www.adventureaquarium.com
[107] http://www.philadelphiazoo.org

When we look at learning we think of it as a change in a person's knowledge, skills and beliefs. Physiologically, in the brain, there is a change in neuronal pathways and connections. Socially, our knowledge can be shaped by our family members as each family has their own culture, values and experiences. Families can share the memories and knowledge initiated by a museum visit straight after visiting or even long after. Most of the audience for science museums are family groups and families learn about the world by discussing new experiences, relating this learning to prior knowledge and questioning and sharing memories. So PISEC ran a research project to measure and identify family learning and thereby help other museums to create better family learning environments and experiences. They worked alongside 'Community Connections', an outreach programme that helped museums appeal to African-American and Latino families who would not usually visit museums.

Linking back to 'science capital'[108], those taken to museums as children were more likely to visit museums as adults. And the more educated the adults, the more likely the family were to visit museums. Timshel Purdum also mentioned the benefits of museum visits especially the use of dioramas to get an idea of scale, of say a buffalo, which you cannot gain from watching a nature documentary.

Research by D.D. Hilke[109] found that 66% of family behaviour at an exhibit was transferring information and 5% was about relating this information to the experiences of other family members. Sharing information through these social interactions can increase cognition and help visitors make connections to other phenomena. I would be interested to see if this kind of learning is applicable to learning from entertainment media when family members view together.

The 'Family Learning Project' came up with seven attributes for family-friendly exhibits:
- 'Multi-sided: family can gather around exhibit;
- Multi-user: interaction allows for several sets of hands;
- Accessible: comfortably used by both adults and children;
- Multi-outcome: observation and interactions are sufficiently complex to foster group discussion;
- Multi-modal: appeals to different learning styles and levels of knowledge;
- Readable: text is arranged in easily-understood segments;
- Relevant: provides cognitive links to visitors' existing knowledge and experience.'

I feel that these attributes not only apply to museums, but to outreach in general such as activity stations at family-friendly events and festivals and when producing temporary exhibitions at community venues.

Speaking of such venues, the amount of community engagement work happening through libraries was overwhelming. Libraries are no longer purely about books. Free libraries in neighbourhoods are offering free activities, and more offerings the larger the library. Particularly the Carnegie Library network[110] in Pittsburgh and the LEAP afterschool programme in Philadelphia[111]. Paul Taylor also mentioned The Franklin Institute's work with medically fragile children at Frankie's World[112], as an example of working with audiences that want such engagement but are often overlooked.

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[108] https://www.youtube.com/watch?v=A0t70bwPD6Y
[109] http://engagefamilies.org/wp-content/uploads/2015/01/hilke-strategies-for-family-learning.pdf
[110] https://www.carnegielibrary.org
[111] https://libwww.freelibrary.org/programs/leap
[112] https://frankiesworld.com

2.4. Early Years, Teens and the Elderly

As my afterschool sessions allow siblings to join in as parents cannot leave them at home, I wanted to know more about early years engagement when working with families. Sometimes accompanying siblings may be much older (teenagers) or even elderly relatives may attend (particularly at community events), so I was interested in ways to keep everyone engaged.

Allison Krisch at the Academy of Natural Sciences of Drexel University introduced me to CHISPA[113] (CHildren Investigating Science with Parents and Afterschool) where a network of organisations work together to help Hispanic families engage with local science resources. The Academy runs family science days (80% of the families have never visited a museum), and parents are offered classes to help their children's learning (8 bilingual units, 5 lessons per unit). They partner with Head Start[114] (a government programme helping low income families with early years education, health and parenting) preschools for 3-4 year olds in the Philadelphia district and church preschools, training the teachers to become more confident with science.

Erica Peterson from ScienceTots[115] described her work running parent-child workshops and engaging with communities all over Western Pennsylvania and West Virginia. She had to leave her life in academia when she had children and now through her work with early years she is helping encourage other parents to promote STEAM[116] (science, technology, engineering, arts and mathematics) learning at home. Erica collaborates with other like-minded educators in fun ways to reach underserviced audiences, which many others have missed.

In the 'Itty Bitty Science'[117] session at ASTC, Janella Watson from NYSci told us about Design-Make-Play[118] with early years i.e. problem-solving, getting hands-on and being joyful. Janella confirmed a lot of my thoughts. She mentioned parent-child workshops as a vehicle for teacher professional development (it is much less patronising than training workshops) and in helping teachers connect with parents so that children can continue the learning at home. Janella also supported the use of 'simple materials but complex ideas' i.e. using easily accessible materials, and even mentioned butter making (or 'reverse emulsion').

Whilst in Tampa, Jen Stancil from Glazer Children's Museum[119] invited me to take part in a charette on their water exhibit focussing on 7-8 year olds primarily, but also engaging younger and older children, parents and teachers. As someone who works with 7-8 year olds I felt I could offer my experiences as well as learn much from the people around the table. The community aspect appealed to me here. There were colleagues from the local education board, scientists, consultants and Tampa Bay Water representatives at the meeting. It was here I met Victoria Prizzia from Habithéque, who had done some amazing work at Fairmount Waterworks in Philadelphia[120] bringing the arts and sciences together under the theme of water. She said how difficult it is to get people to care about water when they can just turn on the tap. This exhibit planning was not simply about how to educate young people about water but to motivate them into thinking about the importance of their local water system. Tampa Bay Water comes from three different places: ground

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[113] http://chispanet.org
[114] https://en.wikipedia.org/wiki/Head_Start_(program)
[115] http://www.sciencetots.org
[116] http://stemtosteam.org
[117] http://www.astc.org/conference/astc-2016-session-presentations
[118] http://nysci.org/dmp-stem-institute
[119] http://glazermuseum.org
[120] http://www.vimeo.com/182689755

water, river and bay. All three sources need to be protected. But how do you get people to care? Through citizen science projects perhaps, and interactive activities engaging all members of the family?

The Glazer Children's Museum is one of the only museums to have a SMALLab (see later).

Lennie Dusek from the Museum of Discovery, Little Rock[121] spoke at ASTC about having a set of developmentally-appropriate activities for all those turning up for events, and asking older siblings to help lead, allowing them to take a more active role model approach. Parents like to see their older children gaining leadership, confidence and other social and transferable skills. Even at the Mütter Museum, it was one of the educator's young daughters running the paper flower workshop as part of their Day of the Dead[122] festivities.

Having volunteered with the elderly in the past, I was interested to hear about colleagues' experiences engaging seniors. Christina Smiraglia from Project Zero described her research taking museum objects out to the elderly who are unable to access a museum either geographically or physically. She said they enjoy this and want to learn, sharing memories and mentioning a general feeling of wellbeing. Mandi Lyon from the Carnegie Museum of Natural History[123] and Karen Elinich from The Franklin Institute, who are both part of the CUSP project mentioned earlier, worked with seniors too. CUSP is a climate change impact project taking place in Philadelphia, Pittsburgh, New York and Washington DC. Karen told me that Philadelphia is becoming hotter and wetter each year. It is a relatively old city with an old infrastructure and is not ready for downpours. This leads to street flooding and the rainwater combining with sewage. CUSP encourages communities to talk about how they can collectively make life better in hotter, wetter Philadelphia. Through hands-on

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[121] https://museumofdiscovery.org
[122] https://en.wikipedia.org/wiki/Day_of_the_Dead
[123] http://www.carnegiemnh.org

activities at afterschool youth projects, visiting old senior centres and festivals the team help people visualise what is happening, and follow up with strategies to adopt such as installing rain barrels.

