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A new direction for public understanding of science: toward a participant-centered model of science engagement.

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A NEW DIRECTION FOR PUBLIC UNDERSTANDING OF SCIENCE: TOWARD A PARTICIPANT-CENTERED MODEL OF SCIENCE ENGAGEMENT

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DEDICATION

To my wife, Kayla, who supported me all the way.

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ABSTRACT

A NEW DIRECTION FOR PUBLIC UNDERSTANDING OF SCIENCE: TOWARD A PARTICIPANT-CENTERED MODEL OF SCIENCE ENGAGEMENT

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Engaging the public with science is not an easy task. When presented, scientific findings, public health recommendations, and other scientific information filter through the personal values, beliefs, and biases of members of the public. Science communicators must contend with these differences in order to be effective in cultivating a public understanding of science. Given the importance of scientific understanding for living well in a complex world, increasing science understanding through science engagement is imperative. The field of public engagement with science is dichotomized by a public information deficit approach and a contextualist approach. The deficit approach prizes the factual content of science, its epistemic authority, and its communication to the public while the contextualist approach recognizes the sociocultural embeddedness of science in society, how science is received by publics, and how local knowledges intersect with science. I contend both approaches are incomplete, and I put forth a synthesis. My approach, the participant-centered model of science engagement, incorporates the factual content of science and its epistemic authority, but in a way that is sensitive to context. I argue for a deliberative democratic approach to public engagement with science and articulate a model inspired by learner-centered approaches to teaching in the formal education literature. I outline and assess six participant-centered strategies along with recommendations for particular practices associated with each.

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CHAPTER I

INTRODUCTION

Dual Crises

There is currently a public health crisis and public information about science crisis in the US. As of this writing (November 2022), the COVID-19 pandemic has gripped the world for over two years. Scientific, medical, and public health misinformation and disinformation have run rampant across social media and other public channels. There is currently no clear, veritable explanation about the origin of COVID-19 (more specifically, SARS-CoV-2, the virus itself); however, we know it to be highly transmissible and carry risks of serious complications for those with underlying conditions. As of November 2022, and according to the World Health Organization (WHO), there have been over 612 million confirmed cases of COVID-19 and over 6.5 million deaths worldwide (World Health Organization, 2022). Public health experts suggested and continue to suggest that it did not need to unfold as it did. Models indicated, and public health experts recommended, that the institution of universal mitigation strategies could have decreased transmission rates and reduced total deaths.

Unfortunately, such recommendations from public health officials and medical experts were not universally heeded or given good faith consideration. In fact, the recommendations of public health officials and medical experts (and those political, business, or other organizational leaders who *did* institute their recommendations) became the subject of obtuse skepticism, vicious mockery, and even outright disdain within the public sphere. Moreover, some leaders who called for, or who had the power to institute, disease transmission mitigation strategies faced death threats from members of the public (Bosman, 2020). Those not in positions of power, but who simply asked that others follow guidelines became collateral damage – for instance, a New York City restaurant hostess was violently attacked by patrons when she asked for their proof of vaccination status (Thorbecke, 2021). The rampant spread of misinformation, disinformation, and the deployment of intimidation strategies is, as I have called it, a public information crisis. Social media posts blatantly misrepresented the dangers of the virus. Politicians nefariously highlighted and manipulated normal scientific disagreement as a reason to reject scientific expertise root and branch. Some news anchors told viewers that things were just not *that* bad. Over the course of a few years, many across the world – particularly in the US – faced the social consequences of science, medicine, and policy.

The pandemic and public health responses to COVID-19 became highly politicized in unfortunate ways with unfortunate social consequences. Some US governors and other local officials called for or signed executive orders mandating the wearing of cloth face coverings in indoor spaces to reduce the spread of the virus. Other US governors rejected such an approach. Some elected officials even went to court against the decision-making bodies in local school districts that wished to institute district-wide mask mandates to protect their students, staff, and faculty. The public divided on mask wearing generally along US political party divides. Republicans were generally opposed while Democrats were in favor (van der Linden et al., 2020).[1] Viral spread mitigation policies, strategies, and practices became the subject of baseless skepticism, rage, mockery, and even violence. As time elapsed, vaccinations for COVID-19 would become available; however, their legitimacy and safety – as well as their uptake – would become another front in the public information crisis.

Vaccine skepticism rooted in misinformation and disinformation is an already prevalent feature of some online communities in the US, but with the politicization of the COVID-19 pandemic response, others would soon join their ranks as the COVID-19 timeline unfolded into late 2020 and 2021. The US Food and Drug Administration (FDA) granted Emergency Use Authorizations (EUA) to two vaccinations – from Pfizer and BioNTech – in December 2020. Both vaccine programs (named programs since they both required two doses) demonstrated high efficacy against spread and pathology in large scale clinical trials; however, the vaccination push would face politicization much as cloth face covering guidance and calls for social distancing. Vaccine hesitancy tracked along political lines just as mitigation strategy guidance skepticism – with Republicans showing much higher levels of vaccine hesitancy than Democrats (Cowan et al., 2021). A preponderance of scientific evidence pointed to wearing cloth face coverings, social distancing, and getting vaccination as the keys to stopping the spread of COVID-19 and reducing severe infection – so why would there be a political divide? There are some answers to this. And some possible strategies to overcome the divides, as we will see in

[1] In studies, researchers asked independent voters which way they leaned.

due course. To be clear, this dissertation is not a dissertation on COVID-19. That would be a failed project given that we are still enwrapped in it as of this writing. Many future social science, natural science, and medical science students will write those dissertations. There are myriad other issues which require re-thinking science engagement and public understanding of science. I bring the COVID-19 pandemic to the fore only because of its relevance to the aims of the project and, on a many-worlds interpretation, the pandemic unfolded in the timeline I found myself living in.

COVID-19 pandemic notwithstanding, other issues call for increased public *engagement with* and *understanding of* science. Global climate change is a similarly concerning issue which requires collective social action from the public; however, political divides complicate this issue too. In August 2021, the Intergovernmental Panel on Climate Change (IPCC) released its Sixth Assessment Report on global climate change. The report, approved by 195 governments and relying on over 14,000 studies, raises the alarm for policymakers to take action or see irreversible and detrimental effects of climate change (Intergovernmental Panel on Climate Change, 2021). According to Dunlap (2013), the divides on climate change – in the US in particular – are due, in part, to concerted disinformation campaigns. He writes, “The primary strategy employed by this campaign has been to ‘manufacture uncertainty’ over [anthropogenic global warming], especially by attacking climate science and scientists” (p. 692). Both the pandemic response and climate change share a collective social action call whereby people must communicate with one another about the issues, the stakes, their interests, etc.; however, other scientific issues open socio-political or ideological divides without the kind of collective action imports which COVID-19 and global climate change have.

A prominent example of this kind of scientific issue is degree of belief in evolution by natural selection. Acceptance of evolution by natural selection has surged in recent years in the US from 40% in 2005 to 54% in 2019 (Miller et al., 2021). Though, as one might expect given the preceding discussion of political divides, gaps in acceptance of evolution by natural selection run along the same political/ideological lines. According to the study, as of 2019, only 34% of conservative Republicans accepted evolution compared to 83% of liberal Democrats (Miller et al., 2021). Given the scientific community's consensus on this matter – among other issues of scientific import – what explains the gap in acceptance? The cases rehearsed so far motivate the need for re-thinking science engagement. The pervasiveness and effectiveness of scientific and health misinformation; distrust of scientists, public health officials, and other science adjacent experts; and hesitancy or skepticism toward some technologies give us good reasons to revise current approaches to engaging the public in science. It is important to admit that no one should seriously demand a univocal public. A cognitively homogenous public is undesirable as such a public would be incapable of birthing new ideas. However, one should expect that public discourse about issues of science and related to science be informed by available evidence and be productive. So, how might we think differently about the problems? How might we do things differently? In this dissertation, I propose a new way, rooted in a pragmatist philosophical orientation and informed by research in education studies and psychological science (among other related fields).

A New Model

In this dissertation, I articulate and defend a novel, revisionary model of science engagement which I argue offers solutions to the challenges of science engagement and public understanding of science. I see the challenges as issues of social or political resistance, content-related challenges to understanding (difficulty in making sense of findings), and issues of trust in science. I call my model the *participant-centered model of science engagement*. The model is novel because it is a public engagement with science model with a deliberative democratic ethos scaffolded by findings in the formal education literature – and no extant models follow this lead. Particularly, my project is inspired by American pragmatism and learner-centered approaches to teaching and learning (which have shown to be efficacious in formal educational settings and beyond).

The participant-centered model of science engagement is applicable in a wide sense. What I mean by this is that science engagement can be conceptualized in two ways, wide and narrow. On the one hand, a narrow concept of science engagement limits it to cases of just informal science education.[2] By informal education, I consider museums of natural history, planetariums, science lectures, STEM (science, technology, engineering, and mathematics) camps, online science video series, or other informal educational content, institutions, and projects. On the other hand, a wide definition of science engagement includes those narrow cases given above but it also includes cases where participants are invited into the process of science either via direct participation (like participatory science or what has been called 'citizen science'), direct feedback and discussion (like science roundtables or consensus conferences), or other bi-directional science and public forums like public comment sessions. Each of the domains I have specified here (with the aspiration of effectiveness in those unmentioned) would do well

[2] I exclude formal education settings – schools – since these spaces have already garnered much attention in the literature; however, I do think one could extend my overall approach to formal educational spaces. I leave this open for future research.

with a dose of deliberative democracy scaffolded by research and practice in the formal education studies literature.

American pragmatist philosopher John Dewey's approach informs the deliberative democratic ethos I envision. Effective science engagement is an amalgam of both educational and social aims and so Dewey's vision of democracy squares well. It is in the learner-centered principles of teaching and learning where I make those educational and social aims actionable. Learner-centered principles of teaching and learning serve to inspire what I call *participant-centered principles* within my proposed model of science engagement. Since (1) learner-centered principles are meant to provide educators with a framework for understanding learners, designing curricula, effectively managing classrooms, and delivering content and (2) relevantly similar practices imbue the work of science communicators and science engagement professionals, the benefit of drawing on these principles for science engagement comes into better focus. A further bootstrap to drawing on learner-centered principles is that they are informed by decades of research in the psychology of learning and practice in education studies.

Cognitive, metacognitive, motivational, affective, developmental, social, and individual differences factors inform the learner-centered principles. Cognitive and metacognitive factors refer to the constructive nature of knowledge and the importance of active self-awareness in encountering and encoding new information.[3] Motivational and affective factors include the finding that more information is encoded by learners when the material to be learned is relevant to the lives of learners – as they filter information through their own belief-value systems (Hidi & Renninger, 2006; Rosenzweig &

[3] By constructive nature of knowledge, this simply refers to psychological constructivism and does not necessarily entail social constructivism in any strong or weak sense.

Wigfield, 2016).[4] Developmental and social factors emphasize that learners encode information differently depending on a number of variables – like age, ability, and so on (Snowling, 2000; Zsolnai, 2002). Lastly, the individual difference factor acknowledges human cognitive, social, and cultural diversity in the processes of learning. The participant-centered model of science engagement harnesses these principles with some modifications from their original applications in formal classroom settings.

The participant-centered principles form a core from which to establish new strategies and practices in the pursuit of effective science engagement. In the dissertation, I *begin* the work of developing and defending some efficacious strategies for engagement in light of the framework established by the principles. Further, I formulate some particular practices professionals and communicators may experiment with in their work. However, I concede that the practices I put forward are only the beginning. Those I propose in Chapters III, IV, and IV will need to be assessed and evaluated empirically. Other particular practices may – and will be – derived from the principle framework, strategies, and the general ethos of the participant-centered model of science engagement. Given the preceding discussion of the effects of the model, if adopted, I turn now to positioning the model amongst the extant models of science engagement and science understanding informing current practices. Much of the literature on these models comes out of the field of public understanding of science.

The field of public understanding of science is a relatively new field of inquiry, all things considered, only taking on an institutional form somewhere in the mid-1980s (Wynne, 1995). The primary academic journal and space for debating values,

[4] John Dewey was one of the first to make this point – see Dewey, J. (1913). *Interest and effort in education*. Houghton Mifflin Co.

frameworks, and presenting empirical research in the young field, *Public Understanding of Science*, was founded a bit less than a decade later (in 1992). As one might expect in any burgeoning field, particularly a field within the social and behavioral sciences (like public understanding of science), foundational theoretical and paradigmatic debates took center stage in the early years.[5] The debate of interest for this project is the framing of the science and society relation.

The Intellectual Landscape in Public Understanding of Science

Two positions on the science and society relation emerge in the public understanding of science literature. The first position goes something like this: The public (read, society), as an entity, has a scientific knowledge deficit as demonstrated by results from large-scale science literacy questionnaires. Science, as a set of institutions, can fill this deficit by providing more scientific facts to the public. Call this the public knowledge deficit approach to science engagement. The second position goes something like this. Publics (pluralized to emphasize heterogeneity) must be understood on their terms as engaged in the processes and products of the sciences. Those studying and connecting with publics must do so in ways relevant to the individual contexts of those publics. Call this second approach the contextualist approach. The deficit approach highlights a problem of *understanding* while the contextualist approach highlights a problem of *engagement*.

Over time, there has been a shift in contributions to the journal *Public Understanding of Science* which track a move from addressing problems of understanding to problems of

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[5] This comment is not meant as defamatory toward the social/behavioral sciences in any way. It is just an observation confirmed by research into the history of the social sciences. They tend to have theoretical framework debates which arise early and can rage, well, forever.

engagement (Stilgoe et al., 2014). Policies, initiatives, and practical experiments have accompanied this shift as well. Bauer (2009) offers an historical account of the evolution of public understanding of science discourse in the literature and in public policy across three distinct periods in the Twentieth Century.

The first period begins in the 1960s and ends in the early 1980s so it mostly pre-dates the institutionalized form of the public understanding of science field of study. Bauer terms this period the "Science Literacy" period and its germ is in the first survey on science perception in the United States from the *National Association of Science Writers* (NASW) published in 1958 (Cortassa, 2016). The dimensions studied in this survey were the following: levels of interest in science and knowledge of scientific information; information sources; understanding of scientific facts, methods and process; attitudes towards science; and images of scientists. The study sampled 1,919 adults (21 or older) – 828 men and 1,091 women – and surveyed their media consumption habits before delving into correlational analyses of interest, knowledge, and attitudes toward science. Cortassa (2016) writes,

> Since the mid-twentieth century, *interest*, *knowledge* and *attitudes* built the frame that accompanied the evolution of these kinds of studies. However, the NASW survey's heritage was not only to set forth the relevant aspects for further research. Even more importantly, its results led to the drawing of an inference about a linear correlation between the cognitive and attitudinal indicators (448).

One reason this conclusion about the linear relation may have been drawn from this study is the "portrait of the science consumer" outlined in its conclusion (Cortassa, 2016). In this portrait, the typical science consumer is male, educated, urban/suburban, Midwestern/Western, and young to middle-aged and that "his interest in science is reflected in a high level of science information" (National Association of Science Writers, 1958, p. 224). Further studies implied a causal role from the cognitive (knowledge about science) to the attitudinal (attitudes toward science) (Cortassa, 2016). In other words, in order to change attitudes, one needed to provide more scientific information to the public. Bauer (2009) writes that this period of public understanding of science research and policymaking was characterized by conceiving the relation between science and society as society having some surmountable knowledge/information deficit. The proposed solution to "fill this gap" was education (in a very passive, fact-giving sense). It is here we see the inklings of the public knowledge deficit approach. In the public understanding of science literature, this approach is variously termed the knowledge deficit hypothesis, the information deficit model, the public deficit model, or just the deficit model. I will henceforth refer to it as the deficit model.

Examples of this type of thinking abound historically and even in contemporary discourse. Historically, consider the following passage from the Director of Public Understanding of Science with the American Association for the Advancement of Science, Edward G. Sherburne, Jr. from a 1965 editorial in *Science*,

> Individual laymen have no one, except perhaps the more responsible representatives of the mass media, to whom to turn for the holistic point of view that the citizen needs. Add to this situation the fact that the high-school or college-educated citizen of today, aged 40, scarcely heard of or imagined during his years in school any of the scientific-social problems he faces as an adult…These facts, and the [National Science Foundation] budget figures cited, point to a gap in national thinking and planning. There is remarkably little formal assumption of responsibility by government agencies for informing and educating the public about problems, and solutions, to which scientific research gives rise (Sherburne, 1965)

The scientific-social problems Sherburne identifies are use of pesticides, threats of automation, smoking and health, choosing science curricula for schools, and automobile exhaust and health. The conclusion Sherburne draws is a kind of “if only they knew” conclusion – something like, “if only the public knew X, they would do/not do Y”. As we will see, this underlying assumption of “if only they knew” is not entirely true. There is a temptation to suggest that deficit model approach has been abandoned in contemporary discourse, but research has indicated otherwise. A recent survey found that scientists, in particular, prioritized defending science as their primary communication objective in online interactions with members of the public rather than engagement-focused objectives like building trust or tailoring messages to contextual factors (Dudo et al., 2016). The continued reliance on a strictly public deficit attitude by scientists or other science communicators motivates the need for continued scholarship on this issue and I take the view that a more dynamic, two-way model offers a richer approach to doing science engagement.

Firm reliance on the deficit model approach continues into the 1990s during a period that has been called the “Public Understanding” period (Bauer, 2009). In this period, as with the last, the identified problem to be solved is the public’s information deficit. The solutions promulgated call for a need for public attitude shifts toward science and the solutions range from education reforms, as the previous period did, however it is also characterized by more emphasis on attitude-change measures and particularly, through targeted public relations (PR) efforts. So, the public (still) has a literacy problem which could be solved through education and, also, science has a PR problem – which could be solved by some outreach or communicative efforts.

Taken together, these two solutions lent themselves to communication strategies designed to make science look informative and trustworthy to a (perceived or real) skeptical public. Most PR practiced amongst scientists and science organizations falls within the category of 'explanatory PR' and this kind of PR is generally referred to as public information practice within the realm of scientific organizations (Borchelt, 2014). Borchelt (2014) explains, "The word [sic] that many people often use in referring to explanatory PR of this type is 'spin control' – making sure the public knows a lot about the science or the scientists, but only the 'right' things that the [organization] thinks the public should know" (149).

He gives two examples of this type of one-way communication practice. First is the UK Department of Health's downplaying and minimizing the risk of bovine spongiform encephalopathy (or otherwise called 'mad cow disease') when it first came to the public's attention. A second example is the reaction from a US national laboratory in Long Island after it was discovered a research reactor's pool was leaking tritium into the groundwater. Lab officials insisted there was no health or safety issue even as residents protested and demanded action (Borchelt, 2014). Both cases demonstrate an image control stance in an attempt to sway public attitudes. Both cases also demonstrate the limitations of this approach. It cultivates public mistrust of science, the institutions of science, and those institutions which deploy science in their operations and recommendations.[6] The public is

[6] The point I am making is that mistrust and science is complicated. It is not always abundantly clear at which target an individual aims when they either implicitly or explicitly mistrust science. One possibility is that one does not trust scientists qua scientific inquirers (that humans lack such a truth-seeking capacity). Another possibility is that one does not trust scientists qua political animals (that scientists have a political agenda, say). Another possibility is that the mistrust is not in scientists, but how governmental or non-governmental agencies deploy science (mistrust in policymakers and not necessarily science). In some cases, the mistrust is a combination of these possibilities. In other cases, it is none of these. I fully admit that mistrust and science are messy.

only invited to participate in communication as the organization sees fit. As Borchelt (2014) writes, “Explanatory PR may employ focus groups, polls and surveys, and other means of finding out what the public knows or thinks in order to determine the right ‘spin’, but it does not engage in any two-way dialogue with its publics” (150). The approach relies solely on a one-directional information exchange – the filling of a deficit one might contend – in order to produce the desired result.

The final period, “Science-in-Society”, finishes out the 1990s and spans to at least 2009 at the publication of Bauer’s article. The problems identified are a bit more complex and they flip the focus from thinking about problems of the public to thinking about problems in the institutions and practices of science. The proposed solutions during this period suggest inviting the public to participate in the processes of science and to encourage public deliberation through science policy roundtables, public comments, and science festivals (Bauer, 2009). This is a marked improvement. It is at this juncture where we can recognize the transition from an understanding-centric approach to an engagement-centric approach. Cortassa (2016) contends that the practices within this final period were born out of influences from the social studies of science, technology, and medicine literature (usually referred to as just science and technology studies – STS) – an interdisciplinary field comprised of mostly historians, and sociologists, but also some philosophers, among others. The approach abandons the deficit model’s underlying theoretical assumption of a public knowledge deficit and a dialectic of science (as the base of knowledge) versus public (as those needing the knowledge which science has). Here we see the blooming of the contextualist approach.

The contextualist model becomes a dominant theoretical paradigm in the field of public understanding of science. The contextualist approach studies how scientific information and findings (and science itself) fits into society-at-large in ways sensitive to individuals, local communities, or other segments of society. For instance, contextualists engage with and analyze programs engaging with local knowledges (for instance, Traditional Ecological Knowledge).[7] In addition to local knowledge engagement, Lewenstein (2003) adds the notion of 'lay expertise' to the landscape. He writes, "The lay expertise model argues that scientists are often unreasonably certain – even arrogant – about their level of knowledge, failing to recognize the contingencies or additional information needed to make real-world personal or policy decisions" (4). Miller (2001) writes that the contextualist approach in the new "Science-in-Society" era jettisons the *interest, knowledge,* and *attitudes* trifecta of the deficit model in bygone eras of Science Literacy and Public Understanding for a new trifecta of *dialogue, discussion,* and *debate*. In other words, the contextualist turn in the literature and in practice encourages public participation and engagement with science. Lewenstein (2003) calls the dialogue, discussion, and debate turn in public understanding of science the 'public participation model' and Reincke et al. (2020) call it the 'dialogue model'. Overall, the general contextualist ethos is toward engaging the public in important and, of course, context dependent ways. I take this to be a marked improvement but have reservations which I will outline below.

[7] Traditional Ecological Knowledge (TEK) refers to knowledge, practices, and/or beliefs regarding relationships between living beings and to the physical environment held by Indigenous populations. See Berkes, F. (1993). Traditional ecological knowledge in perspective. *Traditional ecological knowledge: Concepts and cases, 1,* 1-9.

The contextualist model encourages a more textured view of both science (as both institution and practice) and the public. By a textured view, I mean that the contextualist model is more sensitive to historical and social factors that undergird our understanding of science. And, regarding the public, the contextualist model recognizes that "the public" is not a homogeneous entity – rather, some researchers, as has already been introduced in this chapter, a move to refer to 'publics' in their analyses of issues central to public engagement with science.

Thus far, I have given a brief history of these two approaches – deficit model and contextualist model – as they have emerged in the public understanding of science literature and how they have shaped or informed public policy, academic discourse, and even public discourse about public understanding of science. Further, I have outlined some of the key assumptions and themes in each the deficit and contextualist models.

Limitations of the Deficit and Contextualist Models

At this juncture, I want to turn to assessing these models and showing their limitations. I discuss their limitations to motivate a new way forward – I seek a synthesis of the two, harnessing the virtues of each. Asserting specific criticisms of the models is a complicated endeavor, but there are identifiable issues in each. I have used the terms 'model' and 'approach' when referring to both – this is intentional as they are not formalized in any particular fashion. The deficit model and contextualist models are, in my view, pre-theoretical models as opposed to the kinds of well-defined and explanatory models of phenomena we might find in the sciences. As pre-theoretical models, they are still important, however, as they form the basis for formulating research questions, designing studies, interpreting findings, constructing communications, and putting together learning experiences. It is not possible to identify a well-formed statement of *The Deficit Model* or *The Contextualist Model* toward which to articulate specific and direct criticisms. Instead, I – as others have – must operate by articulating limitations at an understanding of the models distilled from previous research and discussions (Cortassa, 2016; Layton et al., 1993; Wynne, 1991; Ziman, 1991).

With this caveat explicitly made, I begin with a key limitation of the deficit model. The problem I identify is its disregard for “non-epistemic factors”. I call this limitation the *Non-Epistemic Factor Exclusionary Problem*. Turning to the contextualist model, I suggest that the contextualist model undermines the epistemic authority of science. For some, this is a desirable result; however, a deflated notion of science is neither necessary nor desirable for effective engagement and the cultivation of understanding. I call this problem the *Scientific Authority Deflation Problem*.

The Non-Epistemic Factor Exclusionary Problem for the Deficit Model

The limitation I highlight here is that the deficit model undervalues (or ignores) the non-epistemic factors central to what we know about effective science engagement and public understanding of science. I use the term non-epistemic to refer to social, pragmatic, moral, or other considerations regarding knowledge and belief. For instance, an epistemic value might be something like the internal consistency of a set of beliefs. In other words, do the beliefs contradict one another? If so, they must be revised accordingly. A non-epistemic value might be something like the social consequences of having a particular belief. For instance, a belief that it is safe to eat foods grown with pesticides might ostracize one from their family who vehemently disagrees with that view. As discussed previously, the public’s acceptance of scientific findings does not always follow from the presentation of true theories to the public. An effective theory of science engagement must be sensitive to and negotiate with social, moral, and pragmatic factors and not just epistemic factors. I claim this because a wealth of empirical research contradicts an alleged positive correlation between scientific literacy and appraisal or acceptance of science (Dunlap & McCright, 2008; Kahan et al., 2007; McCright et al., 2016).

Attitudes and values toward emerging science and technology may have little to do with knowledge about scientific findings or knowledge of technological capacities. Negative attitudes or divergent values about new scientific findings and technologies have been shown to be ‘functional’ in an anthropological sense (Wildavsky & Douglas, 1983). In other words, the negative attitudes toward some scientific finding or framework provide a basis for individuals to maintain cultural associations within their social milieu. For example, a family may have strong opposition to levying taxes on any business as a kind of “job killing” initiative. For this reason, they may also oppose carbon tax schemes which seek to disincentivize companies from producing additional environmental pollutants, particularly carbon dioxide, a known contributor to global climate change. On the deficit model view, the choice of ignoring “objective” hazards – those hazards that pose a demonstrable, existential risk to oneself or one’s community – should be overcome with more knowledge, but they are not.

Similarly, other predictors can intervene in the relation between knowledge and attitudes. While a significant positive correlation between knowledge and attitudes toward scientific research has been demonstrated, attitudes can vary significantly with specific kinds of research. For instance, when findings or research programs were categorized as “non-useful issues”, “useful issues”, and ‘moral issues’ researchers found varied attitudes (Evans & Durant, 1995). In addition, other predictors intervened on the correlations between science literacy and attitudes toward science – for instance, religiosity, authoritarianism (meaning deference to a political authority), left-right political affiliation, and powerlessness (meaning perceived lack of power in society) (Evans & Durant, 1995). In another example, political orientation was the most reliable predictor of concern over global climate change with level of education acting as an interactive predictor such that more education made one increasingly skeptical (if conservative) and increasingly convinced (if liberal) (Hamilton, 2011). These predictors – political orientation, age, religiosity, authoritarian/libertarian, and so on – complicate public scientific understanding and appraisal of science; however, they are not the whole story. Affective appraisals are also an important driver.

A growing body of literature has shown the effectiveness in emotionally charged rhetoric in anti-vaccination disinformation campaigns (Bean, 2011; Kata, 2010, 2012). One study analyzed affective appeals on anti-vaccination websites. Some of the affective appeals identified were appeals to civil liberties and parental testimonies (Kata, 2010). These sites included presentations of cases where children were taken from parents by social services after it was discovered they were not immunized. Further, “Accusations of totalitarianism were made by 63% of websites. This included warnings that citizens were being prepared for draconian measures in the event of a pandemic” (1712)

Personal testimonies were the most common emotive appeals used on anti-vaccination sites with 88% containing some form. According to the study, “The majority were narratives from parents who felt their children were damaged by vaccines” (1713).

Harnessing the cultural association finding previously discussed, this study also found that "Half of websites included the notion of 'us versus them', where concerned parents and vaccine objectors were portrayed as battling physicians, governments, corporations, or the scientific establishment" (1713). Direct pleas were made by 50% of websites calling for parents to be "responsible" and to make decisions in the best interests of their children – the implication to avoid vaccination. It is widely recognized that emotions are integral to diverse cognitive processes important for learning (Goetz et al., 2006; Um et al., 2012), so it would seem prudent to incorporate this finding in a theory of science engagement.

Empirical findings give reason to think the deficit model's approach to science understanding and science engagement is incomplete. This is not to say that the deficit model is completely ineffectual; however, it is to say that there is a better way of structuring science engagements. The central aim of the deficit model is to present scientific information in a unidirectional way with the expectation that recipients accept the information. One who adopts the deficit model approach might agree to much of what has been said thus far about emotions and social identities. Indeed, they may grant that emotions and identity-protective reasoning are key factors in human cognition. For instance, they might claim that fear is a powerful emotion and that fear could (and perhaps should) be harnessed for science literacy ends. In this way, the deficit model proponent has acknowledged what I have taken as an objection to a strictly deficit approach and assumed it for their own purposes. This revised deficit model proponent's goal – to fill the deficit of knowledge of the public – remains the same as the original version but with some additional non-epistemic tools (for instance, manipulating emotions with science literacy/science engagement as an end-in-view). This move for the deficit model proponent, though, raises some important objections.

The manipulation of emotions with science literacy as an end-in-view raises a clear problem for the revised deficit model defender (*unless* they add on some crucial provisos). The revised deficit approach which manipulates the emotions of members of the public with science literacy as an end-in-view violates the epistemic agency of members of the public. It does this by treating the emotional states and social identities of members of the public as merely instrumental to accepting scientific facts. This revised deficit model approach is objectionable because it rests on a program of mass manipulation. A less manipulative strategy is available. The participant-centered approach does not rely on such a program of manipulation.

Of course, the revised deficit model adherent may assent to the argument this far. They may object to the manipulation strategy and propose a proviso that forbids manipulation via negative emotions as a motivator for the public accepting scientific facts. In this new formulation of the deficit model, it is no longer clear that what we have is actually a strictly deficit approach any longer. The revised approach is akin to a physician abiding by a standard biomedical principle of respecting autonomy (autonomy defined as the right of a patient to determine her own ends). A physician acting in accordance with the principle of autonomy is not, on a reasonable interpretation, manipulating her patient or operating according to a knowledge deficit model.

The participant-centered model's view of emotions and identities is that they are not instrumental to understanding, but that they are part of a cognitive-affective nexus which must be acknowledged and negotiated with to do successful science engagement. For instance, a crucial affective state (with cognitive consequences) is trust. Trust-building and a relationship of trust between participants and science engagement professionals and science communicators is crucial for ensuring the public remains engaged in and is engaged by science (Goldenberg, 2021).

Let us take stock of the Non-Epistemic Factor Exclusionary Problem thus far. I have objected to the deficit model's approach of a unidirectional delivery of scientific information with the expectation members of the public will accept this information. Particularly, the deficit model undervalues or ignores the non-epistemic features of reasoning – those affective, motivational, or social identity features which research demonstrates influence science understanding in important ways. Epistemic factors are important, as scientific information should certainly be prized, but the intervening non-epistemic features must be taken under consideration and negotiated with. I turn now to a limitation of a contextualist approach.

The Scientific Authority Deflation Problem for the Contextualist Model

The contextualist model's vindication of local knowledge, popular knowledge, and individual knowledge (among other liberal epistemic appraisals) is an important reason to think the contextualist approach is incomplete. Lay expertise or popular expertise under a contextualist approach presents challenges to the epistemic authority of scientific knowledge. In this way, the methods of science and indexed scientific knowledge do not carry epistemic privilege. Consider a contextualist approach in Reincke et al. (2020). In what they call the 'dialogue model of science engagement' they state, "non-scientific forms of knowledge, such as cultural and experiential knowledge, are considered to have *equal value* [emphasis added] as scientific knowledge" (2). They maintain use of the term ‘expert’ with respect to scientists, so their deflation of scientific knowledge is confusing. This aim for experts is laudable – that experts should share knowledge, listen and learn from publics, and invest in relationships – however the claim that cultural and experiential knowledge bears equal epistemic value to expert knowledge is objectionable. Instead, cultural/experiential knowledge must filter through the values of empirical adequacy, experimentalism, and other important epistemic values endemic to the sciences.

The problems with valorization of popular or local knowledge is not a new critique of contextualist models. Consider the following passage from Miller (2001) who writes,

> We do not want a public understanding of science political correctness in which the very idea that scientists are more knowledgeable than ordinary citizens is taboo. Scientists and lay people are not on the same footing where scientific information is concerned, and knowledge, hard won by hours of research, and tried and tested over the years and decades, deserves respect (118).

The concern is that elevating and empowering individual knowledges can carry negative consequences – the devaluation of scientific expertise creates a popular expertise.

Contextualist approaches to public engagement with science are largely informed by theoretical frameworks in the science and technology studies (STS) field which, in the past two decades, has had some internal reckonings about its theoretical contributions to the science wars and our age which some have termed ‘post-truth’ (Fuller, 2017; Latour, 2004). Particularly, some STS scholars lament the extent to which STS scholarship served to undermine a durable conception of scientific objectivity – a key feature which grounds the epistemic authority of science. Popular expertise is not necessarily a bad thing, but the components of popular expertise – beliefs and values about the social and natural worlds – must be subjected to critical appraisal and discussion in the public realm. Further, popular expertise or individual experience must have a touchpoint with some reliably truth-conducive standards which adhere to a standard of empirical adequacy. Let me use a hypothetical case to illustrate the issue.

We could suppose that some community is increasingly convinced that their primary water source has become tainted because they collectively report a metallic taste to their tap water. In this scenario, residents begin to circulate the belief that their water source is tainted in their interpersonal exchanges at the grocery store, the hairdresser, the local bar, and so on. This belief, that the water source is tainted, becomes a public truism in the community as a result. Now, an account of popular expertise could end the story here. On this 'popular expertise vindication' view, the community has identified the problem and determined its cause. However, let us further add in the condition of a touchpoint with reliably truth-conducive standards.

Let us suppose that our community members take their concerns to the water company – through a municipal government intervention (citizens press for city council to get involved, say). The water company, as a result, directs their chemist to assess water quality from multiple sites feeding the primary water source in the community. The water company discovers that heavy metals are not present in the water at levels which would yield a metallic taste based on the available evidence. This gives good reason to question the popular expertise narrative of tainted water. Now suppose that a local educational cooperative officer begins investigating the metallic taste issue. Through interviews, research, and testing, she amasses evidence against the water quality hypothesis and proposes an alternative hypothesis: that sustained exposure report to copper compounds in fungicide used on local potato farms is the source of the metallic taste residents. In high enough levels, such exposure lends itself to reports of metallic tastes. While the community was aware there was a problem – and they knew something was certainly wrong – the water hypothesis needed empirical testing. Popular expertise can express interests in useful ways, but it cannot be the whole story.

The Scientific Authority Deflation Problem for the contextualist model motivates the need for an account which has a defensible account of the nature of science as epistemically distinguished. Alternative approaches to science engagement where science is deflated are troublesome for encouraging fruitful dialogue. For instance, consider the deflationary account of science in a science museum exhibit detailed in Reiss and McComas (2021). The authors discuss the exhibit *A Question of Truth: Race, Bias, and Science* at the Ontario Science Centre in Toronto, Canada. In a video promoting the exhibit, the curator stated, “western science is biased ... this exhibition explains that provocative fact” (Reiss & McComas, 2021, p. 719). Reiss and McComas (2021) quote the curator as saying, “There are many ways of knowing … but whose ways are taken to be the real science?” (719). The aim of the exhibit was to show cases where some have used science to justify slavery and discrimination – which are certainly unjustifiable – however, to construe this as reason to suggest that bias and nefarious use undermines scientific objectivity is suspect.

Of course, I recognize that the notion of epistemic authority is fraught. To hold that an individual does not have epistemic authority over her own body, say, is a contentious claim, but this is not what I am claiming. Particular claims of scientists or physicians are not what are being taken as authoritative. Instead, it is the practices and institutions which ground authoritativeness. I am defending the epistemic authority of science within the participant-centered framework where science is a set of democratic institutions which engage the public in democratic ways.

Conclusion and Outline

The intellectual landscape in the field of public understanding of science (particularly as it relates to informal science learning and participatory research) as akin to the field of science studies in the late 1990s and early 2000s. At that time, the field (at least in some corners) underwent a collective reflexive analysis and new research pathways emerged. I am particularly drawn to the diagnosis of the field of social studies of science by Longino (2002). Longino distinguished between, on the one hand, the rationalist approach in philosophy of science which drew attention to purely cognitive values (truth-seeking) in science and, on the other hand, the strong programme sociology of scientific knowledge approach which took science as a set of practices awash in sociological peculiarities. On the former approach, science produces objective truths. On the latter approach, science is one social/cultural institution among many with no special claim to objectivity. In Longino's estimation, both approaches held an implicit commitment to a dichotomy between rationality and sociality. All research proceeded from this, on her assessment, false implicit commitment.[8] Instead, she argued that sociality and rationality are not dichotomous but rather integrative and are hallmarks of science which make scientific knowledge objective (Longino, 1990) and justified (Longino, 2002).

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[8] However, for a critical view of Longino's implicit commitment assertion, see Kitcher, P. (2002). The Third Way: Reflections on Helen Longino's The Fate of Knowledge. *Philosophy of Science*, *69*(4), 549-559. https://doi.org/10.1086/344617

My project finds different research programs from the ones Longino did in her project; however, there are palpable congruencies between (1) the deficit approach in public engagement with science and the rationalist impulse in philosophy of science and (2) the contextualist approach in public engagement with science and the strong programme sociology of scientific knowledge in social studies of science. The deficit model approach and the contextualist model approach are both implicitly committed to the same dichotomy Longino asserted – between rationality and sociality. In the model I propose, science has epistemic authority in virtue of its social character – questions of science are deliberated intra and inter-institutionally amongst scientific experts who bring diverse cognitive resources to bear on matters of scientific frameworks, observations, and biases. Maintaining scientific authority is a key differentiator of my approach from strict contextualism. I am pressing for deliberative practices to be extended into a further realm than Longino – into science engagement spaces which bridge science and the public.[9]

In this chapter, I offered a distinction between science engagement as either narrow or wide and stated my model serves as a fruitful framework for a wide definition – where wide science engagement includes informal learning cases (like museums, planetariums, science talks, science podcasts, and so on) but also direct participation in science (like citizen science projects, science roundtables, and other science outreach and feedback opportunities). The participant-centered model contributes to cultivating a deliberative democratic ethos via both informal science learning and participatory science. Informal

[9] One might press on why I maintain the epistemic or cognitive values of science while concomitantly endorsing a pragmatist philosophical orientation to the project – since a pragmatist might reject a firm distinction between epistemic values and non-epistemic values in the first place. My aim is to carve out a pragmatist approach which coheres with a stance holding that science is an epistemically distinguished endeavor. For a similar pragmatist effort, see Haack, S. (2003). *Defending science--within reason: between scientism and cynicism*. Prometheus Books.

learning spaces are a place where the intellectual and practical habits necessary for democracy can be both sharpened and deployed. Participatory science offers citizens the opportunity to exercise a democratic ethos by engaging in discursive exchange with scientists and science adjacent professionals to the potential benefit of both parties – and, I would argue, beneficial to science itself.[10]

Thus far, I have claimed that there is something useful in each approach – deficit and contextualist. In this dissertation, I put forward an account that recognizes the need for maintaining the special status of scientific inquiry for its epistemic richness. And I do hold that there is a public deficit, but not one diagnosed by survey research on scientific literacy (conceived of as the ability to correctly reproduce scientific facts). Knowledge deficits about science can be filled, but they must be done in a way that recognizes where an individual or community is coming from, what their interests are, and other contextual features. Thus, from contextualist model, my approach will advocate for public engagement with science through deliberative democratic mechanisms and recognize the importance of non-epistemic factors in the practice of science and the appraisal of science by members of the public. I do not aim to suggest that either the deficit model or the contextualist model are incorrect or stagnant research programs; rather, I take each to be simply incomplete. My project aims to integrate features of both into a cohesive and fruitful theoretical framework for conducting research, developing best practices, and

[10] To be clear, I do not advocate that all scientific research programs must take a participatory approach. I laud participatory research's aims; however, there may be good reason for a research program (or just a single research project) to take a non-participatory tack. For instance, in some psychological research projects, if the research participants (or research subjects) were to be involved in the design, execution, or analysis of the research, it might sacrifice the epistemic aims of the research. One example would be research trials where research participants are intentionally deceived in order to study some behavioral phenomenon. If researchers had clued the participants into this experimental condition, the results would be skewed.

actualizing those practices. The evidence supporting my approach is to be found from many different lines of research across multiple disciplines.

The plan of the dissertation is as follows. Chapter II introduces the deliberative democratic vision for the participant-centered model of science engagement. I outline and assess a Deweyan version of deliberative democracy and how this could operate in the space of science engagement between science and society. To fill in this space and offer practical suggestions for structuring science engagement, I lean on insights in the formal education literature – particularly learner-centered models of teaching and learning. Principles and practices for science engagement informed by learner-centered models of teaching and learning are introduced and assessed.