Senior citizens have lived climate change: they have lived in the same area their entire life, so it takes nothing to convince them that it is hotter and wetter now. Both Karen and Mandi said that care homes were craving activities so enjoyed the CUSP interactives. Also, as many of the seniors are female they said, 'Thank you for letting us learn science.' The elderly are very influential as they talk to their children and grandchildren. One lady told Mandi that she still loves learning and, 'I wish someone told me as a girl that I could do science. I'm going to tell my granddaughter all about this.'

2.5. Makerspaces, Collaboration and Technology

Pittsburgh was heaving with inspiring makerspaces. A makerspace (also known as hackerspace or fablab) are collaborative spaces with access to all kinds of tools and open to anyone to come in and create[124]. Whilst each space in Pittsburgh seemed to be aimed at a different audience, they regularly join forces to encourage more making and creativity within the wider community. To truly engage families with exploratory learning, makerspaces could be the answer.

The interest in making is because creative, improvisational and problem-solving activities using tools and technologies are engaging for all ages. As everyone is learning, makerspaces provide an equal playing field allowing for equitable experiences for all. However there is still the issue of whether attendees are learning[125]. There is hardly any professional development for facilitators: they only have how-to guides for making rather than training in how to question, listen, prompt and provide rich learning opportunities.
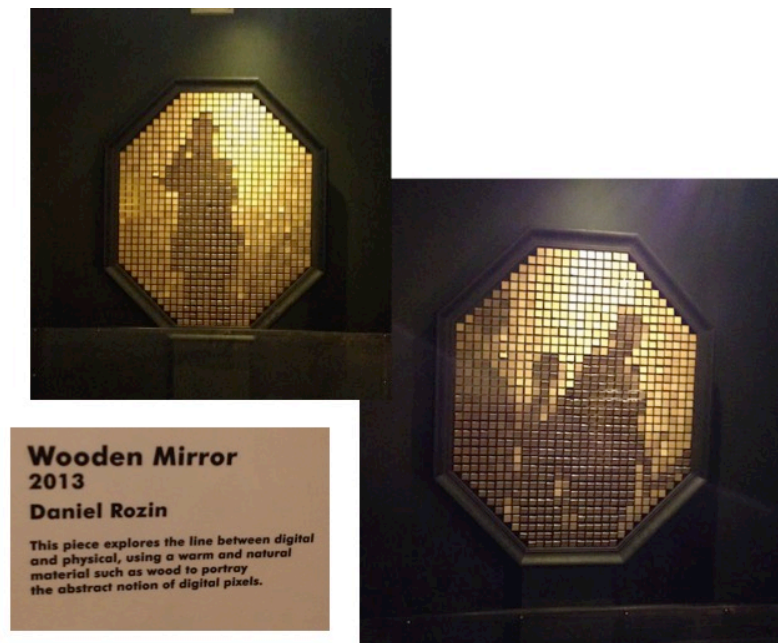

Maker Faire Pittsburgh, and MAKESHOP activities.

I attended Maker Faire Pittsburgh[126] where there were over 250 workshops at the Children's Museum of Pittsburgh[127]. What I love about Maker Faires is the eclectic-ness of it all, anyone who is 'making' can take part: from those making and selling greeting cards to those demonstrating augmented reality sandboxes. You see children teaching other children, adults sharing tips, and the collaborative learning between young people, caregivers and random visitors.

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[124] https://www.makerspaces.com/what-is-a-makerspace
[125] http://researchandpractice.org/resource/stem-making-in-afterschool
[126] http://makerfairepittsburgh.com
[127] https://pittsburghkids.org

The 'Wooden Mirror' exhibit at the Children's Museum of Pittsburgh.

What was beautiful about the Children's Museum of Pittsburgh was observing the children and adults together. It is a place where the parents are just as engaged in the exhibits. I was mesmerised by an art piece called the 'Wooden Mirror', and as I stood there I watched so many parents see what was happening and grab their children to show them. Another exhibit with balls bouncing into different hoops completely baffled me until I heard a father explain it to his children. He had noticed the mechanism that his children, and even I, had missed. This is a children's museum where the parents *want* to try things out. They even have a very successful MAKEnight[128] for adults, which is a testament to their engagement abilities. This museum not only shows that museums are not just for children, but that *children's museums* are not just for children.

Most museums all over the world where families visit tend to be places where parents often sit and watch (or surf on their gadgets) while children run riot. Maureen Weinhardt from the Children's Creativity Museum[129] asks that people embrace the phone: encourage parents 'to Instagram' pictures of their children at the museum, and to help parents understand how their children are learning. Jen Stancil from the Glazer Children's Museum and staff from the Discovery Center at Museum of Science, Boston[130], said exactly the same. Becki Kipling, Janna Doherty and Katie Baur from the Museum of Science, Boston, ran a hands-on session at ASTC that gave us a good sense of how to work with caregivers who might be disengaged, or feel that the child is 'just playing'[131]. They show parents that children learn through experience, exploration, asking questions, describing, making decisions and learning from their mistakes. Play is so important in learning, and yet many educators and parents do not value it. Playfulness builds social skills, increases creativity and by making actual connections, the cognitive process can aid formal learning too[132].

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[128] https://pittsburghkids.org/events/3002
[129] https://creativity.org
[130] https://www.mos.org/exhibits/discovery-center
[131] http://www.Informalscience.org/learning-about-learning
[132] http://www.maketime2play.co.uk

In Philadelphia, I met with Rebecca Fabiano[133], a consultant working with youth and teens, who said we need to encourage children to play more and allow boredom in order to nurture creativity and imagination. However she thinks parents do not need to be there during all outreach activities. Maybe they could be engaged at the beginning and at the end. We sometimes forget that parenting is hard work and they need wind down time. Perhaps it is more of a balancing act? With my activities I want parents present to see just how engaged their children are, so they can follow up later; and for teachers to see how easily the activities are transferable to the classroom.

I was fortunate to take part in some of the MAKESHOP[134] activities over the Maker Faire weekend, thanks to Lisa Brahms and Rebecca Grabman. The MAKESHOP really was a flexible tinkering space: anyone could come in and learn how to make anything.

Whilst trying to get my head around e-textiles myself (sewing LEDs and batteries in circuits with conductive thread), I noticed a young father juggling his 18 month old and 4 year old, with the latter excitedly wanting to sew several buttons onto a piece of cloth with a repeated pattern of Tutankhamen on it, that he found in the MAKESHOP materials box. I offered to help him, much to the delight of his father, and I was amazed at the dexterity of this 4 year old (he corrected me later that he was actually 4 and a quarter). I watched him as he carefully pushed the needle and thread through the button into the cloth, and peered to the other side of the cloth to check where the sharp point of the needle was. I think even his father was pleasantly surprised. Happily the young boy left saying thank you clutching his piece of fabric with exactly seven buttons sewn all over it. And the quiet hope that his father would now let him sew buttons on his shirts.

But not all parents were as encouraging. Later that day, I watched children turn up who were thrilled at the thought of creating something unique. But their parents refused to let them take a lead, and asked the children to watch while they made items for them. The children looked bored and upset.
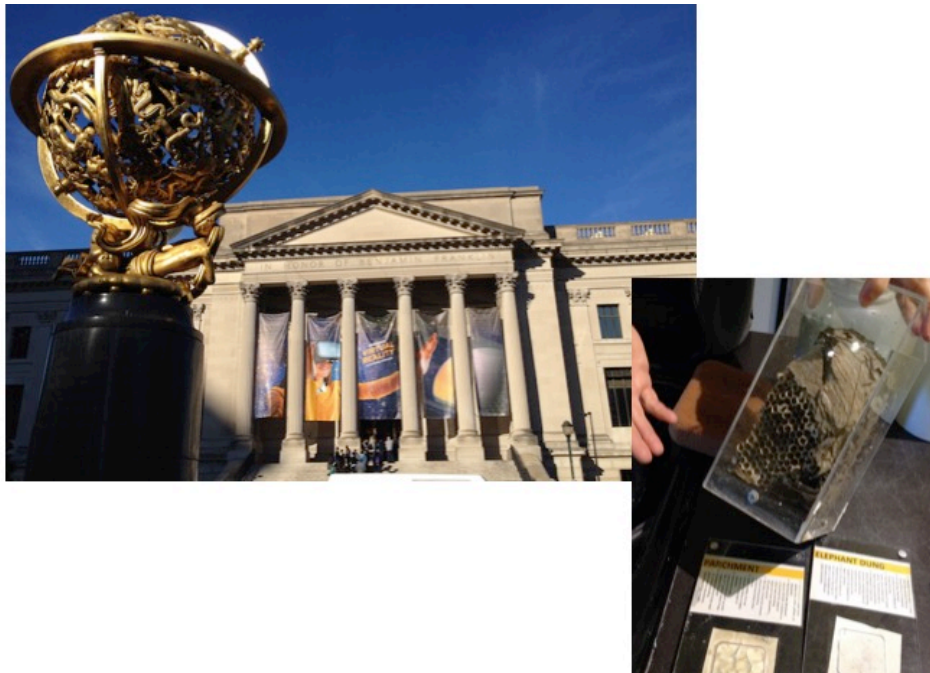
The Franklin Institute and a paper wasp's nest.

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[133] http://www.rebeccafabiano.com
[134] http://makeshoppgh.com

Regardless of how simple the activities are, or whether the tools and materials are readily available at home, the advantage of having such spaces in museums is that there are other people that can help. However Karen Elinich from The Franklin Institute had some views that made me think. The 'maker' movement of fixing, mending and creating is nothing new, it is just a space that people in non-educational areas of the museum feel is needed to keep up with others. Philadelphia has other spaces available in the city and Karen feels that the Institute should offer experiences not gained anywhere else. The Institute has always had make-and-take areas throughout the museum, one being the paper-making station run by volunteers. I made paper too and the volunteer narrated anecdotes about paper wasps' nests and elephant dung. While I was making the paper (as the stand was en route to exhibits) other visitors gathered around to see what I was doing and asked to have a go themselves. This does not always happen in dedicated makerspaces often far removed from the exhibit areas. And when there are only a few people creating, these spaces look messy and empty. That is a lot of time and effort to invest in a bare space.

The general museum visitor does not want to spend time on a project in a makerspace. Especially if they have paid admission fees and have a limited time to see everything in the museum. Offering quick activities does not promote learning, they may as well be colouring in. Parents have often pulled their children away from spaces telling them to hurry up instead of *wasting time*. This is a counterproductive message where children will associate making things with a waste of time. Karen does however see the benefits of using such spaces for 'captive audiences' i.e. afterschool clubs and events.

There may be fewer makerspaces in Philadelphia but there is a lot of collaborative work happening there. Especially bringing the sciences and arts together, or STEAM, through the ExCITe Center at Drexel University[135]. Director Brian Smith showed me round and spoke about his previous experience at RISD[136] and MIT[137], and how the ExCITe Center has a similar philosophy. Brian showed me some of the wearable technology innovations happening as a result of smart materials. This is a far cry from the addition of LEDs to leather jackets, but knitted belts for pregnant women that can record a baby's ECG or transmittable clothing for robots that can make the robot move. I was even shown a robot wearing an outfit that helped him dance to 'Walk Like An Egyptian'[138].

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[135] http://drexel.edu/excite
[136] http://www.risd.edu
[137] http://web.mit.edu
[138] https://en.wikipedia.org/wiki/Walk_Like_an_Egyptian

L-R: ExCITe Center robot dancing, 'Technology' graffiti, Roboceptionist at Carnegie Mellon University's Robotics Institute, MIT Media Lab's Scratch mascot made of LEGO.

Community spaces are probably the way forward, such as Parts and Crafts in Somerville, Assemble in Pittsburgh[139] and Millvale Community Library[140], which are genuine community spaces. It is difficult to know how many local people know of their local makerspace or would feel the need to engage with one. It also depends on the generosity of community champions to run them. Will Macfarlane of Parts and Crafts said that 'Design Squad'[141] on WGBH featured them in one episode, and soon after it aired they had people from as far as Connecticut come over to use their space. As impressive as it was, he did wonder why their local community could not provide for them instead.

Brian Wolovich from Millvale Community Library, a library that is completely sustainable and community-run told me about collaborating with Carnegie Mellon University asking local volunteers to help check air quality with special monitors. They are equally passionate about the 'low and no tech' i.e. turning barrels into windmills, running knit-a-longs, and simply being there for the community: enabling whatever anyone wants to make in their workshop space, to do so.

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[139] http://assemblepgh.org
[140] http://remakelearning.org/organization/millvale-community-library
[141] https://en.wikipedia.org/wiki/Design_Squad
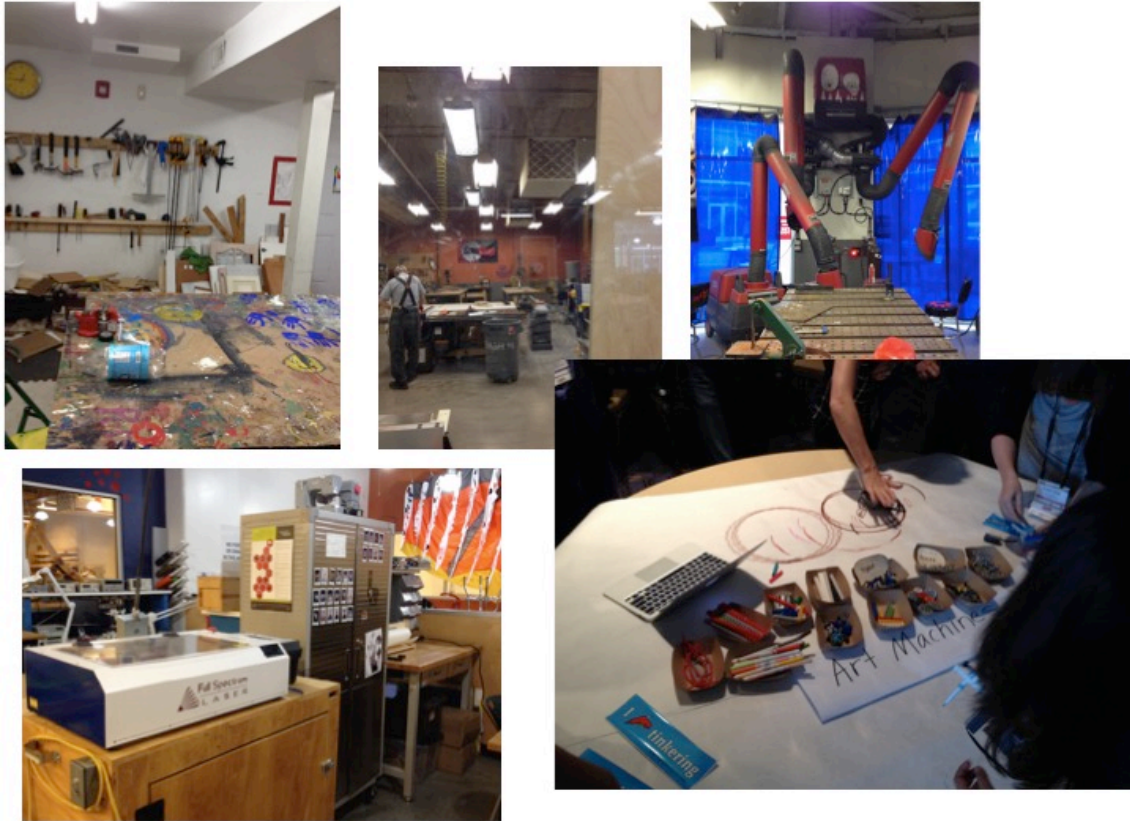
L-R: Parts and Crafts in Somerville, TechShop in Pittsburgh, Tinkering session by Exploratorium at the ASTC conference.