The remainder of the project is the explication and evaluation of these strategies and practices. Chapter III takes up the first two participant-centered strategies of science engagement alongside particular practices aligning with these strategies. The two strategies are to Re-Think Power Structures and Value the Participants and frame how to think about the relationship between participants (members of the public) and science engagement professionals or science communicators. Chapter IV takes up the next three participant strategies – Engage with Belief-Value Systems, Recognize Stages of Development in Learning, and Scaffold Metacognition. These three strategies refer to the psychological properties of participants and how science engagement professionals should take these into account when designing engagement opportunities. Chapter V introduces and assess the final strategy, Encourage Social Bonds. This chapter addresses the social cognition of science engagement and the need for social bonds in order to solve societal problems. Chapter VI serves as the conclusion.

CHAPTER II

DEMOCRACY, INQUIRY, AND PRINCIPLES FOR ENGAGEMENT

Democratic Motivations for Science Engagement

The participant-centered model conceives of science engagement as a dynamic, two-way process for rich exchanges between the public and scientific expertise. Some existing philosophical and social science research programs similarly frame the science and society relation; however, they tend to center on values in science, science communication, and science policy while neglecting other forms of science engagement – like informal science learning institutions and participatory science (Dietz, 2013; Kitcher, 2011; Rogers, 2014).[11] My project seeks to fill this gap. I do this through the introduction of a deliberative democratic approach to structuring science engagements. As well, my account maintains a firm commitment to science as a social, truth-seeking endeavor.[12]

[11] However, see Douglas, H. (2021). *The Rightful Place of Science: Science, Values, and Democracy*. Consortium for Science, Policy & Outcomes.
[12] I am highlighting the importance of science and truth here in order to differentiate my project from some neopragmatist conceptions of deliberativism and democracy which shirk the concept of truth or its pursuit. For a discussion, see Green, J. M. (2006). Pluralism and deliberative democracy: A pragmatist approach. In J. R. Shook & J. Margolis (Eds.), *A Companion to Pragmatism* (pp. 301-316). Wiley-Blackwell.

In this chapter, I begin with a framework for my account of deliberative democracy and why I take both deliberation and democracy to be key features of an account of science engagement. From there, I fill out the account by drawing on classical American pragmatist approaches to democracy and inquiry – particularly the work of John Dewey – and learner-centered models of teaching and learning.

Engagement through Deliberative Democracy

By deliberative democracy, I mean an arrangement where participants have the ability to openly communicate with one another about some issue or problem and work in common toward some resolution. For reasons I outline below, both the elements of deliberation and democracy must be taken together (instead of advocating for just deliberation or just democracy, say). First, deliberation – understood as the communication of interests and their consideration by a group of agents through an iterative process – is a principal element since it recognizes that promoting social communion through communication maximizes the possibilities of engagement and understanding. In other words, when participants are empowered to communicate with (a) one another and (b) with those in science and those who are science-adjacent (science communicators, science engagement professionals, etc.), the participants' interest in and willingness to consider issues of scientific import is increased. I will explore this further in Chapter III. Second, democracy is important since it holds that individuals' interests and claims are openly and equitably considered. The form of democracy I am advancing does not require that all forms of *inquiry* be equally reliable though.[13]

The central holding in my account of democracy is just that all individuals' interests and claims be considered, not necessarily accepted. One might be tempted to suggest this is not a viable account of democracy since it does not endorse equality for both claims and their mode of production (or the process by which one arrived at some conclusion).[14] However, the account is committed to *equity* as a motivation and not *equality*. The equity motivating my account of democracy is spelled out in terms of equality of interests and equal recognition of individuals as sources of claims while not committing to the veracity of the content of the claims or committing to their method of generation. The participant-centered model maintains partiality to some forms of inquiry over others. As far as the reliability of forms of inquiry and its partiality toward certain forms of inquiry, the participant-centered model is committed to the institutions, practices, and norms of the sciences – the sciences construed as experimental, iterative knowledge-generating enterprises. These core features of science (not neglecting the critical social elements) afford it epistemic privilege and warrants partiality toward it.

One way to think about my partiality toward science as a mode of inquiry over others is to compare the analysis to Karl Popper's (1945) treatment of tolerance (the paradox of tolerance) in *The Open Society and its Enemies.* The paradox of tolerance is that

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[13] For the problem of Deweyan democracy and pluralism see Talisse, R. B. (2003). Can Democracy Be a Way of Life? Deweyan Democracy and the Problem of Pluralism. *Transactions of the Charles S. Peirce Society*, *39*(1), 1-21.

[14] See my discussion in Chapter I regarding the town who popularly determined that there was a water quality issue.

tolerance of intolerant ideas within a society can corrode a society from within.[15] To maintain tolerance, as Popper argues, a society may need to be intolerant of intolerance. In the same way, certain forms of inquiry (say, inquiry motivated by creation science or some other non-naturalistic set of assumptions, or an ideological motivation) cannot be said to be on the same par as experimental science. The participant-centered approach is committed to experimentalism and empirical adequacy of hallmarks of science. It is then reasonable to deny the appropriateness of intelligent design or other ideologically motivated forms of inquiry as acceptable forms of inquiry. It is reasonable to be intolerant of such approaches rather than to maintain a stance of equipoise between competing modes of inquiry.

Three Deweyan Insights

With a general picture of deliberative democracy, I move to fill out more details of how this connects with the participant-centered model and its aim of increasing engagement. Context will tend to drive exactly how deliberation functions within a particular science engagement opportunity; however, it is not fruitless to try and stipulate how this might look in advance. I offer some examples to gain some tractability and offer possibilities. The details of the account are inspired by classical American pragmatist approaches to democracy – I am particularly drawn to John Dewey's vision of democracy and deliberation. Three Deweyan insights are useful for filling out the deliberative democratic approach governing the participant-centered model.

Human Conduct: Habits and Science Engagement

[15] For instance, to tolerate the speech of a fascist group that calls for the extermination of some ethnic group in a society is counterproductive. Speech against their speech is insufficient to address the problem they pose.

The first insight is Dewey's general account of human conduct. Dewey's view on human conduct begins with the recognition that humans are naturally social beings who move through the world as a result of habits. According to Dewey, individuals develop habits over time and those habits canalize with successful repetition. To be clear, this should not be construed to mean that humans become automatons over time; rather, it is simply the recognition that previous experience is a reliable guide for future experiences. I offer an overview of how habits figure into the participant-centered model and why I see the Deweyan account of habits as important for thinking about effective science engagement.

Of human conduct, Dewey writes, "All conduct is interaction between elements of human nature and the environment, natural and social" (Dewey, 1922, p. 9). The accumulation of these interactions are what Dewey calls habits. Further he writes, "[Habits] are interactions of elements contributed by the make-up of an individual with elements supplied by the outdoor world" (Dewey, 1922, p. 16). Habits constitute the character of individuals. Dewey characterizes just how central habits are, writing, "They form our effective desires, and they furnish us with our working capacities. They rule our thoughts, determining which shall appear and be strong and which shall pass from light into obscurity" (Dewey, 1922, p. 21). Again, this reading of habits may suggest that they produce an automaton view of human nature, but Dewey's view is not that. He clarifies that "habit does not preclude the use of thought, but it determines the channels within which it operates. Thinking is secreted in the interstices of habits" (Dewey, 1927, p. 235). Habits guide our actions in the world and are the accumulation of our experiences – as natural, social beings.

Some habits are more generatively entrenched than others according to Dewey (1928). The reason for this entrenchment is that some habits provide a cognitive/affective homeostasis, or balance, and they aid us in knowing that the world makes sense and that our actions in the world make sense. He writes,

> The influence of habit is decisive because all distinctively human action has to be learned, and the very heart, blood and sinews of learning is creation of habitudes. Habits bind us to orderly and established ways of action because they generate ease, skill and interest in things to which we have grown used and because they instigate fear to walk in different ways, and because they leave us incapacitated for the trial of them (Dewey, 1927, p. 335)

To explain the deep entrenchment of habits into what we recognize as customs within a community, Dewey explains that the habits, over time, coalesce within communities. Over periods of time, the nexus of these habits congeals into what are typically called customs. Customs guide a community and its members to take appropriate actions as needs or problems arise. An example would be instructive here.

One might consider a coal community in Eastern Kentucky. In Eastern Kentucky and other areas in the Appalachian region, coal and coal mining are revered as an economic engine for communities. So, because of decades of coal mining as the main source of economic development, a community’s habits may coalesce around the centrality of the coal industry for continued success and a hope for prosperity. Of course, as has been the trend over the past thirty years, the coal mining industry’s changes in extraction methods and changes in worker’s rights, the industry and how it contributes to a community look quite different now than a half or three-quarters of a century ago. However, the customs-qua-entrenched-habits in the community may not have changed as quickly as the industry did. I make this last point – about the inertia of customs – to emphasize a worry for the viability of this project. If the participant-centered model is committed to facilitating public engagement with science and promoting public understanding of science, habits must be amenable to change. Dewey's answer to the worry of intransigent habits lies in his account of impulses.

Impulses are starting points for generating new paths of action or thought deviating from the historically entrenched habits. Dewey writes, "Impulses are the pivots upon which the re-organization of activities turn, they are agencies of deviation, for giving new directions to old habits and changing their quality" (Dewey, 1922, p. 67). Impulses are the result of environmental perturbances which, considering the importance of internal homeostasis, require redress. Dewey's examples of impulses include negative emotional experiences – like anger and fear – and the subsequent impact on habits. Frustration might similarly function to amend habits and even positive emotions, like awe, may force one to consider her habits.[16]

The importance of impulses for this account is that they are a place where habits become disrupted. Impulses generate doubt, tension, or move the imagination. Considering the coal mining industry example again – some in the community may see the tension between the past ways of life in coal country and the present realities of the energy markets and take their interests to their neighbors at the grocery store, the town council, or in churches and seek change. They may recognize that the past is no longer the best guide to the future. For successful science engagement, science engagement professionals and science communicators will need to generate impulses in individual agents.

[16] I have in mind a situation where awe – perhaps at the wonder of nature – may force one to consider how her actions (perhaps recycling, reducing carbon output, etc.) could contribute to sustaining nature.

Democracy as a Way of Life: Sociality and Inquiry for Engaging in Science

The second insight is that Dewey conceives of democracy as a way of life. The participant-centered model is both a descriptive and prescriptive project, so it not only considers the ways in which humans conduct themselves in social relations, it also envisions ways in which these relations should change and what institutions and practices must change to facilitate such relational changes. One ideal is to make democracy a way of life for all. Democracy as a way of life means fostering a public that is open to communicative exchanges, confident in the efficacy and outcomes of communicative exchanges, and communicatively well-equipped. For Dewey, democracy structures our social interactions (Dewey, 1939).

Democracy as a way of life is an individual ideal – individuals must practice it in their everyday lives – with social consequences. Clarifying this point, (Dewey, 1927) writes of the nature of the democratic idea in its social sense,

> From the standpoint of the individual, it consists in having a responsible share according to capacity in forming and directing the activities of the groups to which one belongs and in participating according to need in the values which the groups sustain. From the standpoint of the groups, it demands liberation of the potentialities of members of a group in harmony with the interests and goods which are common. Since every individual is a member of many groups, this specification cannot be fulfilled except when different groups interact flexibly and fully in connection with other groups (147).

There is an interactional (or transactional) relation between the individual and her groups. Both the individual and her groups are influenced by these interactions/transactions – or, more appropriately, their mutual participation. The important takeaway is to recognize that living democratically means recognizing that one is a member of many distinct groups – family, neighborhood, social or religious organizations, schools, and work – and that one must navigate these different groups and navigate their contact with one another. What Dewey has in mind is an analogy with the biological concept of symbiosis.[17] The individual and group must stand in a symbiotic relation to one another – through the individual participating in the life of the groups, but also the groups enriching (or participating in the life of) the individual. For Dewey, participation can mean different things. A central mode of participation of interest for the participant-centered model is Dewey's notion of *inquiry*.

Inquiry is an essential element of Dewey's account of democracy. For Dewey (1938b), inquiry is a method of problem-solving. He writes, "Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (108).[18] In other words, inquiry is an intentional and active process of making what is unintelligible and/or intractable, intelligible and/or tractable. Furthermore, Dewey insists that inquiry is context-bound and self-correcting.[19] For Dewey, inquiry, as a contextual and self-correcting process, has twofold aims: to realize personal growth and to participate in community (Johnston, 2006).

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[17] Findings in the biological sciences influenced Dewey's views.

[18] Some have interpreted Dewey's theory of inquiry as monological and raise objections to its efficacy as a theoretical framework for deliberative democracy; however, this is a mistaken interpretation. See Ralston, S. J. (2010). Dewey's Theory of Moral (and Political) Deliberation Unfiltered. *Education and Culture, 26*(1).

[19] A couple of points. First, my account of inquiry will deviate from Dewey's in at least one crucial way. Dewey's account attempts to break with a cognitivist tradition (or subjectivist) and does not deploy mental representations as elements of inquiry. Contemporary enactivist/ecological research programs in psychology have more affinity to a Deweyan approach; however, I maintain a representational stance. I do not make an argument for deploying a cognitivist stance. Second, my account will follow Johnston (2006) in rejecting readings of Dewey's inquiry as either overly scientistic (or positivistic), on the one hand, or overly focused on aesthetic experience on the other. I take the view that modes of inquiry can shift depending on contextual factors.

This connection between inquiry, personal growth, and participation in community is important for it highlights the value of the individual's cognitive composition as well as the value of sociality.[20] By personal growth, Dewey means something like enriching the meanings of future experiences by accommodating the current experience into our existing experiential framework. This is, in part, accomplished by 'grasping' relations between the parts of the situation and thus connecting those parts into a whole. Dewey (1938a) writes,

> As an individual passes from one situation to another, his world, his environment, expands or contracts. He does not find himself living in another world but in a different part or aspect of one and the same world. What he has learned in the way of knowledge and skill in one situation becomes an instrument of understanding and dealing effectively with the situations which follow (p. 44).

The parts of the situation in the environment are what we might call fixed elements. These are factual states of affairs. Regarding the connections between them, I import the term grasping intentionally, here. The mental phenomenon of 'grasping' appears in the epistemology literature on understanding (Kvanvig, 2003; Strevens, 2013) and is a useful way to think about how individuals recognize and act on dependency relations between aspects of a given situation. The other element of personal growth is *how* the enrichment of meanings affects our future states in either positive or negative ways. For Dewey, the aim should be to enrich experiences in a positive sense. Personal growth as an aim of science engagement is an important thread of the participant-centered model since the model aims to cultivate individuals who engage in free and open communication with one another. Let us consider two examples of inquiry and personal growth.

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[20] It is difficult to disentangle the social and cognitive elements without weakening the account of inquiry I develop in this project.

First, suppose that my wife and I take a leisurely trip to California. On this trip, I park our rental car on a street in a bustling part of town and we walk to get lunch. After an hour or so, suppose we return to the street where I had parked the car. As I approach, I notice something is off. I see broken glass on the sidewalk. A fixed element of the situation. I approach faster and notice the rear passenger window of the car has been broken out. Another fixed element. Peering into the rear of the vehicle, I now see that all our luggage and our laptop bags are missing. A final set of fixed elements. The fixed elements of the situation are, of course, related. The broken glass on the sidewalk, at first glance, is indeterminate; however, from this a determinate inference is that something in the environment is a problem. The broken glass is from the window. From this fact, a causal inference from effect to cause – someone broke the window. Of course, a broken window does not always necessitate that someone broke it – just a some*thing*. One consideration is that an escaped antelope from the Oakland Zoo could have rammed it; however, this would not be a live option for a hypothesis given the fixed element of the missing bags. Lest our antelope be a crafty fellow looking for a few bags of clothes and two laptops? Unlikely. The elements of the situation are grasped together into a unified whole. In this case, breaking and entering and robbery.[21] This lends itself to action steps. For instance, going to the police department to file a report, contacting the rental car company, and finding a place to get new clothes. The experience lends itself to personal growth insofar as heed is henceforth taken to the warnings of not leaving bags unattended in a vehicle, locked or not.

[21] In this case, the dependency relations were causal; however, the dependencies need not be causal chains. Dependencies could also be logical inferences. Kvanvig, J. L. (2003). *The value of knowledge and the pursuit of understanding*. Cambridge University Press.

Regarding the case above, two potential issues arise. The first is that one might object that the experience is just a case of learning and not one of personal growth. This would be to misunderstand the concept of personal growth – there are cases of learning which are not instances of personal growth. Dewey uses the example of a young recruit in a gang of thieves. While the thief apprentice might learn how to swindle, steal, and other thief-related activities, she cannot be said to experience personal growth since her future possible free interactions with others are frustrated – as being a thief makes one socially isolated (Dewey, 1916). Second, one might object to the action steps stemming from the example above.[22] For instance, one could object that an alternative outcome of the situation described above might be that carrying a weapon in California is advisable. Or perhaps that one should onboard the belief, “everyone is a criminal” and then to act in accordance with such a categorical belief about the character of others. Either of these is a possible outcome of the robbery experience detailed above, certainly. But, then again, those resulting outcomes would have to be put into the iterative cycle of testing against future experiences. Are my future experiences enriched by either of these results in the space of public deliberation and the world of experience? An important consideration in answering this question is that inquiry ideally facilitates community participation.

In what way does weapon wielding or omnicriminality beliefs facilitate critical experiences between agents – those with diverse backgrounds, beliefs, and so on. Perhaps wielding a weapon might provide some personal relief, but does it strengthen social bonds? In some ways, perhaps. What about the omnicriminality belief? It seems worse

[22] Many have criticized Dewey’s concept of personal growth as lacking direction. I see its roots in Aristotelian *eudaimonia* (or, human flourishing) which is similarly subject to various interpretation. I think it would rob the account of teeth to pull away any normative dimensions to personal growth. For early criticism of Dewey’s concept of personal growth, see Hofstadter, R. (1963). *Anti-intellectualism in American life*. Knopf.

off when tested against future experiences and social bonds. Such a belief guiding habits seems to lead to social isolation and paranoia. What I want to motivate is a way to think about inquiry where personal growth can occur – but also leave open those instances where it does not occur. I want to consider another case of personal growth.[23]

Consider the case of belief in conspiracy theories. Conspiracy theories – as instances of repressive ideological commitments which do not connect with actual experience – corrode the process of successful inquiry. The trouble with conspiracy theorists is that their beliefs are self-insulated (Keeley, 1999; Napolitano, 2021). A self-insulated belief is one which does not admit of disconfirmation by available counter-evidence under normal circumstances – meaning that the conspiracy theorist might admit counter-evidence; however, her standard for what would *count* as counter-evidence would be far-fetched or absurdly high (Keeley, 1999; Napolitano, 2021). Given that the conspiratorial belief is shielded from experience, we could rightfully deny a conspiracy theorist the claim of personal growth through inquiry. The conspiracy theorist does not engage with actual states of affairs and, to make an even stronger point, conspiratorialism defies democracy for it bars effective communication – and democracy breathes only through

[23] Regarding personal growth, Dewey writes, "Experience and education cannot be directly equated to each other. For some experiences are miseducative. Any experience is miseducative that has the effect of arresting or distorting the growth of further experience. An experience may be such as to engender callousness; it may produce lack of sensitivity and of responsiveness. Then the possibilities of having richer experience in the future are restricted. Again, a given experience may increase a person's automatic skill in a particular direction and yet tend to land him in a groove or rut; the effect again is to narrow the field of further experience. An experience may be immediately enjoyable and yet promote the formation of a slack and careless attitude; this attitude then operates to modify the quality of subsequent experiences so as to prevent a person from getting out of them what they have to give. Again, experiences may be so disconnected from one another that, while each is agreeable or even exciting in itself, they are not linked cumulatively to one another. Energy is then dissipated and a person becomes scatter- brained. Each experience may be lively, vivid, and "interesting," and yet their disconnectedness may artificially generate dispersive, disintegrated, centrifugal habits. The consequence of formation of such habits is inability to control future experiences. They are then taken, either by way of enjoyment or of discontent and revolt, just as they come. Under such circumstances, it is idle to talk of self-control." Dewey, J. (1938a). *Experience and education*. Macmillan.

communication. Of course, the lack of personal growth is limited to those inquiries which concern conspiratorial beliefs in this case. In other words, one might be a conspiratorialist about, say, global climate change (believing it to be an elaborate scientific hoax) but still be capable of personal growth in other domains.

By participating in community, Dewey takes individuals to be products of the social institutions of which they are a part – and deeply interconnected with them. Dewey explains,

> As matter of fact every individual has grown up, and always must grow, in a social medium. His responses grow intelligent, or gain meaning, simply because he lives and acts in a medium of accepted meanings and values. Through social intercourse, through sharing in the activities embodying beliefs, he gradually acquires a mind of his own (Dewey, 1916).

Inquiry, in its democratic sense, is a cooperative human pursuit and need not be solely understood as the province of individuals. Inquiry is a social process for solving problems and problems can have different scales. For instance, problems can be interpersonal, local, or societal (and possibilities in between). Problem-solving is done via public deliberation – determining which policy is the best one to try (with the emphasis that the policy is an experiment out of many options) – and differences of opinion about the right course of action will continue to exist (Dewey, 1927). This brings me to the second example of inquiry and personal growth. In this case, I want to show how inquiry, participating in community, and science engagement can all intersect.

Consider the case of COVID-19 vaccinations and reports of changes in menstrual cycles amongst people who menstruate. The first formal reporting of irregular menstruation and the COVID-19 vaccination appeared in The Lily (McShane, 2021). It was reported that many people who menstruate took to social media sites such as

Facebook, Twitter, and Reddit in order to share their experiences of earlier than expected periods, heavier flows, and other irregularities from what they knew of their own bodies all occurring after receiving COVID-19 vaccinations. A particular Twitter thread in early 2021 from Dr. Kate Clancy, a professor of anthropology at the University of Illinois, received so many replies that she and a team initiated a research study to collect data on those who had similar experiences (Lee et al., 2022). In this case, the Twitter thread and other social media posts welled up a particular public – people who menstruate concerned about COVID-19 vaccination. According to McShane (2021), the COVID-19 vaccine trials did not specifically ask about adverse effects of the vaccine on menstrual cycles – in terms of timing and volume.

As more and more COVID-19 vaccine recipients came forward with similar menstrual irregularity experiences, researchers eventually pursued the research question of the menstrual effects of COVID-19 vaccination programs. Collectively engaging in discursive exchange, the public opened new avenues of inquiry in science. In May 2021, the Eunice Kennedy Shriver National Institute of Child Health and Human Development would release a notice of special interest to investigate COVID-19 vaccination and menstruation (NIH Funding Opportunities and Notices, 2021). It would not be until August 2021 that $1.67 million in grants would be awarded to begin the studies (Office of Communications: National Institutes of Health, 2021). As Lee et al. (2022) note, “Vaccine trial protocols do not typically monitor for major adverse events for more than 7 days, and additional follow-up communications do not inquire about menstrual cycles or bleeding. Therefore, manufacturers had no way of addressing the extent to which this observation was a coincidence or a potential side effect of the vaccines” (1). The absent subsequent follow-up questions regarding menstrual cycles in the initial trials led to unfortunate social consequences, but the public inquiry did move researchers to uptake an important research question.

Of course, not all community participation is positive for it can cause discord between individuals or between groups. Dewey uses the example of a gang of thieves as a demonstration of the possibility of inter and intra-group discord (Dewey, 1916); however, let us here consider something more apposite to science engagement. We could suppose that membership in an anti-vaccination group could have relevantly comparable results as the gang of thieves.

Suppose that members of the anti-vaccination group make public utterances or social media posts declaring vaccination programs for children cause autism. Some of the posts might claim that it has to do with the number of vaccines given to children. Some of the posts may specifically target a specific vaccine, like the measles-mumps-rubella vaccine. Others may target a specific ingredient in a vaccine, like Thimerosal (a mercury-based preservative). Such claims of causal links in any of these cases, claims with no evidential support (Farrington et al., 2001; Glanz et al., 2018; Rimland, 2004; Taylor et al., 2014), frustrates this individual's associations in other groups. Though the claim of vaccination being a cause of autism has not been shown to be tenable, if it is entertained as plausibly true, it contains an unfortunate suppressed proposition. The suppressed proposition is this: A person with autism is undesirable. Though I say the proposition is suppressed, it is only barely so. Such dehumanizing rhetoric would sow discord between our anti-vaccination group member and her associations with others who do not carry such negative attitudes (and who do not affirm falsehoods about vaccine programs anyway). Critical engagement with others has the capacity to shift our judgments and force reflection on how we orient ourselves in the world. The hope is that individuals become more public-spirited and aim toward positive social relations.

Democracy and Education in the Realm of Science Engagement

The third insight is the intimate connection between democracy and education. Many classical American pragmatists recognized this connection – particularly Addams (1893/2008), Dewey (1916), and Locke (1945). For the participant-centered model, education (particularly informal science learning) and democracy are intimately linked. Experiences in the realm of science engagement are opportunities to learn (they are educative), to communicate one's own interests, and be communicated with. Science engagement as an educative and communicative manifold is the ideal toward which the participant-centered model aims.

Informal learning (or informal education) tends to be defined against formal education (Scribner & Cole, 1973; Wellington, 1990).[24] Formal contexts are usually defined as compulsory, structured and sequenced, assessed and certificated, more-closed, and teacher-centered just to name a few features. On the other hand, informal contexts are voluntary, unstructured and unsequenced, non-assessed and non-certificated, open-ended,

[24] Some have moved away from relying on the distinction between informal and formal at all. Thus, for these theorists, the focus of the research and discussion is about the process of learning itself and not on the place where the learning occurs. Pragmatically, it is wise to uphold the formal/informal distinction simply for the purpose of distinguishing between the aims of my project – for science engagement professionals and science communicators – and a different project altogether for classroom educators in formal educational settings. Of course, the framework I will articulate is useful beyond the scope I delimit; however, I want to keep focused. Theoretically, I find dropping the distinction appealing since the cognitive processes of learning do not substantially differ from inside brick and mortar and out. For further discussion, see Rogoff, B., Paradise, R., Arauz, R. M. a., Correa-Chávez, M., & Angelillo, C. (2003). Firsthand Learning Through Intent Participation. *Annual Review of Psychology*, *54*(1), 175-203. https://doi.org/10.1146/annurev.psych.54.101601.145118

and learner-centered (Ellenbogen, 2003; Wellington, 1990). Informal contexts vary as they can include intentional and unintentional sources of learning and accidental versus deliberate encounters with learning sources (Lucas, 1983). For instance, an unintentional and accidental encounter with science engagement might be reading a sign about the harmful effects of debris in stormwater run-off at a state park. And an intentional and deliberate encounter might include attending a lecture about Jupiter's moons at the local library. Whether formal, informal, intentional, or unintentional, informal learning, much as formal learning, requires the kind of Deweyan inquiry outlined above.[25]

Education should focus on the realization of one's potential rather than learning some static body of knowledge. To this Deweyan insight, I add that we ought to widen the notion of education to include informal learning contexts as well. Dewey writes, "Were all instructors to realize that the quality of mental process, not the production of correct answers, is the measure of educative growth, something hardly less than a revolution in teaching would be worked" (1916, p. 207). Following an expanded understanding of education, we can be more inclusive as to what we mean by "instructor". We can include science communicators and other science engagement professionals on this account. Doing so shifts the focus of practice toward sharpening the skills required for inquiry. It is important not to lose sight of content (the body of scientific knowledge), however. Dewey's experience and writings illuminate this point.

Dewey had proposed a "progressive education" model in his early writings against, what he called, the "traditional education" model. By progressive, Dewey argues that

[25] Dewey tended to hold that formal education is the whetstone where inquiry is sharpened and he also tended toward a focus on educating children; however, we do see some hope in for informal learning and adult education. See Dewey, J. (1934). The Supreme Intellectual Obligation. *Science*, *79*(2046), 240-243.

educational experiences must align with the possible experiences of students such that those educational experiences make sense for the student. In contemporary education speak, we might call this "meeting the student where they are". His progressive educational model was a reaction against traditional, content-focused, highly standardized models of education where educators take students to be passive vessels. A later commentator on educational models, Brazilian educator Paulo Freire (1970), would refer to the traditional approach as the "banking model of education" since the student is seen as a passive, empty vessel where a teacher simply deposits information.

Opposite traditional models, Dewey opposed what he saw as an overcorrection by those who sought to follow his progressive education ideals but swung too far. He argued that too narrow a focus on the child could be just as detrimental as its opposite. There is a lesson in here for the contextualist. Dewey writes, "the child and the curriculum are simply two limits which define a single process. Just as two points define a straight line, so the present standpoint of the child and the facts and truths of studies define instruction" (1902, p. 16). A critical insight for this project from a Deweyan standpoint is how to navigate the Scylla and Charybdis of deficit model versus contextualist model. From the preceding chapter, it is clear that there is rightful concern for, on the one hand, a deficit oriented narrow focus on epistemic factors – on delivering true content to the public – and, on the other hand, a contextualist oriented narrow focus on the contextual factors of the public.

One publicly available space where informal science learning is a priority is within museums. This was not always the case, however. It was only in the 19th Century when educators were to see museums as learning environments rather than, as it had been, a place to hold research collections and a cultural center for the highly formally educated (Crowley et al., 2014). In the 20th and 21st Centuries museums curators began to focus on designing engaging and educational exhibits. Museums have moved to emphasize their educational mission over other aims. In fact, many museums, like interactive science museums and children's museums, lack collections at all (Crowley et al., 2014). Only very recently have museums moved to consider how to increase impact on both cognitive processes (inquiry skills) and conceptual knowledge (scientific content). The National Research Council (2009) has suggested harnessing the use of technology to augment visits by sending willing visitors follow-up web-based learning and engagement activities to reinforce the cognitive skills introduced during the museum visit and offer additional explication or new conceptual information. This approach has demonstrated some success in changing attitudes and behaviors regarding issues of scientific import (Bueddefeld & Van Winkle, 2018; Pan et al., 2020).

In order to fill out the actionable steps of the participant-centered model of science engagement, I turn to the formal education literature on learner-centered models of teaching and learning. These models – focused on practice – can serve as a guide for science engagement professionals. Learner-centered models of teaching and learning have their roots in the same kind of Deweyan (among others) democratic foundations I rehearsed in the previous section, so their fit as a model for guiding practice makes sense.

Learner-Centered Education

The American Psychological Association (APA) undertook a large-scale literature review in the 1990s and developed a set of learner-centered principles for pedagogical and school reforms. There is little doubt that the learner-centered movement has

Deweyan roots – among others, including Maria Montessori (1912) and later Carl Rogers (1969). The literature base amassed by the APA and subsequent studies have demonstrated the efficacy of learner-centered principles in fostering learning in formal educational settings. Of course, science engagement does not always come in the kind of environment we imagine students in. There are no desks in the exhibits at the natural history museum. There is no chalkboard along the main road in Glacier National Park. I could go on. Formal education is different, but learner-centered models are not necessarily in the business of simply reforming traditional classrooms anyway as I will show. Learner-centered approaches are primarily concerned with the substrata needed to both engage learners and foster learning. No desks or chalkboards needed.

Principles of Learner-Centered Education

The Presidential Task Force commissioned by the APA on Psychology in Education, in concert with the Mid-Continent Regional Educational Laboratory, published the "Learner-Centered Psychological Principles: Guidelines for School Redesign and Reform" in 1993. The task force produced 12 psychological principles which pertained to learners and the learning process (APA Task Force on Psychology in Education, 1993). A review commissioned in 1995 resulted in an additional two principles in the revision ultimately published in 1997 (APA Work Group of the Board of Educational Affairs, 1997). The 14 principles are given below in Table 1 adapted from McCombs (2000).

Table 1: The Learner-Centered Psychological Principles	
COGNITIVE AND METACOGNITIVE FACTORS	Principle 1: Nature of the learning process. The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience.

	Principle 2: Goals of the learning process. The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge. Principle 3: Construction of knowledge. The successful learner can link new information with existing knowledge in meaningful ways. Principle 4: Strategic thinking The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals. Principle 5: Thinking about thinking Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking. Principle 6: Context of learning Learning is influenced by environmental factors, including culture, technology, and instructional practices.
MOTIVATIONAL AND AFFECTIVE FACTORS	Principle 7: Motivational and emotional influences on learning What and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests and goals, and habits of thinking. Principle 8: Intrinsic motivation to learn The learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests, and providing for personal choice and control. Principle 9: Effects of motivation on effort Acquisition of complex knowledge and

	skills requires extended learner effort and guided practice. Without learners' motivation to learn, the willingness to exert this effort is unlikely without coercion.
DEVELOPMENTAL AND SOCIAL FACTORS	Principle 10: Developmental influence on learning As individuals develop, they encounter different opportunities and experience different constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account. Principle 11: Social influences on learning Learning is influenced by social interactions, interpersonal relations, and communication with others.
INDIVIDUAL DIFFERENCES FACTORS	Principle 12: Individual differences in learning Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity. Principle 13: Learning and diversity Learning is most effective when differences in learners' linguistic, cultural, and social backgrounds are taken into account. Principle 14: Standards and assessment Setting appropriately high and challenging standards and assessing the learner and learning progress-including diagnostic, process, and outcome assessment-are integral parts of the learning process.

The fourteen principles are mostly consistent with Deweyan inquiry as I outlined in the preceding section. Admittedly, a strict Deweyan might counter some aspects of the principles. For instance, the use of representations as it refers to knowledge and belief endorses a research tradition in philosophical psychology and psychological science which holds that the mind is furnished with representations, or mental objects which bear a direct resemblance relation to objects in the world.[26] Dewey rejected representations as an inherited ontology from the empiricists (ideas impressed upon the senses) or from the rationalists (concepts mirroring reality). No matter, this is not sufficient reason to reject the principles as they relate to informing a theory of inquiry for the participant-centered model of science engagement. My account of democracy, inquiry, and education are only inspired by Dewey rather than strictly Deweyan. This issue aside, I do however find a set of fourteen principles to be a bit unwieldy. I will instead proceed with a distilled version of these principles.

From the fourteen principles, McCombs and Whisler (1997) distill five 'premises' (I will maintain use of the term principle, however). The five principles are as follows. The first principle holds that learners are distinct and unique. This principle directs us to consider that learners' distinctiveness and uniqueness must be recognized and accounted for in the learning process. The point of this principle is to ensure that learners are engaged qua individual. By this, I just mean that learning opportunities match their interests and connect with their experiences. Furthermore, this principle holds that learners must take responsibility for or internalize their own learning. This amounts to aiding a learner in finding intrinsic motivation for learning through relevant material.

The second principle holds that learners' unique differences must be considered. These unique differences include emotional states of mind, learning rates, learning styles, stages of development, abilities, talents, feelings of efficacy, and other academic and nonacademic attributes and needs (McCombs & Whisler, 1997). This principle directs

[26] Though see Godfrey-Smith, P. (2019). Dewey and Anti-Representationalism In S. Fesmire (Ed.), *The Oxford Handbook of Dewey* (pp. 151-174). Oxford University Press.

educators to appropriately challenge learners and to engage with learners on a level that does not exceed their boundaries – psychological, emotional, or otherwise. The content cannot go beyond the learner's experiences lest they disengage from the process of learning.

The third principle holds that learning is constructive and that the content should be relevant and meaningful to the learner. Constructivist approaches to learning hold that learning occurs within individual agents through the active process of mental constructions within a particular context. New information to the agent is actively incorporated into their existing framework(s) and may require some revisions.[27] In other words, this principle holds that the learner should be actively engaged in constructing her understanding by creating connections between what is being learned with prior knowledge and experiences.

The fourth principle holds that learning occurs best in a positive environment. This means that the learning environment must contain positive interpersonal relationships and interactions both with the educator but also with other learners. Preventing 'othering' or ostracizing learners for having diverging views is an important element of a learning conducive environment. The learning environment or learning context provides individual learners with a feeling of comfort as well as a sense of order. Furthermore, the learner should be made to feel appreciated, acknowledged, respected, and validated (McCombs & Whisler, 1997).

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[27] Some extend constructivism to make further claims about knowledge and reality von Glasersfeld, E. (2002). *Radical constructivism : a way of knowing and learning*. RoutledgeFalmer. His 'radical constructivism' makes a Kantian move and rejects the possibility of knowledge of an objective, mind-independent reality. I do not enter this debate. My constructivism only refers to psychological processes.

The fifth principle holds that learning is a fundamentally natural process. This means that learners are naturally curious and intrinsically interested in learning about and mastering their worlds. An important add on to this principle is that although negative feelings sometimes interfere with this natural inclination, learners must address these negative feelings in productive ways. Learners do not require fixing as though they are broken or defective. Educators must employ strategies for drawing in these learners who have negative feelings (McCombs & Whisler, 1997).

While these principles certainly contribute to envisaging a revisionary model of public engagement with science, one supplementary principle is needed given that all of the principles thus far are plausibly consistent with the deficit model. In other words, all are consistent with a presumption of a rigid epistemic power hierarchy with an expert teacher and novice pupils. This presumption is to a considerable extent apt in traditional educational settings, but the rejection of the deficit model of science engagement is an amendment to this presumption. A direct rejection of the presumption of a teacher with the *sole* relevant expertise is thus an important additional ingredient to the new model developed in this project. Given this, a sixth principle is appropriate. A sixth principle holds that all parties involved may have expertise, ideas, and values relevant to the learning experience, and learning best proceeds from that basis.

Objection and Reply to Learner-Centered Applicability

To this point, much of the discussion has centered on examples and research within traditional classroom contexts and that may seem like an appropriate wedge to drive into the analogy I am making by proposing we think about science engagement much as we think about classroom engagement. Is the difference in context enough to ground a disanalogy? In a K-12 classroom one has a necessarily captive audience. Science engagements, though, are more diverse. They vary widely. From a high-level perspective, while it may seem that formal contexts defy the participant-centered model (explicitly mentioning that they are teacher-centered), they need not.

The reply to the objection is that learner-centered principles are sufficiently general to overcome a claim that they apply only to classroom learning. A survey of the principles shows that they focus upon the nature of learning and the general properties of effective learning environments rather than anything having to do with specific brick and mortar desiderata. These general learner-centered principles have shown effective in a number of different environments. Learner-centered principles and active learning strategies have been shown effective not simply in K-12 classrooms where one has a captive audience compelled by truancy claims against parents and guardians, but in other contexts as well. In an immediately similar setting, higher education, creating learner-centered classrooms with active learning strategies has become an important focus. Omelicheva and Avdeyeva (2008) and Freeman et al. (2014) have shown increases in student learning in traditional college classrooms and, a bit more distal, increases in student learning have been shown in online college courses too (Hannum & McCombs, 2008). Outside of the educational sphere, Naveh et al. (2015) showed how an active learning climate of enactive exploration and guided learning in a hospital setting decreased physician error further showing that the learner-centered ethos and application of active learning principles are translatable to other contexts.

Participant-Centeredness

The language of the six learner-centered principles is directed primarily at those in formal educational settings; however, as I have argued, they are applicable in science communication and science engagement contexts. Just for the sake of clarity, I offer these principles transformed to use the language of science engagement rather than references to learners, in a formal educational sense, in Table 2.

Table 2: Participant-Centered Principles of Science Engagement

Principle	Description
1. Participants are Distinct and Unique	Individual participants are situated in their own socio-cultural spaces, have particular belief-value systems, have varied abilities, and have many interlocking identities.
2. Participants' Unique Differences Must be Considered	The needs of individual participants must be considered when designing science engagement opportunities. These needs can be motivational, affective, cognitive, or otherwise must be taken into account.
3. Content Should be Relevant and Meaningful	Because understanding is constructive (background beliefs and attitudes are relevant), relevant and meaningful content facilitates the cultivation of revised or new understanding. Participants must be active in the construction of their understanding and not passive receivers.
4. Positive Environments are Conducive for Participation and Learning	Science engagement must occur within or cultivate a safe epistemic environment where individuals feel recognized, understood, and validated. Where appropriate, the social character of developing understanding must be harnessed.
5. Learning is a Natural Process	Science communicators and science engagement professionals must recognize that participants are naturally curious and attempt to control or master the world. Any reticence to learning must be recognized and addressed in an appropriate way.
6. Participants Generally have Relevant Experience and Expertise to Matters of Science Engagement	Science communicators and science engagement professionals should value the input and lived experiences of participants.

With these principles guiding practice, a new way forward is possible with new strategies. I venture six general strategies which emerge from the six participant-centered principles.

Participant-Centered Strategies

Given the six principles, some general strategies for a participant-centered model of science engagement emerge. To demonstrate the direction I see each strategy pointing, I offer at least one example practice which would fall under each general strategy; however, I recognize that particular practices which fall under these strategies will need to 1) be developed within a particular context and 2) be directly empirically tested and replicated.[28]

Science engagement will undoubtedly evolve under a participant-centered regime. It will evolve conceptually, practically, and ethically. I present the strategies and practices in Table 3.