Justin Harvilla of TechShop[142] gave me a tour of their facilities. They have a plethora of gadgets and machines from sandblasters and vinyl cutters to 3D printers and pneumatic tools, and for a monthly membership fee it provides the perfect 'office' for small businesses to operate out of. (The computer software fees alone total much more than the membership fee to use *everything* on site). They offer scholarships for disadvantaged young people to come in and work on projects, and schools often invite the outreach team to train them how to use gadgets and tools that have been donated.

Robert Ware from Penn State University[143] located at the Energy Innovation Center[144] in Pittsburgh, has so much experience with youth from different communities having also worked in Chicago and Orlando. Penn State takes the university to the people, educating them in rural and agricultural studies, assisting with community-based problem-solving, environmental horticulture and quality of life, and has a base in every county in Pennsylvania state. Community engagement is paramount, with projects such as the East Liberty Project 15206[145], a major green infrastructure initiative partnering with the city.

Justin and Robert both mentioned the conflict that can arise from youth of differing neighbourhoods taking part in the same programmes. Because of rapid gentrification in certain areas (such as Bakery Square[146] where there is a Google head office), there can be problems. When a place is very neighbourhood-focussed there is a huge responsibility on the organisation running

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[142] http://www.techshop.ws/pittsburgh.html
[143] http://www.psu.edu
[144] http://www.eicpittsburgh.org
[145] http://pittsburgh.center.psu.edu/project-15206
[146] http://bakery-square.com

the event or activity, to be aware of and understand the historical community differences to pre-empt any possible rifts. Again, it is about knowing your community.

I learnt about the various experiential learning clubs Robert and his team provide for youth, such as horseback riding, urban agriculture, junior master gardeners, robotics, and even collaborating with The Citizen Science Lab[147] (housed in the same building) on bacterial testing. Robert used the 'Pittsburghese' word 'nebby' to describe himself, meaning 'nosey'. He said that by getting to know everyone who is working with youth (in and outside of their building) and communicating with them is the only way to make collaborations happen. It all begins with small conversations.

Collaboration was a key take away from my Fellowship. Robert mentioned asking people and listening to their needs. What is the best way for everyone to serve the community? What do the youth want? And why re-invent the wheel when you could just partner with others? Mandi Lyon from the Carnegie Museum of Natural History and Ellen Doherty from the Fred Rogers Company agreed about partnering. If the YMCA and Girl Scouts already have the programmes and audiences in place, why not work with them? Partnerships are vital for afterschool clubs: local universities, museums and organisations could partner with community-based clubs rather than start up their own.

Nancy Peter from the Philadelphia Education Fund[148] is building such partnerships. She brings together formal and informal educators, connecting them and providing services such as professional development forums. Nancy brought up some points I had not thought of before: 'not all informal education is synonymous with a good education. Good education is multidisciplinary, is more likely to happen outside of normal school settings, and does not have to be academic learning.' We also discussed the terms 'informal learning', 'free-choice learning', and 'out of school learning': depends on whether there is a facilitator or whether the learner is making an active choice themselves to learn. This got me thinking. How many children choose to go to an afterschool club?

The 'America After 3pm Survey'[149] says that 10 million children are in afterschool programmes in America, and that participation and demand is much higher from lower income (73% low income, 66% more affluent) and ethnic households (69% Caucasian, 71% Hispanic, 74% African-American). Over half the parents (70%) said they wanted afterschool programmes to offer STEM. Rural students find it harder to get any good science teachers let alone science engagement opportunities, so afterschool clubs would be a great start. It also seems that museums are unlikely to spend time, effort and money on a club for only 20 children at a time, over several weeks. This is why training community educators and collaborating with others would be the perfect way forward to offer more afterschool science experiences for young people. Many educators like myself have the issue where funders want to see numbers (how many students, teachers, parents etc.) to gauge reach and value for money. However there is much to be said for the social, emotional and empowerment that happens when you see the same children for 8 weeks (or even longer). You may end up working with their siblings, and getting to know their parents who ask for advice on other science resources, careers, places of interest and websites. Science shows and one-off visits to community groups and schools cannot give this same level of engagement.

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[147] http://www.thecitizensciencelab.org
[148] http://www.philaedfund.org
[149] http://www.afterschoolalliance.org/AA3PM

L-R: At the ETC: Anki's Cozmo, The Incredible Hulk, The Simpsons, Mike Wazowski and Sulley (Monsters Inc.), The Last Lecture tribute.

Speaking of collaboration, my favourite place visited during the Fellowship was the Entertainment Technology Center[150] (ETC). Founded 17 years ago by Randy Pausch (of 'The Last Lecture' fame[151]) and drama professor, Don Marinelli, it offers a two-year master's degree in entertainment technology. Students work on projects with communities and companies to develop entertainment for positive social impact.

ETC's emphasis on interdisciplinarity interested me. Director Drew Davidson said that the ETC promotes interdisciplinarity by being multidisciplinary. They bring together talented individuals of all disciplines and help them to learn, to compromise and to work together towards a common goal for good. Students even begin with an improvisation course to get them thinking collaboratively. Drew said that some students cannot do it. They say they want to become freelancers, which made me laugh. As a freelancer myself I work with the largest and most diverse teams. Innovations do not come about from the lone inventor anymore. These courses prepare students for the future and Pittsburgh on the whole is all about this.

This is also what the MIT Media Lab[152] recognises:

'To thrive, people must learn to imagine creatively, reason systematically, work collaboratively, and learn continuously. This is true not just for individuals, but for companies, communities, and even nations as a whole.'

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[150] https://www.etc.cmu.edu
[151] https://www.youtube.com/watch?v=ji5_MqicxSo
[152] https://www.media.mit.edu

Meeting Mitch Resnick, Director of the Lifelong Kindergarten[153] research group was definitely another highlight of my Fellowship. He too mentioned working with communities to find out their needs, and in order to sustain projects people need to feel part of a community (even if it is online as with 'Scratch'[154]).