Table 3. Participant-Centered Strategies and Practices

Strategy	Strategy Description	Practice
Strategy 1. Re-Think Power Structures	Question the implicit (and traditional) power structure of expert scientist teaching non-expert outsiders to science.	1a. Train Professionals in Positionality
Strategy 2. Value the Participants	Take into account key features of audience, participants, or interlocutor as a group, as well as variation among individuals, and value what they bring to the table. One feature of this is placing trust in their epistemic	2a. Decolonize Science Engagement

[28] As a note, the six engagement strategies are not a one-to-one mapping on the six participant-centered principles offered in the previous section – it is mere coincidence that they both number six.

	agency.	
Strategy 3. Engage with Belief-Value Systems	Activities should support changes to one part of individual participants' structures of beliefs and values, respecting these structures by minimizing extent of requested changes.	3a. Survey Publics to Structure Engagements 3b. Forefront How Science Works
Strategy 4. Recognize Stages of Development in Learning	Craft science engagement goals that match expected features of participants, including their structures of beliefs and values. This may result in a goal that is only one step toward some ultimate goal regarding participant ability, belief, or value.	4a. Implement Guided Discovery Programs
Strategy 5. Scaffold Metacognition	Promote metacognitive awareness and leverage participants' motivations so they become active participants in the engagement experience.	5a. Mindfulness Interventions in Informal Science Learning
Strategy 6. Encourage Social Bonds	Encourage participants to see one another and themselves as resources and supports for the learning in which they are engaging.	6a. Deliberative-Mini Publics as Sites of Change

I will here outline how I will present the strategies and practices in the remainder of the dissertation. The first two strategies – re-thinking power structures and valuing the participants – refer to how science communicators and science engagement professionals must orient themselves toward the participants to science engagement. Thus, I combine these two strategies and term the two together "Science Communicator Relation to the Participant" and outline and assess these strategies and their associated practices in Chapter III. The next three strategies – engaging with participant belief-value systems, recognizing stages of development in learning, and scaffolding metacognition – refer to the habits of mind of participants and how the science communicator or science engagement professional must contend with these. Thus, I have bundled and termed these three strategies together as “Psychological Properties of the Participants”. I outline and assess these three in Chapter IV. The final strategy – Encourage Social Bonds – is a critical strategy in the overall participant-centered model which recognizes the social character of learning, the social character of scientific knowledge, and the social character of our common political situation. I take the six strategies to be comprehensive of the participant-centered model, but the particular practices I offer in this project are but a place to begin.

Conclusion

I have mostly tried to avoid using foundationalist rhetoric like “groundwork” or “foundation” when referring to the development of the participant-centered model, so, instead, I want to say that this chapter outlined the critical threads in the complex web that is the participant-centered model of science engagement. A new way forward for science engagement recognizes the need for science communicators and science engagement professionals – and I really do mean these two categories to include a diverse array of professions – to commit to productive deliberation in a democratic sense. The other thread introduced in this chapter is how a learner-centered model of teaching and learning from the formal education literature has the capacity to actualize the deliberative systems approach the participant-centered model adopts. The six participant-centered strategies inspired by learner-centered approaches fill out the remainder of the project. With the principles and general strategies introduced, it is time to move into a sustained analysis of them.

CHAPTER III

THE SCIENCE COMMUNICATOR RELATION TO THE PARTICIPANT

Elements of the Relationship

Increasing public engagement with science is the central aim of the participant-centered model and this chapter takes up the first two strategies for doing so. I have paired the first two participant-centered strategies, (1) Re-Thinking Power Structures and (2) Valuing the Participants, because they frame the relationship between the science engagement professional and the participant. The participant-centered model is revisionary in many ways and one such revision is democratizing the relation between the expert and non-expert in science engagement contexts. Democratization refers to movements fostering social arrangements structured in a/n (more) egalitarian way. In these arrangements individuals are empowered to fully participate. Pressing for egalitarianism while maintaining a meaningful concept of expertise is difficult given that an expert, presumably, has some sort of advantage over the non-expert. Critically examining the relationship between expert and non-expert does not undo expertise – the participant-centered model does not deny expertise; rather, it navigates the tensions which arise in an expert/non-expert relationship.

The participant-centered model (1) breaks with the deficit model approach of experts unidirectionally delivering information to non-expert and (2) breaks with the contextualist model's rejection of epistemic authority of science, so there are good reasons for treading carefully through issues of power and expertise. Let me unpack each of these claims.

First, my model breaks with the deficit approach because it encourages reflection on and flattening of power relations; it encourages professionals to take participant background knowledge and experience into account; it is attuned to developmental differences among participants and holds that those developmental features be considered in the design of engagements; and it fosters the development of social bonds as an important key to engagement. The unidirectionality of information flow which frames the relation between participant and professional in most deficit approaches assumes that participants have little to nothing to offer in return in a communicative exchange. Such a deficit-oriented relational stance undermines the agency of participants – assuming they are passive receivers rather than active constructors in the communicative context. The participant-centered approach does not adopt this stance and holds that participants do, in fact, have much to offer.

Second, my model breaks with the contextualist approach since it does not dispense with a robust notion of expertise. Certain forms of contextualism dispense with expertise; however, the participant-centered model commits to critically examining the expert/non-expert relation without dissolving it. I accomplish these breaks with extant models by taking a Deweyan inspired approach – democratizing the relation between participant and science engagement professional without sacrificing a commitment to the epistemic authority and epistemic virtues of scientific inquiry.

The plan of the chapter is this. I begin with the first strategy, Re-Thinking Power Structures, and offer an analysis of the overall strategy. I then suggest a particular practice which accords with this general strategy, training science engagement professionals and science communicators on the concept of *positionality*. I offer evidence from the social sciences and formal education literature to support the efficacy of this practice. I then move to the next strategy, Valuing the Participants. I offer an analysis of this general strategy and I argue for a particular practice for science engagement professionals and science communicators to adopt – de-colonizing science engagement. I introduce evidence from the science education literature to bolster this practice as efficacious for increasing engagement of participants.

Re-Thinking Power Structures

Democratic arrangements require that participants engage in communication (or discursive exchange) as more or less equals and many fields of study and practice have re-thought power structures over the past few decades. Researchers and practitioners in formal education, medicine and bioethics, the physical and life sciences, and the social and behavioral sciences have all, in some parts, participated in democratization (Gergen & Gergen, 2000).[29] The reasons for democratization vary by (and within) fields. In medicine, the modern bioethics tradition is rooted in rejection of medical paternalism.

[29] I use the 'some parts' qualifier since democratization is not universally accepted and many maintain a deficit mindset in their research and practice.

Most contemporary bioethicists advocate for bolstering patient self-determination and patient rights in medical care (Beauchamp, 1978; Veatch, 1976). In education, democratization stems from arguments concerning the political and/or ethical foundations of education. Democratization proponents claim that learners should be empowered in the classroom and their voices included in the development and assessment of the curriculum (Biesta, 2007; Dewey, 1916; Freire, 1970). Social science democratization advocates tend to fall into post-positivist research paradigms – constructionist, feminist standpoint, and so on (Karnieli-Miller et al., 2009). These researchers actively work with research participants (or, as some have moved to call research participants – collaborators or co-constructors)[30] on research questions, research design, and interpretation of results (Karnieli-Miller et al., 2009). The commitments to democratization of social science research can have liberatory aims, as within the feminist standpoint tradition (Hartsock, 1983) or a commitment to knowledge as actively constructed within social networks.[31]

In each of the fields surveyed, democratization is about empowering the individuals occupying what we might call the 'non-expert' position in the relation and elevating their status as a knower and an agent more generally. None of the cited fields dispense with expertise; rather, they elevate the non-expert's role and responsibility. Moreover, they import a program of self-reflexivity for practitioners – such that the expert recognizes the proper bounds of their role as an expert. My project forges a similar path for science engagement. The flattening of power relations is important for the participant-centered model since it is a deeply democratic move and facilitates

[30] Use of this term, with concomitant shifts in informed consent practices, works against structural inequalities in research. Douglas, H. (2020). *Science and Social Justice* Doing Science in a Pluralistic Society Colloquium, Dayton, OH.

[31] These are neither mutually exclusive nor jointly exhaustive of the perspectives in social science research paradigms

engagement with science through opportunities for discursive exchange. In the next sections, I offer some conceptual reasons for the claim that reducing power differences increases science engagement and then turn to empirical evidence to further support it.

Power, Expertise, and the Science Engagement Professional-Participant Relation

Asserting that power relations must be flattened between experts and non-experts warrants both an account of power and an evaluation of the problem with power differences between experts and non-experts. Dewey endorses an agency view of power. What this means is that power is tied to one's ability to communicate in the overall communicative manifold.[32] Dewey's agency view of power is useful; however, institutions and other aggregative mechanisms must be recognized as actors too.[33] For this, I turn to Foucault (1977, 1978) for additional analytical tools. He defines power thusly,

> [Power] is a total structure of actions brought to bear upon possible actions; it incites, it induces, it seduces, it makes easier or more difficult; in the extreme it constrains or forbids absolutely; it is nevertheless always a way of action upon an acting subject or acting subjects by virtue of their

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[32] According to some, the American pragmatist tradition in philosophy lacks an adequate analysis of power and Dewey has faced the brunt of criticism. Dewey's commitment to communication as the key to democracy as a way of life does invite questions of how to navigate structural or other forms of oppression. For instance, if a group has been historically excluded from the communicative manifold, how is it that more communication does the work needed to fight oppression and exclusion? One response to this criticism is that Dewey's vision of social interaction and communication does not negate a polity from adopting anti-oppressive practices or policies with the aim that anti-oppressive practices and policies empower all agents to fully participate in the life of those communities. In fact, a polity would be *encouraged* to find ways to maximize.
For problems with Dewey's view of power see Diggins, J. P. (1994). *The promise of pragmatism : modernism and the crisis of knowledge and authority*. University of Chicago Press.
See also Mills, C. W. (1969). *Sociology and pragmatism: the higher learning in America*. Oxford University Press.

[33] Power can also be wielded by an aggregative agent. By an aggregative agent, I mean something like a corporation, organization, or some other socially composite institution. In addition to power being wielded by an aggregative agent, power could be wielded against an aggregative agent, like the public, say. Dewey tends to focus on individuals qua agents and not aggregations qua agents. See Hildreth, R. W. (2009). Reconstructing Dewey on Power. *Political Theory*, *37*(6), 780-807.

> acting or being capable of action. A set of actions upon other actions. (Foucault, 1982, p. 789)

In other words, power refers to an ability to constrain future possible actions. Of particular importance is how agents are constrained in their exercise of actions – communicative or otherwise.

When an agent exercises power they can either 'excite' or 'inhibit' the actions of some other agent. What I call *excitatory power* promotes an agent to act in ways which accord with her own goals. What I call *inhibitory power* frustrates an agent's ability to act in accordance with her own goals. For instance, inhibitory power could be to send a child to her room after she became upset that her Halloween pumpkin carving experience was not going as she planned. She cannot act in accordance with her goals as a result of being sent to her room. Excitatory power could, for instance, be to use one's cachet in an institution to effect changes allowing those historically excluded to participate in policy discussions more fully. The historically excluded now have more communicative agency and can act in accordance with their goals because of our cachet-wielding individual. For this project, I want to focus on cases of power where the upper hand is held due to a knowledge gap – where expertise is a function of advanced knowledge. The kind of power conferred upon the expert in cases where the gap is one in knowledge is what I call *epistemic power*.

Epistemic power can be similarly sub-divided into inhibitory or excitatory. Excitatory epistemic power would be the use of one's knowledge in order to foster another agent's ability to act in accordance with her goals.[34] Inhibitory epistemic power

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[34] I anticipate an objection that excitatory epistemic power could be taken to a logical extent whereby experts wield their power for good in the mold of 'benevolent authoritarians'. The objection does not

would be the use of one's knowledge to frustrate another agent's ability to act in accordance with her goals.[35] For the most part, inhibitory epistemic power is an irresponsible wielding of epistemic power since it undercuts agents from acting maximally as epistemic agents – and the participant-centered model aims to cultivate such individuals with the attending capacities to participate in deliberative democratic engagement opportunities. With a sense of power – particularly epistemic power – I now take up the matter of responsible wielding. Findings from the formal education literature inspire the participant-centered model, so I turn there to make a few points which are instructive for thinking about wielding epistemic power and democratization. I forge an analogy between models of education and models of science engagement to lean on findings in education studies for my claims about the effects of power and science engagement.

Power, Expertise, and Education

In education, one finds parity in models of education and models of science engagement. Consider Dewey's categorizations of education models as a starting point for setting up the analogies. Dewey critiques two models of education he observed in his

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succeed given that an opposing principle in the overall participant-centered model is to develop the deliberative democratic skills which allow for critical participation in the public sphere. The principle of developing agency in participants is a backstop against someone acting in the participants' best interests as a benevolent authoritarian.

[35] A few clarificatory points. First, I have not said that the conferral of epistemic power on the expert is always just. One could say that expertise is contextual – the physician may have a level of knowledge about anatomy and physiology which exceeds that of the patient; however, the patient has firsthand expert knowledge of her body. I would agree. Epistemic power does not confer absolute authority. At this point, the analysis I am offering in the text is descriptive and not prescriptive (though I recognize the difference between these can be one of degree and not dichotomous). Second, and relatedly, I have not articulated what counts as expertise. I have claimed science maintains epistemic authority due to its epistemic richness and self-correcting capacities, but other domains may not – say history, economics, or some other fields. I have not ventured any necessary and sufficient conditions. Third, nothing I have said so far suggests that experts should be shielded from feedback. In fact, the participant-centered model requires a feedback relation between science communicators and members of the public.

time: the traditional model and the child focused model. On the one hand, traditional education models focused on a curriculum filled with content divorced from student experience and delivered unidirectionally in rigid classrooms. The traditional model conceived of students as passive receivers of information and did not prepare children to become active citizens. On the other hand, child focused models relied on chaotic freedom for students in the classroom with an inchoate curriculum (driven by whatever students decided to focus on in each moment) (Dewey, 1902, 1938a). Dewey frames the differences between these two approaches thusly, “The history of educational theory is marked by opposition between the idea that education is development from within and that it is formation from without; that it is based upon natural endowments and that education is a process of overcoming natural inclination and substituting in its place habits acquired under external pressure” (Dewey, 1938a).

In the traditional education model, one sees echoes of the deficit approach to science engagement. In the traditional model, the focus is on delivery of content and, further, teachers do not deem feedback from students as useful or informative to the lesson. The connective tissue in the analogy between the traditional model of education and the deficit model of science engagement is 1) the unidirectionality of the delivery; 2) the focus on content; and 3) the positioning of the students/public (the non-expert) as passive receivers of content. In the child focused education model, one sees echoes of the contextualist approach to science engagement. The focus is on the children and their interests and structure (or guidance) interrupt the learning process. The connective tissue in the analogy between the child focused model and the contextualist model is 1) a focus on the activities of the students/public and 2) the positioning of the students/public as active constructors of content. With these analogies sketched, I want to draw on the empirical education literature and motivate the claim that on the one hand, a deficit model approach tends toward using inhibitory epistemic power with some negative consequences for engagement. On the other hand, a contextualist model approach tends toward excitatory epistemic power with some negative consequences for expertise.

In contemporary formal education literature, one finds that teachers who follow a traditional education approach often meet resistance from students (Brooke, 1987; Linehan & McCarthy, 2000). The traditional approach here means that teachers refuse (or deem irrelevant) student input into the content of the lesson in the classroom. For instance, students who bring in popular culture references to a classroom discussion in order to make sense of a concept would be denied or discouraged in the traditional approach. In this way, the teacher is exercising inhibitory epistemic power over the students by refusing feedback and not engaging the students in this way. The teacher is situated as the knowledgeable one – an expert who directs what is important and what is not – and renders the students as incapable of appropriate participation and tamping down future participation (Vetter et al., 2013).

Denying student feedback as relevant leads to student disengagement (Duncan-Andrade, 2004; Vetter et al., 2013) or a feeling of alienation (Mann, 2001). Dewey prefigures these findings writing, “The notion that some subjects and methods and that acquaintance with certain facts and truths possess educational value in and of themselves is the reason why traditional education reduced the material of education so largely to a diet of predigested materials” (Dewey, 1938a, p. 44). Though he does not explicitly refer to engagement/disengagement, he sums the disengagement consequences of inhibitory epistemic power wielded against students thusly, “If the pupil left it instead of taking it, if he engaged in physical truancy, or in the mental truancy of mind-wandering and finally built up an emotional revulsion against the subject, he was held to be at fault” (Dewey, 1938a, p. 44), To be clear, this is not a complete indictment of the traditional model in toto; rather, it is an indictment of resisting feedback from learners and divorcing content from the experience of students – which leads to learner disengagement.

Of course, it is important to be similarly cautious of the child focused approach. The child focused approach devalues a structured curriculum and instead places direction of learning in each student’s interests. Dewey frames child focused models thusly, “because the older education imposed the knowledge, methods, and the rules of conduct of the mature person upon the young, it does not follow, except upon the basis of the extreme Either-Or philosophy, that the knowledge and skill of the mature person has no directive value for the experience of the immature” (Dewey, 1938a). Limited empirical research shows that a deviation from content and a focus on strictly contextual factors leads to student resistance, less higher-order thinking, and student frustration with a lack of order (DiCamillo, 2010; Pace, 2003; Page, 1991).

Conceptually, the very exercise of reducing the teacher’s role to a guide and the absence of a structured curriculum warrants the reasonable conclusion that expertise is devalued in such models of teaching and learning. It is no doubt that the teacher in such classrooms wields excitatory epistemic power insofar as she encourages the whims and interests of each student – these classrooms are indeed described as “fun” (DiCamillo, 2010). The child focused model is admirable in this way, but, again, the limitation is the loss of a coherent curriculum and the value of educative experiences. Against both the traditional and child focused models, models which position the teacher in a more egalitarian way while simultaneously encouraging student participation and a feedback loop show promise in the literature.

Studies of teacher-student dialogue and relations show that uptake of student interests is beneficial to learning and engagement (Ainley et al., 2002; Palmer, 2005). For instance, researchers found that students invoke popular knowledge (i.e., content from music lyrics) in classroom discussions in order to make sense of content from a particular lesson. Teachers who resist or do not uptake these perspectives and interests undercut the agency of students as active, deliberative, and co-constructive learners. When students are able to bring local or popular knowledge into the classroom discussion and it is explicitly connected with the lesson, students were more engaged and the teacher and students co-constructed knowledge in the classroom (Gutierrez et al., 1995; Vetter et al., 2013). The co-constructive nature of teaching and its positive outcomes for engagement frame the kind of excitatory epistemic power I have in mind for the participant-centered model of science engagement. Referring back to a trope in Dewey, the students know where the "shoe pinches" (1927, p. 207) – their lived experiences and relevant ideas should be considered and incorporated into the discussion and connected to the content.

Some Limits to the Analysis of Power

Thus far, the account of epistemic power and responsible power-wielding has assumed that those who are in the non-expert position in the relation are acting in good faith.[36] Consider a case of a physician who resists the claims of pain by a patient. The

[36] By "good faith" I mean that the agent's stance is genuine and sincere with an absence of deception or malintent. Bad faith, then, is definable as its opposite.

patient is acting in good faith since she has sought out care, is reporting her conditions as she knows them, and has reasonable expectations about how a communicative interaction ought to unfold in a medical context. There is no reason to suspect deception or insincerity on the part of the patient; however, some good faith actors may still pose a problem for science engagements.

Consider a good faith actor who wishes to be involved in a participatory research project – suppose it is toward the end of the project and the lead researchers have made the data analysis a participatory element. Further suppose our participant lacks the statistical dexterity to do the analyses requested by the lead researchers. It would be reasonable for the lead researchers to redirect this willing and good faith participant to some other aspect of the overall project. Perhaps participating in the discussion section of the research. In this case, the participant (our non-expert) is being inhibited as a result of an epistemic gap and the inhibition, at least in this hypothetical case, seems reasonable.

Bad faith actors present a different challenge. For instance, consider the phenomenon of "trolling" (Donath, 1996). Trolling refers to an individual intentionally deceiving others by saying (or posting in an online forum) something intended to bait others into responding – typically something which draws upon deep emotional or identity-threatening issues. Trolls act in bad faith since their intentions are to deceive, confuse, or frustrate others in a communicative context. The question, then, is how should an expert wield epistemic power toward a troll? If one takes an excitatory approach, one potentially empowers the troll to continue trolling. Imagine a troll at the observatory gleefully claims that the Earth is flat and claims to have done their research to prove it. In both hypothetical cases given – the bad faith actor and the good faith actor

– epistemic inhibition was warranted and so something must affirm the warrant in the face of the participant-centered model's commitments.

Decidability on whether an inhibitory act is warranted is placed in trust maintenance – or a background condition of trust. A troll undermines the trust relationship in a science engagement context by subverting the flow of information between science communicators or science engagement professionals and attending participants. With scientific misinformation, disinformation, or irrelevant information, a bad faith troll seeks to disrupt information flow and destruct any semblance of cultivating science understanding where the general norm is to be constructive. The tack I am urging is to take the stance of being intolerant of intolerance in order to maintain a stable communicative and learning context (Popper, 1945).

Science engagement professionals should exhibit discretion with shutting down cases where a trust-undermining agent threatens the overall epistemic aims of the science engagement context. With the good faith actor, trust maintenance and the background condition of trust is still the consideration for taking inhibitory action. If we take the good faith actor's actions to their logical extent, we end with error-riddled research results. A faulty analysis undermines trust in the enterprise of participatory science (from the perspective of those doing participatory science) and mistrust could bleed into the perception of the public toward science in general.

To this point, I have offered an analysis of power and the concept of power I am deploying holds that power is some action by an agent which either facilitates (excitatory power) or constrains (inhibitory power) future possible actions of another agent. I am specifically concerned with epistemic power as it operates in expert to non-expert relations. The argument has been that wielding excitatory epistemic power should be the *prima facie* default stance of science engagement professionals, but not to the detriment of expertise. Responsibly wielding power means, however, being aware of that power and recognizing its effects in science engagement contexts. To aid in developing this sort of awareness, I turn to the particular practice of positionality training.

Positionality for the Science Communicator

Self-reflexivity and one's positionality are central concepts in research paradigms within the social sciences owing their intellectual lineage to the 20th Century sociologist George Herbert Mead (1934). Reflexivity for a researcher involves a level of self-scrutiny as it relates to the relationship between the self (as researcher) and those being researched (as an 'other') (Chiseri-Strater, 1996). Given that research and practice is oftentimes done in teams, it is also important that research groups practice self-reflexivity and critical engagement. This self- and group-reflexivity prevents researchers, professionals, and teams from confabulating an account of those who are 'being researched'. Self-reflexivity encompasses many methodological and ethical practices within performing research; however, the one I should like to draw upon for this project is that of positionality.

Positionality (and much of the impetus for the general program of self-reflexivity in social research, for that matter) draws upon standpoint theory framework. Standpoint theory holds that one's social or material conditions influence their understanding and interactions in the world (Harding, 1992). Positionality asks professionals and researchers to recognize their 'position' in the world and to assess how their material and social conditions influence their practice or research. Positionality training for science engagement professionals, science communicators, researchers, and teams of individuals has two positive consequences. First is that it has the capacity to uncover underlying assumptions about matters of scientific import. Second is that it has the capacity to uncover underlying assumptions about members of the public.[37] The account of positionality I develop here is informed by Reed-Sandoval and Sykes (2016). They propose three reasonable assumptions governing positionality.

Standpoint theory informs the first assumption. The standpoint theory insight is that one's social position affords a certain lens on the world. Theorists variously interpret what is meant by social position, but one way of thinking about social position is to consider one's social identities. So then, for instance, a standpoint theorist would argue that being Black provides one a view of the structures and relations in the social world which differs from someone who is not Black.

The second assumption refers to the idea that positionality (and its negotiation) is oftentimes overlooked or undervalued in contexts viewed as participant-neutral. By participant-neutral, I mean that the participants or interlocutors and their relative backgrounds are conceived of as unimportant or irrelevant to the matter at hand. This model of rational contexts, one divorced of any identities, is one which I have been and will continue to argue against in this project. The relational boundaries, the psychological properties of the participants, their social bonds, *inter alia* are all important for how we think about increasing engagement in science.

[37] As an anecdote, my work with staff at the Cincinnati Museum Center made this second point clear for me. In a meeting with staff, I suggested that I assumed most museum goers were left leaning and they indicated this was not the case and that museum visitors tended to be pretty evenly split from their research.

The third assumption endorses the notion that the negotiation of positionality is a signal to others that the science engagement professional or science communicator is forthright in her practices of increasing engagement and cultivating understanding. What this means is that one shows others that their goals are not nefarious or suspect – the goal of the professional is to increase engagement in science while being sensitive to those participants with whom she encounters. Communicating or signaling this to others is not necessarily an easy task.

Positionality directs researchers, practitioners, and teams to recognize the power relations between researcher-collaborator, teacher-student, social worker-client, and so on. Epistemic power does not just guide interpersonal interactions, but it also guides questions like what or who is in the curriculum? What research questions are important? And to whom are they important? Educators make curricular judgements, and those judgments may privilege particular perspectives over others. Whose perspective is important in the research or teaching context? Positionality recognizes also difference and asks professionals to be conscientious and negotiate power imbalances in productive ways and to probe their assumptions about those with whom they engage. Let us consider a couple of examples of positionality in action.

First is the case of a White researcher who has identified an important research question in her field, developmental psychology. Let us remain abstract and suppose that the research questions this researcher has identified have to do with how certain family behaviors can influence a child's attachment style. Innocuous enough, but important. In this researcher's lab, she and her team submit the requisite approvals and invite in families from many backgrounds for surveys and interviews to collect data and test their research questions. Based on the literature and her own findings, our researcher draws some conclusions about children's attachment styles, and she wishes to share her research, as any academic researcher is wont to do. But let us suppose that this White researcher finds occasion to particularize her findings to Black families. Suppose she sees some news story or sees something online which prompts such an inclination. Our White researcher puts together a presentation about attachment styles and advice for Black parents and finds an avenue to deliver her findings at a local community center. Our well-meaning researcher will likely face some pushback for her advice to Black families about how to raise their children.[38]

This case is not far from reality. A recent study showed a dearth of psychology research where race was discussed in a social sense and, where it was, the majority of research was performed by White researchers (Roberts et al., 2020). Researchers, and science communicators, must reflect on these issues as they formulate questions, design experiments or exhibits, write up findings, produce online content, and so on. Reflection on one's intuitions about the hypothetical example I have offered may differ by one's identities and/or one's experiences. For instance, one might say that the very idea of the research from this researcher is inappropriate at best, morally repugnant at worst. One might say that the research is fine, but the presentation move is not. Another might still say that neither the research nor the presentation presents any problems. Of course, many caveats could fill in the gaps between these positions.

The conclusion to draw here is not that researchers must come from the cultural or racial group with whom they have engaged as research collaborators. However, there is

[38] I thank Dr. Judith Danovitch for a comparable situation she observed. I amended the details, but the core intuition being pumped remains the same.

an important proviso on this claim. That is this: Researchers (and science engagement professionals and science communicators for that matter) should be engaged, thoughtful, and forthright regarding possible tensions emerging from their research questions, their research methods, their choice of citations in a literature review, their exhibit designs, the words they use in addressing populations – and the list goes on. The consideration under review is whether or not one is using their power in a responsible and participant-oriented way. Recall that the general strategy under consideration is flattening perceived or real power imbalances with the intent to increase engagement. If power is being wielded in ways which reproduce harmful power structures within a culture or society, then the science communicator or science engagement professional must reconsider her efforts. Harmful power structures divide communities and hamper the communicative possibilities needed for democracy as a way of life – as Dewey envisioned and as I have defended as part of the participant-centered model of science engagement. Thoughtfulness and forthrightness of tensions arising as a result of having epistemic power is part of the self-reflexivity in recognizing one's positionality as a science engagement professional or science communicator.

The second case relates to a team of professionals working on designing a sexual selection exhibit for a museum of natural history.[39] I want to consider this hypothetical exhibit design team in light of research on textbook presentations of sexual selection by

[39] The design of exhibits in natural history museums is a collective effort – of scientific experts, graphic designers (or other skilled artists), sometimes museum benefactors, and typically other programmatic museum staff. Each may have different goals, values, or interests, but, with some possible exceptions, they should function as a team and collectively develop a cohesive exhibit. See McKenna-Cress, P., & Kamien, J. (2013). *Creating exhibitions: collaboration in the planning, development, and design of innovative experiences*. Willey.

Fuselier et al. (2018). Both exhibit designs and textbook presentations are the results of team efforts between scientists and other professionals.

Fuselier et al. (2018) found that textbook presentations of sexual selection were rife with masculinist assumptions about sexual selection (for instance, males as active versus female as reactive; females described as ‘coy’; and so on), and we could imagine the exhibit design team might reproduce those same masculinist assumptions in their concept and development. For context regarding masculinist assumptions, the field of sexual selection has undergone several theoretical changes due to internal and external critiques. The field has moved from the original theoretical assumptions grounded in the work of Bateman (1948). Fuselier et al. (2016) summarize these assumptions,

> The general idea of sexual selection is as follows: copious sperm is relatively inexpensive to produce compared to very expensive eggs, so females require more resources and are choosy about their mates. Males compete with other males for breeding opportunities, they mate with many females, and they have high variation in reproductive success. Females mate with few males, are choosy about mates, and experience low variation in reproductive success. Thus, the operational sex ratio is skewed toward males and there is a positive relationship between the number of mates and reproductive success for males but not for females (243).

What Fuselier et al. (2018) found was that textbook images of sexual selection did not keep pace with the shifts occurring in the field of sexual selection. They summarize the following four findings from previous studies of sex and gender in textbook image analyses,

> (1) men are pictured more often than women or more often than expected given the discipline; (2) men are more likely to be in active roles whereas women are depicted as more passive, reactive, or less developed; (3) men are portrayed in more dominant or higher status positions than women; and (4) women are often shown in stereotypical roles of reproduction and domesticity whereas men are depicted in occupational settings (Fuselier et al., 2018, p. 483).

My hypothetical case of exhibit designers could similarly experience the same masculinist trappings. Absent critical reflection, deliberation, and a recognition of one's social identities through a positionality program, the masculinist assumptions could go unnoticed.

Drawing on Longino (1990), background assumptions and biases should be made transparent in the course of debating research programs and frameworks in order to vet their accuracy, social value, and justifiability. Communities of researchers and professionals need to be able to engage in reflexivity and critical appraisal of one another to sort out any implicit issues which should be publicly vetted. An expert involved in designing the exhibit might hold masculinist assumptions when drawing up the proposal for an exhibit on sex selection. To overcome this limitation, a program of team reflexivity and positionality should bring to light implicit biases, and, amongst a community of professionals, these could be critically debated.

The practice I am advocating for is that science engagement professionals, science communicators, and other science adjacent individuals have training or professional development in the self-reflexive process of recognizing positionality. As already noted, those in social sciences tend to have more of an introduction to positionality. In many institutions, this would include those within communications and journalism. As well, humanities-oriented disciplines would tend to have similar exposure to positionality, but this is not a guarantee. From there, whether or not positionality is a topic of education or training is less clear. Ash and Lombana (2012) suggest that professional development for museum educators – as a subset of science engagement professionals – is a burgeoning field of study; however, subsequent literature in the field does not show explicit mention of positionality as a practice deployed.[40] A participant-centered model of science engagement calls for institutions – whether informal educational and/or research-oriented – to adopt a program of development in positionality. Science engagement does include both informal learning cases and also participatory elements. Thus, those working in informal learning institutions or organizations like museums, aquaria, observatories; those science engagement professionals who produce television or online content; and those who design and implement citizen science or participatory research programs must recognized the value of positionality. I will take up the practical steps for implementing such a program.

While positionality is an abstract notion, there are training programs which can aid individuals in increasing their awareness and acting in accordance with that awareness. Many resources exist in print and online. Regarding online resources, for instance, one organization, the Participatory Action Research Center for Education Organizing (PARCEO), offers free resources on its website (PARCEO, 2022b). One of the resources is a positionality training program which includes questions for discussion amongst the participants after the session. Here are four representative questions from this document,

- How do you engage with people with different identities, roles, positions, privilege?
- What influences how you work with others? When are those situations different? Why?
- How does your identity impact the roles or positions you hold in your organization?
- What does the process of connecting the values of the individuals and those of the organization look like? (PARCEO, 2022a)

[40] Though a search of articles does show museum researcher positionality statements – not positionality training for museum educators.

The questions guide participants to consider their backgrounds, but also to consider their epistemic power and how it can impact those with whom they work. This training program from PARCEO is brief, but it addresses some of the core elements of positionality relevant for science engagement professionals; however, it would need to be tailored to context and with relevancy for some of the issues I raised. For instance, many positionality trainings center on social identities, but lack training and reflection on differences in background knowledge and how this connects to developing research questions, selecting competing theoretical frameworks, or framing scientific findings for members of the public.

Valuing Participants

To value participants is to take into account their key features and to recognize what they bring to science engagement opportunities. A participant-centered approach to science engagement means seeking to know your participants – their background knowledge, their values, and so on. Such an interest in the unique qualities of participants paired with a concomitant commitment to doing something productive with that knowledge differentiates the participant-centered model from a strict deficit model approach. A strict deficit approach relies on unidirectional communication of information without an attending interest in participant feedback for revising content, re-thinking the presentation of information, or so on. A contextualist approach may take more interest in feedback and import a commitment to public discourse; however, a contextualist approach sacrifices epistemic virtues of science in the pursuit of public interests and qualities. It is the epistemic virtues of science which warrant asserting science as epistemically authoritative, so a participant-centered approach must not make such sacrifices. In the following section, I fill out what "valuing" participants means from a participant-centered perspective.

Elements of Valuing Participants

Valuing participants ensures that their unique qualities are recognized and considered when designing science engagement opportunities. I take this strategy – what it means to value participants – to be expansive in its reach. Valuing participants includes ensuring that they are able to participate, that their agency is recognized (and cultivated in the process), and that their personal characteristics are taken into consideration in the selection of content, the choice of language, and so on. I unpack each of these considerations by proposing three theses – the access thesis, the agency thesis, and the identity thesis. Taken together, these three theses fill out what it means to value a participant in the context of constructing science engagement opportunities.

The Access Thesis

The access thesis is quite simple. It holds that individuals must have the ability to participate in science engagement opportunities and not be denied opportunities or have their opportunities diminished in unwarranted ways. There are certainly ways in which science engagement opportunities – through their structure or content – disable certain individuals. By disabling individuals, I mean that the structure or content of the engagement do not allow individuals to fully participate since the structure or content was designed with a certain norm of function in mind. For instance, suppose that a participant has an intellectual disability and the science engagement opportunity lacks ways in which to make the content accessible for that individual. It could also mean a disabling structural feature of science engagement spaces – and example might be a space without proper access for those in wheelchairs. Aside from these, there are a number of other possible reasons why individuals may lack access to science engagement opportunities. For instance, a lack of access could be read as an institutional barrier – an individual may not see her values or interests represented in an informal science learning institution, say.[41] Or economic challenges. For instance, a certain museum of natural history may be situated in a place where reliable public transportation is absent or sporadic. Or perhaps public access to science engagement opportunities is made prohibitive to those who work during certain times of the day or on weekends when lower wage workers, on average, tend to be working more than higher wage or salaried workers.

Democracy as a way of life, in the sense I have deployed it in this project, means that individuals must be able to freely participate in communicative exchanges. This could be a challenge for many, however. For instance, consider individuals who find verbal communication extremely psychologically taxing. In this case, quiet spaces in a museum, for instance, may be a welcome space and, furthermore, feedback and communication mechanisms need not always be verbal. A digital feedback kiosk may be the right choice for non-verbal participants. Institutions, organizations, and individual science engagement professionals or communicators must find ways to include all individuals in the overall space of science engagement. Science engagement spaces have the capacity to be sites of deliberation, but responsible parties must make opportunities as

[41] This example highlights how expansive "access" could be read. There are certainly limits to what interests or values might be on display within science engagement spaces. It is also worth admitting that both a deficit approach and a contextualist approach might both accommodate the access thesis in their own ways.

wide reaching as possible or the legitimacy afforded by deliberative mechanisms loses its teeth. What I mean by this is that exclusionary practices rob democracy of its power to equalize individuals as agents.

The Agency Thesis

The agency thesis holds that participants' epistemic agency be trusted and is key to actualizing the democratic threads of participant-centered science engagement. In the formal education literature (specifically science education), there has been a recent growth of interest in understanding and developing student agency in science classrooms. This growth of interest and research reflects long-standing criticisms that science taught in schools is often experienced as irrelevant to students' lives and, relatedly, inequitable (Arnold & Clarke, 2014).[42] A focus on student agency in the classroom, it is argued, rotates the lens of analysis from focusing on shortcomings of the student (for instance, a lack of engagement, a lack of interest in the subject, or a poor attitude) to instead addressing the science learning context itself (for instance, the content of the lessons, its delivery, and the learning environment) (Arnold, 2012). This focus on student agency in the formal science education research tracks a parallel suspicion of strict deficit model adherence amongst science engagement scholars and practitioners. The promotion of agency within the learning environment differentiates a participant-centered approach from a deficit approach since a deficit model approach does not require that individuals participate in a substantive way.

[42] The argument goes that underrepresented students tend to find their voices and interests not reflected in the curriculum. This irrelevance leads to worse outcomes. For instance, see Tan, E., Barton, A. C., Turner, E., & Gutiérrez, M. V. (2012). *Empowering Science and Mathematics Education in Urban Schools*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226037998.001.0001

Education researchers have recently taken up epistemic agency as a concept of interest. For instance, Miller et al. (2018) define epistemic agency as “students being positioned with, perceiving, and acting on, opportunities to shape the knowledge building work in their classroom community” (6). This definition works well, but it lacks an endorsement of the importance of background knowledge and identities in knowledge-construction.[43] I define epistemic agency within a participant-centered approach as participants being positioned with, perceiving, and acting on, opportunities to share in individual and social knowledge construction. I explain each element of this definition in what follows.

By individual knowledge construction, I refer to the individual cognitive processes for making sense of information in light of background knowledge. This point is just to affirm psychological constructivism. By social knowledge construction, I am appealing to the Deweyan insight that knowledge is a socially constituted process – individuals engage in inquiry in and with their communities.

The notion of positioning of participants to knowledge-building opportunities draws on the discussion of epistemic power from the previous section. If participants are treated as irrelevant to the content or delivery of the information in the science engagement opportunity before them, this signals (or in practice affirms) that they do not have influence over the knowledge-building opportunity. That a participant must perceive opportunities for sharing in the knowledge-building means that they must perceive themselves as having epistemic agency. The last element of the definition of epistemic agency is that one act upon the opportunities for knowledge building. This could mean

[43] The authors of the study cited do discuss background knowledge and its importance in epistemic agency, but they do not explicitly include it within their definition. I include it in order to highlight its importance.

within the science engagement realm itself (which is of most interest given that the model is for science engagement professionals and communicators) but also action should be taken in the public and private spheres of life. With a clearer sense of what epistemic agency means, now the discussion moves to considering trust as the stance to take toward participants as epistemic agents since I have said that the participant-centered model places trust in participants' epistemic agency.

There are a few different argumentative strategies for placing trust in the epistemic agency of participants. In the formal educational literature, there is little research on the extent to which *trust*, as a particular stance, in student epistemic agency lends itself to increased student engagement. However, though trust in student epistemic agency has not been studied directly, developing agency through instructional and other means shows positive correlations with outcomes like motivation, positive emotions, and learning (Reeve, 2013; Schuetz, 2008; Stenalt & Lassesen, 2021). And many studies in the formal science education literature point to harnessing student background knowledge in the teaching of science as an effective strategy for learning and student engagement (Campbell et al., 2016; Hammer et al., 2005). As well, formal education studies typically laud background knowledge for its value in scaffolding new information from an individual standpoint, but also for deployment in social interactions (for instance, in peer-to-peer information sharing experiences). For these reasons, placing trust in students' abilities to make sense of new information in light of what they already know is standard practice in formal education and supported by the available evidence. I argue that these formal education research findings be extended to the realm of science engagement.

Access and agency are critical to effective science engagement within a participant-centered model. The participant-centered model envisions science engagements as spaces for communicative exchanges to unfold – as much as reasonably possible given the context and mode of engagement.