Mitch told me how the Computer Clubhouses[155] have stayed clear of labels (i.e. STEM) to prevent constraining themselves to a discipline and to ensure accessibility for all. The most successful Clubhouses are the ones where staff have identified and mobilised mentors from within the community i.e. volunteers who want to take part and they see it as a valuable role for them. Mitch mentioned the Citizen Schools[156] model where talented people who want to teach what they are passionate about can give back to the community after school.

Having worked in community and youth groups where feeding people was a huge part of all our events, I never thought to do this during my family science workshops. Many science communication events offer drinks and snacks but what about a family dinner before an activity? The MIT Media Lab did just that with their Family Learning Dinners[157]: families eating together first and then doing some coding.

Mitch also explained the 4P's, principles that they apply to all work within the MIT Media Lab:

- 'Projects: People learn best when they are actively working on projects, generating new ideas, designing prototypes, making improvements, and creating final products.
- Peers: Learning flourishes as a social activity, with people sharing ideas, collaborating on projects, and building on one another's work.
- Passion: When people work on projects they care about, they work longer and harder, persist in the face of challenges, and learn more in the process.
- Play: Learning involves playful experimentation: trying new things, tinkering with materials, testing boundaries, taking risks, iterating again and again.'

Kris Price from the Cloud ArtScience Foundation[158] shared some inspiring stories of the ArtScience Prize[159], where some of the young people close to dropping out of high school applied themselves and won prize money to make their inventions a reality. The process was all about promoting blue skies thinking, not the low-hanging fruit of science fair thinking. The young people in teams of 3-5 have two mentors (paired-mentoring) to help them over 27 weeks to take part in a big challenge. They do some light-touch prototyping and then receive a couple of hundred dollars to turn it into a working prototype to test and present to a jury of venture capitalists and experts in the field. Kris said that watching these young people flourish in a creative safe space away from their troubles at home and school was amazing. I wanted to know more about replication. Is that the best way forward once you have a successful, proven model? Kris mentioned that the programme did replicate, peaking at 23 programmes internationally. His personal feeling was that replicating learning environments should happen very slowly and locally or regionally in order to protect the brand and for all programmes to have the same values. An organisation I came across by accident

[153] https://llk.media.mit.edu
[154] https://scratch.mit.edu
[155] http://www.computerclubhouse.org
[156] http://www.citizenschools.org
[157] http://family.media.mit.edu
[158] http://www.artscienceprize.org/boston/cloud
[159] http://www.artscienceprize.org/boston

on my travels, inspired by the ArtScience Prize, was solely aimed at affluent teens (or more accurately, their parents' wallets).

Looking at technology, Karen Elinich talked about parental engagement and how technology can help. When talking circuits, the classic behaviours would be for parents to either stand aside and let children do the activity or if they are somewhat engaged, get involved and sometimes explain the phenomena incorrectly. The Franklin Institute now has an AR offering that allows the human body to 'be the path' in a circuit and the flow of electrons can be seen. It engages the adults as well as children and can clarify any misconceptions they might have. The education team are continually probing as to how families are best using the experiences. While most VR and AR experiences may be isolating, this kind of learning is still powerful as participants are learning socially (co-constructivism). Jesse Schell also demonstrated their new VR game to me, 'SuperChem VR'[160], which is helping homeschoolers learn practical chemistry skills.

A team of ETC students worked with Elizabeth Forward School to create learning games to use in their SMALLab (Situated Multimedia Arts Learning Laboratory)[161], an immersive environment that uses games to enable students to learn kinaesthetically. They call it the Gaming Academy and use 3D animation and motion capture. As the games were co-created with the school students, they linked to the curriculum and were enjoyed by students. Drew Davison told me that what was interesting about the collaboration was actually the 'role model effect' on the school students: they were more interested in the ETC students than the technology they were using. While technology was the engagement tool, the impact of the role models was incredible. Thanks to such initiatives partnering with cognitive scientists, game designers and technology entrepreneurs, the dropout rate in this school and others in the district has plummeted.

Speaking with Tyler Samstag from the Allegheny Intermediate Unit, I found out about the Center for Creativity[162] that runs free workshops for teachers and offers credit hours in 3D printing, robotics, apps, video editing, and even writing grant proposals to innovate in education. Teachers can come in and experiment, take risks and reflect, and make their ideas come to life. There is a STEAM lending library offering apps and boardgames (i.e. both the digital and tangible). Finding out about the CREATE[163] lab (Community Robotics, Education and Technology Empowerment) was also useful as they explore socially meaningful innovation using robotics and empower students to think about using technology for societal change. They actually engage with educators at the early stages so that the technology will be useful within education, as opposed to many technologists that create what *they* want and then try to shoehorn it into education.

Towards the end of my Fellowship I was beginning to wonder if I needed more 'high tech' in my outreach work, and how to fund this. After all, everything I was seeing was robots, VR and AR. So it was refreshing to meet with Jeremy Boyle (formerly of the CREATE lab, now at the Fred Rogers Center[164]) and Melissa Butler (Kindergarten teacher) from the Children's Innovation Project[165] in Pittsburgh. They talked about interdisciplinarity and using technology as a raw material rather than a tool. For example the same way we could look at a piece of wood and its grain, we can look at the component parts of a mobile phone or a camera and see how to put these together. This is what meaningful technology learning looks like. Children can make connections to objects in their world

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[160] https://www.schellgames.com/games/superchem-vr
[161] http://smallablearning.com
[162] http://centerforcreativity.net
[163] http://cmucreatelab.org
[164] http://www.fredrogerscenter.org
[165] http://www.cippgh.org

such as how their electronic toys work, and make new toys through taking them apart and repurposing. This turns technology into a means of learning rather than an end.

2.6. Diversity, Equity and Accessibility

One of my interests is how to engage diverse audiences and make science offerings accessible to all. In particular for young girls from all backgrounds who think science is not for them, as I have been unable to run science clubs just for girls. (The girls have requested it but schools are unwilling to allow this as 'boys and girls should just get on', and organisations are unwilling to fund in case it looks like 'pink-fluffy-science'. Which is highly unlikely with me running the clubs). I was keen to learn more about afterschool science and engagement activities for girls where the organisations are demonstrating that science (and STEM) is attainable for girls, in a safe environment.

L-R: Girls of Steel, Women in Science exhibit at Museum of Science, Boston, Rosie the Robot (SCFG mascot) and other images from the SCFG training day.

Visiting Science Club For Girls (SCFG)[166] was another highlight of my trip. Kate Pickle, Abby Cheng and the team were so generous with their time. Kate recommended people to meet and Abby had me helping out with training guides for their upcoming mentor training. SCFG connects girls from diverse backgrounds from Kindergarten to Grade 12 (aged 17-18) with female mentor-scientists through free STEM clubs. These clubs not only nurture scientific thinking but also sisterhood, friendship and life skills, and provides a support system for the young girls. I was invited to observe the SCFG training day as I have often wondered about training up a team to deliver in places that I cannot get to, and because I am not particularly comfortable recommending the current training available in the UK for STEM club facilitators.

Connie Chow, formerly of SCFG and now a consultant, explained something that I have been wondering about in terms of the teams I recruit to help with my activities. Although I want enthusiastic, friendly colleagues on my team, I do expect a certain level of knowledge. Connie said

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[166] http://www.scienceclubforgirls.org

that expertise should be valued. If a person does not understand your initial explanation you can use a metaphor or analogy to help them. But that will be difficult if you, as a facilitator, do not even understand the subject enough to choose the right analogy.