The Identity Thesis

I now turn to consider the identity thesis. Identities present challenges to theorists of democracy and there are reasons to be optimistic or pessimistic about identities as they relate to participation in a democracy.[44] Of course, most democratic theorists may not be conceiving of democracy in the social sense ("democracy as a way of life" as Dewey would have it) as I have been deploying it; however, their insights regarding social identities and democratic participation are still relevant. Social identities figure in how we perceive ourselves and how others perceive us with respect to salient social categories. Social categories include, but are not limited to, gender, sex, race, ethnicity, age, ability, political affiliation, and religion. Identities refer to how we define ourselves or are defined in relation to these categories. Some consider these identities as corrosive to democracy (Chua, 2018; Levitsky & Ziblatt, 2018) while others see identities as ameliorative (Darby & Martinez, 2021; Young, 2000). I take the optimistic route that inclusion of diverse social identities can (1) promote engagement in democratic spaces and (2) lend itself to better science engagement opportunities (by increasing the cognitive resources brought to bear on problems by inviting multiple standpoints to a problem).

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[44] For a review following the optimism/pessimism framework, see Darby, D., & Martinez, E. J. (2021). Making Identities Safe for Democracy. *Journal of Political Philosophy*. https://doi.org/10.1111/jopp.12266 .

Regarding the first claim, the inclusion of diverse social identities promotes engagement because the collective interests and experiences of those individuals who identify with those social identities become a part of the communicative manifold. Research on exclusion in informal science education evidences a problem to be solved. For instance, Dawson (2014) held focus groups with multiple participants with backgrounds from Sierra Leone, Latin America, Asia, and Somalia about their experiences with informal science education centers in the UK. They found that individuals from these communities often felt alienated or unwelcome at informal science centers. Moreover, they found that the representations and messaging within these science centers/museums were exclusive – they did not represent members of these communities (Dawson, 2014). If one takes a participant-centered tack, the implications of a diverse and rich communicative manifold is that it constructs (or, perhaps more accurately, reflects) a diverse and rich picture of science. Once a diverse and rich picture of science is reflected, those who once were marginalized from science see themselves in it. From a motivational perspective, this reflection increases engagement. Of course, the efficacy of this ideal is reached only if the access and agency theses have been achieved as well – and this is a function of the discussion of power earlier in this chapter. Power must be used for excitatory ends.

Regarding the second claim, the inclusion of diverse social identities can lend itself to better scientific science engagements since it means more cognitive resources are brought to bear on an existing problem (or new problems can be identified). In philosophy of science, one finds numerous examples of the benefits to our scientific understanding as a result of inclusion of diverse social identities. For instance, feminist critiques detailed in the philosophy of science and social studies of science literature. A particular instance is Hrdy (1999). She shows how masculinist assumptions in primatology and evolutionary biology led to distorted conceptions of the role of female primates as passive or reactive rather than active members of their social groups. In this case – and many others – an important resolution is the participation of members of diverse groups and the critical appraisal of theoretical assumptions in the conduct of research. The case provided here is within the practices of science; however, and so my claim is that this kind of recruitment of diverse cognitive resources be extended to the realm of science engagement. Critical interaction with more individuals from more backgrounds reframes how scientific information is conveyed to the public.[45]

Decolonizing Science Engagement

One special case of the value of social identities and how science engagement professionals might include them in the planning and implementation of science engagement opportunities is the inclusion of Indigenous identities and ways of knowing in informal science education and participatory research projects. Such a program of inclusion would be to decolonize science engagement. A participant-centered approach to decolonizing science engagement has two intermediate aims – to promote social inclusion and to increase content relevance. In other words, to decolonize science engagement is to identify ways in which informal science learning opportunities and participatory science can respect and engage with Indigenous modes of knowledge production and conceptual frameworks. Before moving to the argument that decolonizing

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[45] Another benefit to this kind of inclusion is increasing the likelihood of more people from marginalized identities to pursue science as a career – thus adding to the diverse perspectives within the sciences.

science engagement has the capacity to increase engagement with science, I want to address a concern that decoloniality and science are in a necessary tension.

While some might argue that decolonization undermines science and endorses a contextualist approach, that conclusion is not warranted. The argument that decolonization endorses contextualism assumes that a decolonial project includes a rejection of the epistemic authority of science – that scientific knowledge is on par with all forms of knowledge. I do not think that one must make this leap. Decoloniality in the mode I am arguing for is to acknowledge contributions to our scientific understanding of the world from multiple sources.

The history of science reveals that science is not the product of one culture or civilization; rather, it is an amalgam of productive engagements over time and these contacts, integrations, and fusions have enriched the scientific enterprise. For instance, Norton (2008) details how Nicolás Monardes, a physician and botanist, and Francisco Hernández, a botanist and naturalist, studied Indigenous cultivation and preparation of cacao and tobacco. They translated Indigenous understanding of cacao and tobacco into the Western framework of Galen's four essential properties – hot, cold, wet, dry – thus integrating Indigenous knowledge with Western modern scientific concepts. Further, such exchanges are not simply historical artifacts.

Recent work in an emerging area of philosophy of science on epistemic decolonization involves possible integrations between currently accepted scientific ontologies and Indigenous ontologies (Ludwig, 2016; Ludwig & Poliseli, 2018; Ludwig & Weiskopf, 2019). This innovative work deserves further analysis and consideration of the ways in which researchers and practitioners can harness integrations in engagement contexts. Endorsing the plasticity of science does not cede the ground to a contextualism. A contextualist view would (perhaps implicitly) endorse a version of epistemic or cognitive relativity or at least take an anti-realist stance toward scientific knowledge. The participant-centered approach to decolonization recognizes the textured nature of science while emphasizing its epistemic virtues.

Respecting and engaging with Indigenous modes of knowledge has the power to increase engagement with science. Indigenous modes of knowledge production and conceptual frameworks ought to be included since this increases the accessibility of science, promotes the agency of Indigenous participants, and increases motivation to learn as a function of content relevancy and positive images of one's social identity. Ultimately, these moves have the power to foster lifelong engagement with science itself. A shift toward decolonization and recognition of Indigenous identities will create new opportunities for communities that have been traditionally marginalized in science and science engagement.

I want to be clear that the intention of the following discussion of a particular practice for science engagement professionals is to promote reflective engagement between Indigenous ways of knowing and science. Historically, many science education and other educational projects which sought contact between Indigenous ways of knowing and Western ways of knowing placed unidirectional demands on Indigenous epistemic communities to acquire the elements of a Western scientific worldview (Darnell, 1972; Orvick & Barnhardt, 1974). One should not construe the proposal I put forth here as placing such a unidirectional demand. Instead, the idea is for science engagement professionals and science communicators to be receptive to and respectful toward

Indigenous ways of knowing and, as well, recognizing ways in which these ways of knowing can be understood and how they can inform new practices, methods, and shape understanding. I first take up decolonizing informal science learning opportunities and then move to decolonizing participatory research.

Evidence from the formal education literature suggests that differences in ways of knowing can cause confusion on the part of Indigenous students. The cause of the confusion is a divergence between Indigenous ways of knowing and what is sometimes referred to as 'western modern science' as a way of knowing. In a study on educator beliefs about science, researchers found that science educators held values of science that espoused it as "non-humanistic, objective, purely rational and empirical, universal, impersonal, socially sterile, and unencumbered by the vulgarity of human bias, dogma, judgments, or cultural values" (Aikenhead, 2001, p. 337).[46] The view of science espoused by formal science educators is quite different from Indigenous science knowledge which is said to focus on "producing knowledge for cultural outcomes to maintain civilization" (Dupuis & Abrams, 2017, p. 582).

A participant-centered model suggests science engagement practitioners recognize multiple possible worldviews and negotiate cultural differences. The task of negotiating difference is a bit vague. I propose the notion of negotiating difference as a third way between claims of (1) 'radical alterity' or the incommensurability of Indigenous modes of

[46] Some of these values and concepts espoused by science educators are unclear – or overgeneralize. For instance, to say that science is non-humanistic means that scientists are unconcerned with the social consequences of their findings. This is not necessarily true. See Longino, H. E. (2013). *Studying human behavior : how scientists investigate aggression and sexuality*. The University of Chicago Press. She surveys multiple research programs on the study of aggression and sexuality and details how the findings are used by public policymakers and how these policy shifts feed back into the research questions. Formal science educators ought to disabuse themselves of such a conception as I would say informal science educators and science engagement professionals ought to as well.

knowledge and the Western Modern Science perspective (Viveiros de Castro, 2014) and (2) a fully integrative project whereby all differences simply fall away. It is not clear that any one individual offers a full-throated endorsement of the latter position, however one does find that such a program has been implemented in the past (Kimmerer, 2011; Nadasdy, 2003). Negotiation of difference through communicative channels encourage and foster a common vocabulary between different epistemic communities.[47]

One proposal for understanding negotiating difference is for science engagement professionals to adopt a tour guide or culture broker stance in their practice (Aikenhead, 1997). In this way, science engagement opportunities become 'trading zones' (Robles-Piñeros et al., 2020). Taking an anthropological perspective and viewing the world of informal science learning as a kind of sub-culture (and similarly viewing members of the public as members of other sub-cultures) could serve as a useful heuristic for professional practice.[48] If we suppose the culture broker metaphor is right, the science engagement professional or science communicator would be one who straddles two (or possibly more) cultures with some attributes of each – since this is how a culture broker is defined (Salazar, 2014).

A culture broker recognizes that the differences between those visiting a culture and those who are within a culture are, (1) a matter of fact, (2) that these differences can be understood by the tourists, and (3) that there can be action from the understanding. As a

[47] One might push back that my notion of decoloniality is not actually decoloniality or lacks teeth, but my approach is an attempt to find a third way that is pragmatic, actionable, and which facilitates engagement.
[48] Aikenhead seems committed to the notion of science (Western science) as an actual sub-culture (as opposed to metaphorically a sub-culture) which requires cultural transmission skills with those not in the culture. I am sympathetic to this approach; however, a more deflationary tack regarding the Western science as sub-culture stance works as well. Thus, the suggestion is that the culture broker stance is a heuristic. Either position is consistent with the argument.

set of desiderata for a science engagement professional qua culture broker, these appear consistent with what we might expect of science engagement opportunities. The culture broker stance, though, does have its limits. I would add a fourth desideratum for a science engagement broker which I could not endorse and would not propose for a traditional culture broker – (4) that the informal learning or participatory science facilitators and their attending spaces be receptive to feedback from participants. Science engagement professionals and science communicators should be open to feedback; however, I also want to be clear that the openness to feedback must include the possibility of institutional or systemic changes. For instance, institutions using world languages in addition to English or working with local communities in the design of exhibits. Adding this institutional or systemic change openness as a condition for participant-centered science engagement professionals serves to increase public engagement. However, it is not a condition I would suggest for a culture broker more generally.[49] I turn to an example informal science learning opportunity which could be a useful blueprint for a culture broker approach to science engagement.

A recent resource from the Science Friday Educator Collaborative indicates just how this can be done from an informal educational perspective (Metz, 2021). The Science Friday educational resource is designed as a lesson plan for students grades 6-12 and either introduces students to or represents to students Indigenous ways of knowing. The activity begins with students watching two short videos on science as understanding the world – which is presented as a human universal – and how knowledge is produced and

[49] This would be to suggest that a culture be receptive to change considering tourist feedback. This does happen (for various reasons); however, I cannot endorse the notion that an extant human culture be receptive to change as a result of tourist feedback as a normative element.

transmitted in Indigenous communities (Metz, 2021). The universality of inquiry indicates our deep human connections while the discussion of knowledge transmission in Indigenous communities – as a species of inquiry – allows participants to encounter differences in a structured way. Through a series of thermal conduction experiments either to be performed at home or in some other setting, students are then introduced to the concepts of heat transfer and energy before they encounter the Cherokee fire pots. Students are asked to design their own containers for carrying hot materials and connecting their findings to the fire pots. Lastly, the resource returns to some of the opening questions about Indigenous ways of knowing, what is scientific knowledge, and how we transmit scientific knowledge (Metz, 2021). Through metacognitive prompts and engaging videos, the resource navigates ways in which science and Indigenous ways of knowing share similarities and are co-productive in developing an understanding of the world. This resource fits well with a participant-centered model of science engagement as an informal learning opportunity and its intentional structuring evidences a culture broker approach to an informal science learning opportunity.[50]

A participant-centered model recognizes the keys to motivating participants is to aid them in seeing how they are respected and reflected in science engagement. In the evidence given in the preceding section, it is possible to see why science learning would be hindered as a function of motivation to learn – in part due to negative feelings of exclusion or even alienation. Respecting individuals *qua* individuals and bringing their

[50] Another example is the *Native Skywatchers* program which catalogs Indigenous astronomical observations. See Lee, A. S., Wilson, W., Tibbetts, J., Gawboy, C., Meyer, A., Buck, W., Knutson-Kolodzne, J., & Pantalony, D. (2019). Celestial calendar-paintings and culture-based digital storytelling: cross-cultural, interdisciplinary, STEM/STEAM resources for authentic astronomy education engagement. *EPJ Web of Conferences*, *200*. https://doi.org/10.1051/epjconf/201920001002

experience into a science engagement opportunity is part of the overall participant-centered ethos. This brings the analysis of decolonization to participatory science.

Participatory science could mean a number of things as I have previously noted (science roundtables, public comment forums, citizen science projects, and so on); however, here, I focus on a research collaboration between scientists and local Indigenous communities. There are numerous instances of science researchers encountering and productively exchanging with local knowledge traditions whether these exchanges were accidental or intentional. The focus here is on intentional collaborative research projects, though. Participatory research projects, generally, have increasingly received scrutiny from those in science and technology studies; philosophy of science; and scientists themselves (Dunlap et al., 2021; Kimura & Kinchy, 2016; Shirk et al., 2012). Some have pointed out problems of coloniality in participatory research settings (Kagawa-Singer et al., 2011) and attention has been given to decoloniality as an aim within these projects (Berkes, 2009). Before addressing aspects of decoloniality and participatory research, I should first like to say more about participatory research, generally.

Participatory research encompasses many approaches committed to direct engagement of community priorities and viewpoints in the development of research questions, design of study, or interpretation of findings. A number of terms dot the landscape of this kind of research. Vaughn and Jacquez (2020) outline twenty-seven different terms for what I have generally termed participatory research. According to their analysis, these different kinds of participatory research projects vary with respect to research traditions, methods, and traditional academic disciplines; however, they note one common thread. The common thread is that participatory research values doing research *with* those who would normally have research performed *on* them (Vaughn & Jacquez, 2020). In addition to engaging members of communities, participatory research methods have the advantage of being informed by real world contexts and have results which can be more easily translated into community and/or non-academic spaces (Cargo & Mercer, 2008; Vaughn & Jacquez, 2020). Given this general orientation, most participatory research frameworks fit into the general ethos of the participant-centered model of science engagement.[51]

A participant-centered approach to decolonizing science engagement with respect to participatory research relies on commitments already outlined – to a deliberative democratic stance toward decision-making, to recognizing one's positionality and avoiding irresponsibly wielding the epistemic power which accompanies a position of expertise. An important case study demonstrating these principles is Moller et al. (2009). They report on a successful adaptive co-management partnership between scientists and members of the Raikura Maori community in southern New Zealand from 1994 – 2009. The partnership was developed to study the long-term ecological sustainability of titi (*Puffinus griseus*) harvests by the Raikura Maori. Analyzing the testimony of elders, birders (those participating in the titi harvests), members of the Raikura Titi Islands Administering Body, researchers, and members of the community, Moller et al. (2009) identified several critical determinants of the success of this participatory research

[51] I wish to emphasize here as I did in Chapter 1 – researchers need not adopt the participant-centered framework for all research programs or research projects. There may be epistemically sound reasons as to why a research project would need to not adopt a participatory framework. For instance, should a social psychologist wish to determine how individuals perform under duress in an experimental condition, cluing in the participants to the methods would skew the results. Epistemic considerations may override non-epistemic considerations depending upon the context, research questions, or methods.

project. Importantly, they point to the core concepts established at the beginning of the research project which included, “(i) trust between parties, (ii) effective communication of scientific concepts and results, (iii) equitable decision-making responsibility, (iv) building scientific capability, (v) monetary support to participate fully in the partnership, and (vi) respect for each other and each party's knowledge” (Moller et al., 2009, p. 219). Each of these, save for perhaps (v), should easily read as consistent with the participant-centered model and I endorse these as fruitful for doing decolonial participatory research. The development of research questions, the design of studies, and the interpretation of results all are subject to deliberative mechanisms.

Specifically, decoloniality here refers to building relationships of trust between science engagement professionals and those within the Indigenous community who carry political or epistemic stature. A deliberative democratic ethos with a commitment to ensuring participation in the deliberations is crucial for building trust and achieving an outcome satisfactory to the parties to the research. The hope of such trust-building and equitable outcome orientation is that more people will engage in science and see it as a valuable, epistemically rich, and practically useful enterprise. There is, of course, no guarantee that such a result will wash over all. I have exalted the value of diverse cognitive resources throughout the project and that might include some who will not engage in science. Those who do not engage present an ever-present problem-space for those in science engagement – a motivation to continue the demanding work of problem-solving public engagement.

Limits of Decolonizing Science Engagement

Decolonizing science engagement has the potential to increase engagement; however, it does have some limits worth considering. A few issues to consider. First, there is an issue of misrepresentation and perpetuating stereotypes of Indigenous people and their varied belief systems. A well-intentioned team of exhibit designers or other science engagement program staff might believe they are representing the belief system of an Indigenous nation but fail to include those within that nation as they plan and execute the exhibit. I hope that the guidance in the preceding chapter – and a participant-centered ethos – would prevent such an issue in the first place.

A second issue could be that Indigenous ways of knowing are expected to fit into extant categories as one finds them in modern science or some other unidirectional demand on Indigenous ways of knowing. I already expressed this point earlier as a cautionary tale, but it bears repeating that decoloniality in the way imagined in a participant-centered model should not force changes or amendments on the part of Indigenous ways of knowing in a "top-down" sense.

The limits to decolonizing science engagement are defined by some important background conditions. As with the discussion of the limits of epistemic power, an important background condition is trust. Trust must be maintained between those in informal science learning institutions or participatory research teams and the participants – here, the participants in question are members of Indigenous nations. It is difficult, in advance, to suggest those instances where decoloniality may go too far or not far enough. Scholars and professionals must exhibit good judgment as they navigate decolonizing science engagement much as those in formal education and other spaces have done.

Conclusion

Conceptualizing the relation between participants and science engagement professionals and science communicators is a critical element for fully thinking through a democratic model of science engagement where deliberation is a central component and, here, I have offered such a conceptualization. I have argued that the strategies of (1) Re-Thinking Power Structures and (2) Valuing Participants in the participant-centered model of science engagement have the capacity to achieve the central aim of the model – to increase science engagement. To re-think power structures is to consider ways in which flattened power structures can bring more people into the fold – to reduce the intimidation that might come with entering into an engagement opportunity whether it is an informal learning opportunity or a participatory science opportunity and to realize the democratic ethos of the model. The practice of instituting professional development for science communicators and science engagement professionals on the concept of positionality should support this overall strategy, but, as I have admitted previously, specific empirical research would need to be conducted to demonstrate its efficacy. To value participants is to recognize their unique properties and what they bring to science engagement – to recognize how science engagement opportunities can reflect what is unique to participants. The practice of decolonizing science engagement has the potential to respect and engage with the unique belief-value systems of Indigenous participants.

CHAPTER IV

PSYCHOLOGICAL PROPERTIES OF THE PARTICIPANTS

Challenges to Engagement and Understanding

This chapter will outline and assess the following three strategies: (1) Engage with Belief-Value Systems; (2) Recognize Stages of Development in Learning; and (3) Scaffold Metacognition in Science Engagement. These strategies address the psychological properties of participants and offer practices which seek to develop a robust epistemic toolkit needed for participants to engage in the deliberative mechanisms critically and creatively in science engagement contexts under a participant-centered model.

One way of thinking about the relevant psychological properties of participants for science engagement (and for formulating the particular practices to build the epistemic toolkit) is to make a rough distinction between (a) psychological properties related to understanding the content of science itself and (b) psychological properties related to critical appraisal of science/scientific findings.[52] Regarding (a), we might see these as a constellation of issues with engagement in science and public understanding of science having to do with the content of science itself – or, in other words, it is hard to accept or even entertain some scientific finding because those findings do not accord with one's intuitive understanding or existing mental representations of the world. I call things of this nature *challenges of accommodation*.[53] Regarding (b), we might see these as a constellation of issues like trust in science, faulty reasoning strategies which maintain in-group/out-group social categories (called 'identity-protective cognition'), difficulty with identifying credible sources, and other non-content related reasons for resisting the findings of science or trusting in scientific knowledge.[54] I will refer to such issues of this nature *challenges of resistance*. Challenges of both varieties can be attenuated via the three strategies in this chapter.