What I particularly liked about the SCFG training was that Lead Junior Mentors (Grade 12, 16-18 year olds) led some sessions. These were young women who had been mentors in clubs for many years and had great personal anecdotes to share. To hear their views and opinions was more valuable than anything a professional trainer could deliver. Their sessions on 'personal identity' were eye-opening: from using a diagram to illustrate what makes 'YOU' (qualities that you identify yourself with) they went onto breakdown stereotypes by playing a game with powerful 'I am...I am not...' statements, for example:

'I am a millennial but I am not always attached to my phone...'
'I am Asian but I am not good at math...'
'I am Somalian but I am not a terrorist...'

Their take home message was to understand that we are all the same, but we are all different. And we will be even more different five years from now.

Mentors-to-be were advised to build a rapport, to understand the girls in their club and to help them achieve their goals. And even if they do not know the answer to work with the girls to figure it out together. Watching the SCFG team catch up with mentors that have worked (and grown up) with them for years was inspiring. Also there is no greater feeling than having young people get back in touch years later, because they were inspired by something you helped them with. Ben Dickow from the Columbia Memorial Space Center[167], who has been running a club for many years, told me how he watches these young children grow into teens and young adults and enter STEM fields, saying it is because of the club they attended.

Gregg Behr informed me of The White House Frontiers Conference[168], a one-day event run in conjunction with Carnegie Mellon University and the University of Pittsburgh for 600 learning scientists, technologists and educators from all over the States. The discussions centred around future-facing innovations of how new technologies are being used to improve society's quality of life, under five tracks: personal, local, national, global and interplanetary. I was able to attend the public exhibition where I met the Girls of Steel Robotics[169], a team of young women on a mission to empower girls in the pursuit of STEM. They were demonstrating their chassis building kit (which I was allowed to test drive) used in workshops to introduce middle school students to robotics. It was a real pleasure meeting these enthusiastic girls to find out more about their work and aspirations (many have already chosen a STEM career path).

This Fellowship saw me learning all the time. While reading the in-flight magazine I found an article about Reshma Saujani[170] from Girls Who Code[171] explaining that society expects girls to be perfect and boys to be brave. Since coding is about trial and error, she says that this may be why many girls struggle with it. This is why I feel it is important to have outreach initiatives that allow girls to trial their ideas without worrying about societal pressures. The Entrepreneurial Games Studio[172] based at

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[167] http://columbiaspacescience.org
[168] http://www.frontiersconference.org
[169] http://www.frc.ri.cmu.edu/girlsofsteel
[170] https://americanwaymagazine.com/breaking-silicon-ceiling
[171] https://girlswhocode.com
[172] http://drexel.edu/excite/discovery/egs

the ExCITe Center (responsible for huge city-wide gaming such as playing Pong[173] and Tetris[174] on skyscrapers in Philadelphia) has worked with TechGirlz[175] to encourage more teen girls into computer science through video game design.

Another inspirational programme, run by Betsy Payne at the Academy of Natural Sciences of Drexel University, is called WINS[176]: Women in Natural Science, an afterschool enrichment programme for 9th grade girls (aged 14-15). Girls are from low socio-economic backgrounds from all over the school district and are nominated to apply for the 25 places available. They need to have good grades though need not be top of their classes, and would never have had access to such opportunities.

The girls cover everything from waste, energy, field trips to Hawk Mountain and Bronx Zoo, hiking in the Appalachian mountains, biodiversity, classification and working alongside museum scientists to learning about the museum's collections. In their 2nd, 3rd and 4th years they also learn about finances, college loans and career development. The girls are given development opportunities such as being 'explainers' in the museum, getting paid for their hours of service and also as interns behind the scenes, for example digitising marine biology records. They also receive family membership for a year allowing them to share their interests with their families, many of whom have never visited a museum before. These experiences allow girls (and their families) to see these scientific careers as attainable.

Related to this, Erin Chapman at the SMASH Media Summit described the 'Shelf-Life'[177] series they run at AMNH on the roles of their curators and scientists. They wanted to promote role models and diversity, and although one of their curators who wears a headscarf was initially reluctant to take part, she agreed later saying, 'some day, some girl in a headscarf will see this and think it's okay to do this job.'

Lesley Kennedy and Maria Cabrera at the Museum of Science, Boston mentioned that many of their explainers were retired Caucasians. Whilst they have diverse staff, these individuals seemed to be restricted to canteen and support staff, which was not a good impression to give those diverse audiences coming in. To encourage young, diverse staff they too have intern schemes to train students to become explainers. Something interesting that Lesley said was when she was invited to watch a polo match. She asked her friend what she needed to do, what should she wear and how she was expected to behave? We all have this: the fear of unfamiliar situations. And if we become too anxious, we avoid them. This is how some populations feel about museums and science events.

Maria reiterated what others had told me: the key is to know your community and the right people within the community. They have to trust you and you have to trust them. Maria said that when people see outreach as something you are doing to feel good about yourself, or that it is a marketing exercise, nothing will work. Maria and her staff join community networks, attend their events and even go out to collect individuals in a bus and bring them into the Museum. They do accessible science, for example discussing climate change and renewable energy alongside the solar pizza box oven activity[178] (to make s'mores[179]) without labelling any of this as 'science' or 'STEM'. Maria and others mentioned the 'Museums for All'[180] scheme, where families that have an

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[173] https://twitter.com/TechnicallyPHL/status/625696557648773120

[174] http://www.cbsnews.com/news/tetris-in-the-sky-gamers-play-on-philly-building

[175] http://www.techgirlz.org

[176] http://www.ansp.org/education/programs/wins

[177] http://www.amnh.org/shelf-life

[178] http://www.beyondthechalkboard.com/activity/solar-smores

[179] https://en.wikipedia.org/wiki/S'more

[180] https://www.imls.gov/issues/national-initiatives/museums-all

EBT[181] card (Electronic Benefit Transfer) can use this ID for free (or low cost) admission into a participating museum with four others. I would be interested to know how many people are happy to show the card.

The best museums are the ones that reflect their own community. Karen Elinich said The Franklin Institute is involved in many community projects. Ten times a year they have a community night where they are open for free until later in the evening, targeting poorer families by providing free transportation and making them feel welcome. There is so much to be said for building comfort and ensuring no one feels awkward.

MCG Youth and Arts.

Making students feel welcome and valued is a vital part of outreach and engagement. Eric Brown from the ETC works on 'The Alice Project'[182] and he introduced me to Dave Deily, the Vice President of MCG (Manchester Craftsmen's Guild) Youth and Arts[183]. Eric had attended their ceramics course when he was in high school and now returns to run coding workshops for young people. There were many moving examples of 'giving back' that I noticed on my Fellowship. Dave told me all about the history of MCG Youth and Arts, Manchester Bidwell Trust[184] and the brain behind it all, Bill Strickland.

MCG Youth and Arts is a centre for arts and learning founded in 1968 that offers art studios in ceramics, digital, photography and design. They also offer culinary programmes, chemistry and orchid propagation (at the Drew Mathieson Center[185]) in safe and productive environments

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[181] https://en.wikipedia.org/wiki/Electronic_benefit_transfer
[182] http://www.alice.org
[183] http://mcgyouthandarts.org
[184] http://manchesterbidwell.org
[185] http://drewmathiesoncenter.com

accepting students of any race, colour, and national or ethnic origin. Manchester is a very underserved area with many people in Pittsburgh not even aware of where Manchester is.

The ethos of MCG Youth and Arts is that 'environment shapes behaviour' (the building is beautiful) and 'everyone is an asset not a liability'. They have 300-500 students a year and while the graduation rate for African-American students is nationally low at 47%, here 97% graduate. The students all sign a charter at the beginning of the semester and all the values are displayed in the room at all times so that everyone respects one another.

Dave kindly gave me a copy of Bill Strickland's biography, 'Make the Impossible Possible'[186] which I thoroughly recommend to anyone wishing to know more. Bill had a teacher growing up, Frank Ross, who inspired him to take up ceramics. Purely by throwing a pot and seeing what he could achieve with a mere lump of clay was what kept Bill from leading what could have been a different lifestyle. Bill had a dream to motivate other young people the way Frank Ross had inspired him. The faith and trust that educators have in young people is what *all* young people need. Someone encouraging them and showing them that they can. Just like Frank Ross.

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[186] http://www.bill-strickland.org/buymaketheimpossiblepossible.html

3. Conclusions and Recommendations

Personally I feel I achieved all my aims, and learnt much more than I had anticipated. Maybe not as much from the neuroscience side, but that is to come. Karen Elinich mentioned a fascinating research project to study fMRI[187] brain scans of informal learning in action: mapping everything from the PISEC research, mentioned earlier, onto the brain.

Exhibits at the August Wilson Center in Pittsburgh, Dream Flags at Jefferson Station in Philadelphia and quotations seen in Boston, Pittsburgh and Philadelphia.

Although my focus was on science learning, I visited several art organisations (Rodin Museum[188], The Andy Warhol Museum[189], Philadelphia's Magic Gardens[190] and others) to find out more about their engagement activities and looked at food and sensory outreach activities too (in relation to using kitchen-based materials in my workshops). It was also encouraging to see companies such as Novartis[191] working closely with STEAM schools and creating lab spaces for young people and the public to experiment and meet real scientists. These findings will be discussed in a separate reports, blog posts and presentations.

One question I asked many of the colleagues I met, about the various outreach projects that I have initiated, is that if they are proven to work should I start replicating these and 'scaling up'? From conversations throughout my Fellowship it would seem that replication is possible, but the greatest need is to engage with communities in different regions and address their needs. People (or community ambassadors) need to see the value in order to take on the responsibility of these initiatives themselves.

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[187] https://en.wikipedia.org/wiki/Functional_magnetic_resonance_imaging
[188] http://www.rodinmuseum.org
[189] http://www.warhol.org
[190] https://www.phillymagicgardens.org
[191] https://www.novartis.com

My main findings and associated recommendations going forward are:

- Stories work at all levels: all ages and all different backgrounds. Stories need to be engaging, but not necessarily content-driven or even accurate (especially when working with very young children). The same applies to children's media, as both forms are better used as 'tools' for inspiring further investigation and learning (e.g. the Disney Junior-NYSci partnership) than didactic teaching.

- Storytelling and children's media can reach wider audiences than any other media (because of the associated family engagement). More people can become aware of complex science and new research (e.g. Baymax and soft robotics).

- Cultural understanding, values, citizenship and practical life skills can be communicated through stories and children's media to vast audiences much more effectively than via other methods (e.g. 'Daniel Tiger's Neighborhood').

- Families, parents and caregivers are extremely important gatekeepers in a child's life. Children want to make their parents proud. By supporting families, new generations from any background can aspire to any future they want for themselves.

- Engagement activities do not need to be 'high tech'. 'Low and no tech' are just as valuable. Tools and materials are there to enhance the content (or learning), they are not *the* content (e.g. activities at Maker Faire).

- There is no magic bullet in informal science education. There is no need to scale up initiatives, replicate or produce highly polished resource materials and equipment. High quality, sustained engagement on a small scale with inspiring facilitators is just as important, and more likely to be valued by communities (e.g. CUSP).

- Too many institutions, festivals and events are labelled as 'science' or 'STEM'. Some of the most successful engagement initiatives do not have these words in their title (e.g. Computer Clubhouses, Remake Learning Days). More of us science communicators need to take STEM-based activities out to where the people are. This can improve staff communication skills but also helps appreciate other cultures, leading to a more tolerant society.

- Social learning or co-learning (co-constructivist learning) in families where they link their learning to previous knowledge and memories, as well as playful learning together is extremely important. This not only aids memory but helps nurture a general love for learning.

- We need to help organisations see the value in not eliminating audiences, or purposely targeting certain audiences (to 'tick boxes') without working closely with them beforehand. Befriending communities and winning their trust can lead to successful partnerships. And when planning projects it is vital to involve the communities you aim to engage with (e.g. Glazer Children's Museum water exhibit).

- The role model effect is extremely powerful, and not just in terms of science (e.g. fathers seeing male storytellers, girls going against the 'societal norm'). Many girls, ethnic

minorities and those individuals from a low socio-economic background do benefit from seeing people like themselves in careers or roles they aspire to. Girls are more empowered when working on STEM projects in single-sex environments (e.g. Girls of Steel, Science Club for Girls) and I hope to pilot science club sessions for girls for this reason.

- Allowing children to take a lead wherever possible helps increase their confidence and transferable skills. As much as we have done this in the past, there are still many individuals and organisations that are not comfortable with giving children (especially those from disadvantaged backgrounds) this valuable opportunity.

- Makerspaces allow for equitable (experiences that help individuals draw upon their own interests and cultural backgrounds to participate fully) and expansive (allowing individuals to be creative while simultaneously increasing their STEM skills and knowledge) learning. Informal science activities in such spaces need to be more open-ended, promoting creativity and inventiveness with facilitators who understand this. However museums do not *need* to have these dedicated spaces if others are available nearby.

- Personally I would like to see more networking, collaboration and encouragement of interdisciplinarity amongst colleagues. By partnering with others more resources and expertise can be leveraged leading to truly innovative ideas. As freelancers and small organisations cannot be everywhere there needs to be more collaboration, and more training of facilitators within the community to sustain engagement activities.

Storytelling and children's media are simply two tools that I use. The bigger picture of my work is around family science engagement and learning in general, and I have many thoughts on this topic, which may not be new to readers of this report.

We do a lot of amazing engagement work in the UK, the envy of many overseas. But it is not that there are no great science-based community projects happening here, it is purely that I wish more people working in the field saw the value in it.

A recurring message throughout all my Fellowship meetings was: there is no magic bullet. I feel many of us working in this field forget that. We try out ideas, receive funding for innovative projects and engage with a variety of talented, driven people. Then based on the evaluation think we have the best engagement/educational model. Whereas in fact it all depends on the facilitator, the audience and what you were aiming to achieve. Different people engage differently and whilst the model might work in one place with one audience, it may fail elsewhere, or with a different audience. The more variety of initiatives available, the better. My storytelling model works because the families I engage with are not keen on science or are fearful of it. Stories attract them.

Jessica Lausch mentioned that they may need to organise separate summer camps in the future: one for those children whose parents think they need more science content and one for those who think 'it's summer, let the kids have fun!' It seems this also applies to science communication events too. Elizabeth Mermel Blaeser from Fraggles and Friggles[192], a scientist who wants to attend more 'after hours' science events at museums, said she feels there is nothing suitable for her and others with a scientific background.

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[192] http://www.fragglesandfriggles.com

While I feel there is a place for high-level science engagement: the celebrity-filled science festivals, the science pop-ups at music festivals, popular science books and television programmes, I do think that many audiences are still being neglected. And that this may be getting worse? Connie Chow shared my sentiments about why many adult engagement activities have to be 'beer science', 'cocktail science' or 'sex science'? Why not just make a volcano? There are individuals from different cultural backgrounds that we are not engaging with because of the topics (or venues) chosen for such events. Even during this Fellowship my butter making activity was just as awe-inspiring for adults of all backgrounds as it was for the children. How do we strike the right balance without alienating an audience? Or how do we run separate events and publicise them effectively so that the right target audiences take part and no one is disappointed?

This again comes back to understanding your community and audience. What are we trying to achieve: turn new generations onto science, or make the general public love science or make everyone more scientifically-literate? As Becky Francis[193] has said about the importance of social justice and social inclusion, 'We have a challenge to make sure that we are open to all and that we are able to realise our mission in drawing in people from all backgrounds.' Too many of us become complacent with the work we do, without pushing ourselves to work with those who want and need us. We also need to be aware of the wider perspectives outside of our own bubbles. Tyler Samstag told me how Pittsburgh schools vary tremendously. There are innovative schools showcased in the national media, but a short drive away in Wilkinsburg, all the high schools have closed down. This is a huge issue in terms of social justice and equity. You see inequalities in schools here in the UK too, but particularly in their amount of external STEM provision.

Funding is a huge issue everywhere. Small organisations simply do not have the manpower or expertise to continually apply for funding or sponsorship. It seems to be only the practitioners, such as Rebecca Fabiano and others, actually doing the work that realise the value in offering grants for sustained successful projects. Not just for those projects that need it, or are brand new and risky or innovative.

I understand that funders want to experiment and take risks on novel projects, ideas and people. But as mentioned before, there is no magic bullet when it comes to education. And there never will be, because we are continually engaging new generations of young people, new communities and working with new educators. If something works funders should support these projects and help them evolve with the times, leveraging other contacts, organisations and ideas to sustain such initiatives. Instead many great schemes come to an abrupt end, with grantees following in the footsteps of the funders: chasing after new fashions and ideas.

Many of us have debated the concern around sponsorship: how can you accept funds from a company with an ethos that does not align with your own? There were instances during my Fellowship where I spoke to organisations that had accepted funding from such companies. Their rationale was that if the right messages are at the forefront this would not be a problem, and it all comes down to being true to your mission. I sometimes wonder if I would be in the profession I am in now, had it not been for a particular fuel company sponsoring an educational outreach programme at my university that required undergraduate volunteers. Although I personally could not accept funds from these sources for my work now, I can see why others do.

In the US there are many more grants given to those working with people at an economic disadvantage, and it is good to see that some UK funders are moving towards this now, but there is

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[193] https://issuu.com/uclalumni/docs/ioe

still a long way to go. Engagement should not be about organising one-off events and activities, it should be about sustained engagement with those individuals that need and want it. And in places where these audiences feel comfortable and safe.

With many makerspaces being established in the UK, I would be interested to learn more about these and the collaborations happening over here. However an afterschool club (or family session) does not need a special space. An empty classroom or school hall works perfectly. Afterschool science clubs help the children build relationships and help them gain transferable skills, so much more than formal science learning. By running clubs in schools that already run clubs, and joining forces with other mentors/leaders we can add to the richness, offering novel opportunities for young people.

This is why I love clubs: the sustained engagement, the social learning, the networking with other providers and the community feeling. Participants are allowed to play and explore, there is no curriculum and there is more contact time with a facilitator than with a teacher or science show presenter, because of the smaller groups. In a world where science engagement consists of one-off events and funders counting numbers, I feel there is so much more value in clubs, or at least repeat visits by science communicators and educators: i.e. showing young people diverse STEM professionals, who are not formal science teachers. Many young people within various communities, and their parents, need to see scientists who look like them to see scientific careers as attainable. But also to see what a successful education and someone passionate about learning can achieve. I think this is vital when children do not gain this from their families. Whilst there are STEM Clubs[194], these are often aimed at entering competitions and for the more affluent schools or students.

Technology is a huge attraction in education, which we see at shows such as BETT[195]. This Fellowship showed me both sides, the laudatory engagement with impressive 'high tech' such as AR and VR, but also the amazing examples of 'low and no tech'. 'Low tech' (using simple accessories like cameras and phones) and 'no tech' (using household materials) can be just as impressive and engaging, if not more, for young people and their families to understand certain concepts. And coming back to the role model effect, the deepest level of engagement can be achieved from having a truly inspiring facilitator...regardless of the materials, 'whizz, pop, bangs' and level of technology.

Speaking informally with parents (with scientific backgrounds) during the Fellowship and their thoughts about how they felt slightly pressured into a science career, made me think about 'science capital'. They said they take their own children to museums but felt they were not pushing their children as much as their own parents may have done, in case their children feel the same pressure. Children do naturally want to make their parents proud. Elin Roberts from the Centre for Life[196] recently mentioned that in their exhibit, 'Experiment Zone'[197] when children put on a lab coat and goggles ready to do some experiments and investigations, the first thing their parents do is to take a photo of them and say how proud they are of 'their little scientist'. And you can see the happiness on their children's faces.

Which is why I feel that more family engagement events are needed. Parents need to see what interests their child and find out how to support this. As well as nurturing a love for learning and

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[194] http://www.stemclubs.net
[195] http://www.bettshow.com
[196] http://www.life.org.uk
[197] http://www.life.org.uk/whats-on/experiment-zone

encouraging curiosity and creativity without prohibiting their children or pushing them down a given path.

Many of the organisations I met with, were proof that interdisciplinarity is beneficial. It is rare to find an Art Studio within the Chemical Engineering department (seen at Carnegie Mellon University). Relationship-building is vital, maintaining these contacts and using our own networks to leverage other networks. I am pleased to see that more is being done in the UK[198] to encourage people to speak with those outside of their own discipline, but there is much more that can be achieved than simply talking to one another. While we do have STEM Hubs[199], ASE Field Officers[200] and BSA Branches[201] and many other networks through professional bodies, and informal 'Sci-Comm Socials'[202], perhaps it is time to have a much wider and open network like the Remake Learning Network?

I was extremely humbled to meet so many people working with underserved and disadvantaged populations, that many of their stories made me cry. From turning autistic young men into public speakers and helping a janitor realise his artistic dreams, it was difficult to not feel incredibly inspired. I may not have all the answers (yet!) but this Fellowship has given me a lot of ideas to work on, who to collaborate with, and the confidence that I am on the right path.

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[198] https://www.britishscienceassociation.org/Event/culture-shock-chapter-1
[199] http://www.stemnet.org.uk/regions
[200] http://www.ase.org.uk/about-ase/whos-who/ase-staff
[201] https://www.britishscienceassociation.org/the-branches
[202] http://scicommsocials.co.uk

Education is for improving the lives of others and for leaving your community and world better than you found it.
MARIAN WRIGHT EDELMAN

Seen on the wall at Simmons College, Boston.