The plan of the chapter is as follows. I begin with the first strategy, Engage with Belief-Value Systems and offer an analysis of the overall strategy. I then suggest two particular practices which accord with this general strategy, using survey research and incorporating elements of how science works into engagements. I then move to the next strategy, Recognize Stages of Development in Learning, and offer an analysis of this general strategy for increasing science engagement. I offer a particular practice of implementing guided discovery programs. I end by offering the last strategy tied to the theme in this chapter: Scaffolding Metacognition in Science Engagement. Metacognition,

[52] I say the distinction is 'rough' since there is some continuity between the habits which emerge from these two sets of properties.
[53] I use accommodation here in a Piagetian sense – that the findings in science do not cohere with one's existing belief frameworks.
[54] I say "non-content related" here meaning that the issues do not have to do with the ability to understand the content of the findings.

as a structured activity, shows promise for learning and other habits arising out of increased executive control. The particular practice I take up in relation to this strategy is inducing mindfulness in participants.

Engage with Belief-Value Systems

The point of the strategy of Engaging with Belief-Value Systems is for participant-centered practitioners to have an awareness of participant worldviews, cognitive biases in reasoning, and the affective difficulties of belief-revision of participants. Beyond mere awareness, participant-centered professionals must adopt particular practices which mitigate the effects of bias and affective disengagement and empower participants to exercise their agency in science engagement spaces. This dynamic taking stock of who one is encountering lends itself to two general stances toward formulating practices in science engagement – careful incrementalism and intentional scaffolding.

These two general stances toward structuring science engagements inform the overall strategy. Careful incrementalism recognizes that learning and understanding is not a singular process and that science engagements should occur across the lifespan in ways that are relevant to participants. Science engagement professionals should see science engagement as an iterative process. Intentional scaffolding, relatedly, ensures that experiences are maximally relevant for participants. Scaffolding refers to methods of instruction where an expert aids a non-expert to learn a new task or concept in a structured way. The expert manipulates the learning task in a way which allows the non-expert to solve problems or understand an issue which otherwise would have been more difficult (Wood et al., 1976). These general stances toward structuring science engagements allow participant-centered practitioners to better navigate participant worldviews and cognitive biases than the alternatives.

Encountering diverging worldviews and creating educative experiences in light of cognitive biases is an expansive and seemingly daunting challenge. In the next section, I zoom in and focus the analysis specifically on cognitive biases as they relate to creating effective science engagements.

Biases and Engagement

Cognitive biases refer to cases where human reasoning deviates from standard epistemic norms (Kahneman & Tversky, 1972). Given this, cognitive biases found in the literature are operationalized relative to some norm of rationality.[55] One class of biases of interest for this project are directional biases. Directional biases are where one's goal in reasoning deviates from the rational norm of accuracy toward some other non-accuracy related goal. For instance, confirmation bias is where one insulates a belief, P, from disconfirmation by ignoring or denying definitive absence to the contrary of P (Druckman & McGrath, 2019). In the case of confirmation bias, the result is to maintain the belief rather than to probe its accuracy. A commonly discussed directional bias in the science engagement and understanding literature is *motivated reasoning*.

Motivated reasoning is where an individual produces judgments that align with her own self-interests rather than what the evidence available would logically imply (Kunda, 1990). Haack (2003) refers to this type of misguided inquiry as "sham reasoning" (8).

[55] For instance, the neglect of probability bias is a tendency for an individual to either overestimate or underestimate probabilities when making decisions in cases of uncertainty. The norm of rationality which the bias is operationalized relative to is accurately assigning probabilities to events. A particular case would be someone who pulled their money from the stock market during a precipitous decline – ignoring the probability that they would, over time, recover the loss.

The motivation for aligning judgments with self-interests and extant beliefs is rooted in affective or identity-based appraisals. By affective appraisal, I mean that the motivation is about maintaining or producing some emotional state – denying evidence to remain happy, for instance. By identity-based appraisal, I mean that the motivation is about the individual aligning her beliefs to maintain status as a member of some social category.[56]

The cultural cognition research program studies these identity-based appraisals (Kahan, 2010; Kahan et al., 2011). Researchers who deploy the cultural cognition framework study public perception of (or trust in) scientific findings as a function of group associative predictors of science acceptance like political affiliation, religious belief, socioeconomic status, culture, and so on. An individual's worldview or identity may impact her willingness to entertain or accept some scientific finding, recommendation, or so on (Kahan et al., 2006).

Consider the case of wearing cloth face coverings during the COVID-19 pandemic in light of the conclusion drawn by Kahan et al. (2011) that "individuals are psychologically disposed to believe that behavior they (and their peers) find honorable is socially beneficial and behavior they find base socially detrimental" (148). During the COVID-19 pandemic, the Centers for Disease Control (CDC) offered guidance on the wearing of cloth face coverings (or masks). Initially, the CDC issued guidance against masks, but revised the guidance shortly thereafter (Centers for Disease Control, 2020). The

[56]For instance, during hurricane season in the United States, when meteorologists predict major weather systems capable of producing damaging winds and flooding, some residents in a community may band together and stake their opposition to leaving behind their property. By ignoring calls by public officials to evacuate and instead favoring community cohesion, the residents shirk the objective hazard in favor of some alternative identity-driven goal. Of course, I do not wish to suggest that all who remain in the path of a hurricane are acting as a result of identity. Some may do so as a lack of information or denial of information. Others may be engaged in neglect of probability. As well, not all reasons for staying have to do with resistance – but they may not be *able* to leave.

preponderance of evidence, eventually, sided with guidance wearing masks (Greenhalgh et al., 2020) and to the wearing of N-95 masks; however, this guidance was the subject of unfair ridicule by some. The public health guidance around mask wearing became an issue of gender politics, for instance. Those who elected to wear masks in public were ridiculed as not being masculine enough by some – that it was a sign of some kind of weakness or deficiency in males (Bhasin et al., 2020; Palmer & Peterson, 2020).[57] Also, mask-wearing became an issue of political party affiliation and in-group solidarity rather than attention to the available medical and scientific evidence. Those who aligned with the Republican Party would shirk wearing a mask in public in order to show that they were of that political persuasion (Gollwitzer et al., 2020). Some Republican politicians wore masks emblazoned with anti-masking words or phrases in an ironic twist. In addition to mask-wearing, anti-vaccination campaigns show similar in-group and out-group divisions.

Anti-vaccination disinformation campaigns have leveraged the notions of amplifying messages of socially beneficial behavior and debasing those that they take to be socially detrimental (Bean, 2011; Kata, 2010, 2012). Anti-vaccination sites, in a study of their rhetoric, relied on affective appeals to civil liberties, emotional parental testimonies, and personal testimonies (Kata, 2010). Skeptics of COVID-19 epidemiological research and

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[57] The male-to-male derogation could be read in at least two ways. One is that mask-wearing violates a traditional masculine norm of 'toughness'. That another male who wears a mask is displaying weak behaviors and is thus subject to ridicule. The second reading is that mask-wearing violates a masculine norm of anti-authoritarianism or some account of negative liberties. The mask wearer is seen as giving up his liberty and is thus subject to ridicule. In either case, the thread has to do with the cultural association of masculinity. For further discussion of gender and male-to-male backlash see Iacoviello, V., Valsecchi, G., Berent, J., Borinca, I., & Falomir-Pichastor, J. M. (2021). The Impact of Masculinity Beliefs and Political Ideologies on Men's Backlash Against Non-Traditional Men: The Moderating Role of Perceived Men's Feminization. *International Review of Social Psychology*, *34*(1). https://doi.org/10.5334/irsp.588

the subsequent push for COVID-19 vaccine uptake similarly used disinformation campaigns (Burki, 2019; Romer & Jamieson, 2020).

Science engagement professionals and science communicators must be attuned to the traps of motivated (or sham) reasoning if they are to meaningfully engage with participants' belief-value systems. However, motivated reasoning as a framework for interpreting science resistance cases has received some criticism and an alternative framework has been proposed (van der Linden, 2019).

Against the cultural cognition thesis, Druckman and McGrath (2019) propose what they call the observational equivalence problem – just that the observations taken in motivated reasoning research might well be interpreted not as cases of motivated reasoning (since the motivations of the participants in the research are opaque to the researchers); rather, the observations might well be explained by an accuracy motivation. What is interpreted as resistance to scientific findings due to cultural or group affinities is explained by a problem with identifying credible sources.

Discussing the nature of the observational equivalence problem, Druckman and McGrath (2019) address a motivated reasoning study's conclusion,

> Consider Feldman and colleagues' study of information selection: the authors show that certainty about global warming at one point in time led individuals to later select significantly less conservative media (which tends to be skeptical of climate change) and more non-conservative media. This could stem from a confirmation bias, where people seek out information that supports a prior belief, or it could reflect accuracy-driven audience members seeking information from sources they perceive to be credible. In the latter case, an accuracy-motivated evaluation of the source/evidence drives the observed [behavior], rather than a directional desire to confirm a prior belief.

The critique of the motivated reasoning interpretation of the data is plausible and an accuracy-driven account suggests some different interventions to ablate the bias. There are some limitations to the accuracy-driven framework given some of the issues rehearsed above. For instance, with vaccination uptake, the cultivation of fear by disinformation campaigns does not seem to connect with an accuracy bias but seems to be fed by affective appraisals. Similarly, the issues with public denouncements of mask-wearing on extrascientific grounds (gender politics, for instance). While the accuracy of interpreting the observational data from these studies is certainly important, it is wise to consider that both interpretations – the motivated reasoning interpretation and the accuracy-motivated interpretation – might sufficiently explain different observational datasets.

I do not seek to settle this theoretical divide; rather, I take a pluralistic route. What I want to propose is that both frameworks have value in the study of public engagement with science. In other words, we can allow for both possibilities depending upon the observations. The two particular practices I put forth under the general strategy of Engage with Belief-Value Systems address the issues raised in different ways. The first is an effort to take seriously the background beliefs and values of the participants using survey research. The second particular practice is an effort to diffuse ideological tensions and to aid in increasing individuals' abilities to determine accurate sources of information. The practice is to forefront how science works in science engagement opportunities.

Survey The Public to Structure Engagements

The participant-centered model of science engagement is committed to treating participants as epistemic agents and incorporating their feedback into science engagement and a tried-and-true method of receiving feedback is survey research. Reasons for conducting survey research vary, but the best species of survey research for science engagement professionals would be a needs assessment survey (Salant et al., 1994). Of particular interest is a community or identifiable population's interests and ideas as they regard some matter of scientific import. This particular practice has the benefit of taking participants' interests into account, ensuring that solutions and their communications are relevant to the needs and interests of the community or identified population, and that the agency of participants is respected. Consider two examples.

First, consider a hypothetical example of a survey administered to a service region of museum of natural history.[58] A number of different possibilities arise for this kind of research project. Depending upon the aims of the program and education staff at the museum, the population, the questions, and the results will differ. In terms of population, the survey could be administered to the community-at-large – capturing a wider net – and engage more people in the process of designing the exhibits within the museum. Alternatively, it could be administered to those who already reliably attend – whether that is through a kiosk at the museum, or an electronic survey sent to members or recent ticketholders – and gather the interest of those who already have a stake in the life of the museum. In terms of the questions, they might seek to determine areas of scientific concern (climate change, environmental degradation, or some other policy-related matter), they might seek to probe scientific misunderstandings (natural selection, genetics, or some other area of misunderstanding), or they may cover the extent to which members of the community feel like they belong. A belonging survey was performed

[58] I use service region here to indicate that most natural history museums are visited by residents within a surrounding area. While museums tend to bill themselves as global, they do serve a community, ultimately.

recently in (Price & Applebaum, 2022). A survey of any kind would need careful design and input from multiple interested parties and be labor-intensive; however, it would allow the institution to be more responsive to the community.[59]

Second, consider survey research used as a needs analysis for certain members of the public. For instance, researchers have surveyed people with autism, their families, their educators, and scientific/medical experts on what each of their views on what funding priorities for autism research should be. Multiple studies have taken up the question of whether research funding aligned with the needs of the autism community (Pellicano et al., 2014; Roche et al., 2021). This kind of survey research draws out community needs and research aims – putting them into contact with one another, however indirectly.[60] Using survey research as a needs analysis allows funders and researchers to see what the needs of the community are and, further, can aid science and health communicators to tailor their messages.[61]

The particular practice of using survey research has the capacity to increase public engagement with science and public understanding of science. It does so by meeting participants where they are by directly seeking their feedback. This commitment to respecting the epistemic agency of participants lends itself to increased participation and exposure to the dynamic practices of science.

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[59] A survey which deals with admissions of misunderstandings might require the most work – individuals may not be motivated to reveal they have misunderstandings or not know that they have them. In order to avoid selection bias out of the survey, it would need to come from a third-party agency which would be viewed as typically trustworthy. As well, in order to avoid incomplete surveys, the questions would need to be designed so as to not read like a quiz where wrong answered questions would be obvious. Making participants feel incompetent would be counterproductive.

[60] I say it is indirect since it is not clear that the surveyed members of the public and the surveyed researchers had an opportunity to participate in any kind of discursive exchange with one another.

[61] To be clear, this kind of survey research should not solely guide research priorities. The point is to engage members of a community and draw out needs and interests.

Forefront How Science Works in Science Engagement

The next practice is to forefront how science works in science engagement opportunities. In putting forward the nature of science – or how science works – ahead of scientific findings which might pose identity threats or disturbances to an individual's worldview, the effect of motivated reasoning is attenuated. The practice seeks to diffuse ideological tensions and allow for a safe environment to consider how scientific findings come about.

Designing informal learning opportunities and crafting science communications considering the motivated reasoning findings demands taking seriously those who may have a vested political, emotional, or religious interest but it also means contending with the problems of information source scrutiny. There are myriad ways in which science engagement professionals and science communicators can address these issues. I highlight one approach – of being explicit about the nature of science and the nature of scientific inquiry – since it has the capacity to address both the problem of motivated reasoning (focused on identity-maintenance) and accuracy motivated reasoning (struggling with information source discernment).

Evidence suggests that providing participants with information about the nature of science (NoS) (or 'how science works')[62] is an effective mode of promoting science understanding even in the face of ideological commitments (Lombrozo et al., 2008; Weisberg et al., 2020; Weisberg et al., 2018). What researchers found was that higher-

[62] Most NoS conceptualization and research is found in the formal education literature. For a review, see Abd-El-Khalick, F. (2004). Over And Over And Over Again: College Students' Views Of Nature Of Science. In *Scientific Inquiry and Nature of Science* (pp. 389-425). Springer Netherlands : Dordrecht. https://doi.org/10.1007/978-1-4020-5814-1_18
See also, National Science Teachers Association. (2020). *The nature of science: NSTA Position Statement*. https://www.nsta.org/nstas-official-positions/nature-science

order knowledge about science and how science works relates to acceptance of particular scientific claims. Furthermore, this relationship was not always attenuated by identity factors. These studies indicate that increasing one's knowledge of NoS or how science works has the potential to increase one's acceptance of scientific claims and without interference from one's political orientation or religiosity. The application of these findings in informal science learning and participatory science is currently lacking (Reiss & McComas, 2020) and a participant-centered approach endorses such application.

One aspect of NoS worth highlighting in designing science engagement opportunities is uncertainty in science. While all the elements of NoS are undoubtedly important to present to members of the public, a discussion of each would be beyond the scope of this project. One aspect of NoS which I am choosing to highlight is scientific uncertainty. I have chosen scientific uncertainty because of its presence in recent debates during the COVID-19 pandemic though it is harnessed by bad faith actors with other issues of scientific import and misunderstood by good faith actors as well.

Scientific uncertainty is a commonly misunderstood feature of scientific inquiry. Communicating scientific uncertainty is not a new issue, however, and it is not without discussion in the literature with some suggesting its communication as an ethical imperative (Keohane et al., 2014) while others questioning whether it ought to be communicated to the public at all (Stocking, 1999). My view does require taking it as an ethical imperative; rather, it is important to communicate scientific uncertainty to ensure that participants are equipped to competently engage in scientific discourse. Let us consider an example of scientific uncertainty and matters of public health.

During the COVID-19 pandemic beginning in early 2020, varying proposals on the spread of the virus yielded varying recommendations for mitigation strategies. Early in the pandemic, it was not clear to what extent SARS-CoV-2 was transmissible via inanimate surfaces (such that one would touch the surface and then touch a mucous membrane like the eyes, nose, or mouth afterward). At the same time, aerosol scientists were studying the transmissibility of the virus through droplets or aerosols – and how long the virus could remain active suspended in the air. Mitigation strategies, like washing one's hand, disinfecting surfaces, wearing masks, and maintaining at least six feet of social distance were proposed, but proposals varied over time. The changes referred to the use of masks, what kinds of masks would be effective, and where wearing masks would be effective (e.g., indoor masking, outdoor masking, and the specific conditions of the indoor environment versus outdoor environment). Indoor masking may have been effective, but could it be more or less effective given ventilation, occupancy, and so on.

As well, the efficacy of certain medical treatments became the subject of disagreement within the medical community. Members of the public were not shielded from these disagreements and most reported an awareness of scientific disagreements and scientific uncertainty (Nagler et al., 2020). Importantly, however, the preponderance of evidence eventually weighed in certain directions as more evidence surfaced – as is typical in a developing situation. This fact did not matter to some – and even those I would say are navigating the world in good faith – as they saw scientific disagreement as evidence of something like, "even the experts don't know what they're talking about!" Given this problem of bad faith malice in exploiting uncertainty and good faith benign confusion about how science works, explicating uncertainty as inherent to how science works is important.

Since the participant-centered model advocates for respecting individuals as epistemic agents, communicating uncertainty is needed, but it must be accompanied by messages which reinforce the epistemically virtuous aspects of the nature of science and the nature of scientific inquiry. Again, using the COVID-19 pandemic, one effective strategy is an admission of uncertainty during a changing situation. We could imagine a public health official saying something like this:

> *The COVID-19 situation is an evolving situation. As other scientists get us more data and pinpoint how this virus behaves, we can be more and more effective in slowing its spread. We are relying on the scientific community to get us data. That is how science works. With more data, we have a better picture. What we do know is that viruses spread mostly through aerosols, so it is important that people wear a face covering.*

In this way, there is an admission of uncertainty, but that uncertainty is not the result of ignorance; rather, it is endemic to science – particularly during a pandemic. As well, there is an admission of the durability of findings in epidemiology and virology.

Allowing for scientific uncertainty yet noting disagreement is part of the process and recognizes disagreement is possible. The possibility of disagreement avoids a picture of scientific discourse which says one is ‘locked down’ to some sort of perceived epistemic tyranny.[63] It is critical to communicate that experts generally have developed a consensus on a number of issues, however. The durability of scientific findings is many times lost in the face of emphasizing the tentativeness or revisability of science. It is not typically the

[63] The research on motivated reasoning and cultural cognition do indicate that anti-authority biases can factor into reasoning. Thus, framing science as a democratic enterprise is important. I would also note that beyond framing science as such, science should be as such.

case that the hard cores of research programs are questioned during scientific discovery.[64] Of course, it should be noted, one should neither expect a univocal community of experts nor a univocal public on issues of science – this will never occur and may end up being for the worse as knowledge grows with diversity of competing ideas. In fact, disagreements in the public on matters of science can spur further scientific inquiry.[65]

Recognize Stages of Development in Learning

The fourth general strategy in the participant-centered model directs science engagement professionals to Recognize Stages of Development in Learning. This strategy has the capacity to address challenges of accommodation (issues having to do with understanding some scientific finding or concept based upon a difficulty making sense of that finding or concept). Challenges of accommodation are not due to resistance for extrascientific reasons; rather, they refer to problems of understanding. Participant-centered science engagement professionals must be attuned to where participants are in their background knowledge and ability – or being attuned to which stage of development one is in.[66]

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[64] I use the term "hard core" here as an explicit reference to Imre Lakatos. For Lakatos, a scientific research program has certain 'negative heuristics' within its theoretical framework which are off the table for tinkering within the course of pursuing research questions, performing experiments, and drawing conclusions. For instance, the hard core of much psychological literature is that the brain is an information processing organ. The information processing nature of cognition is not something to be tinkered with. Of course, there are some who would suggest so, but, then, they are not typically within that research program. See Lakatos, I. (1978). *The methodology of scientific research programmes*. Cambridge University Press.

[65] One example of this is scientific understanding of the bacterial flagellar motor. If it were not for intelligent design theorists who marveled over the structural and functional complexities of the bacterial flagellar motor as evidence of a divine will guiding the hand of evolution (and who strongly opposed mechanistic accounts of evolution), scientists may never have invested as much effort into uncovering the requisite mechanisms for such a complex biological entity (among other subsequent targets of intelligent design theorists).

[66] I use the term stages here, but the account could easily work on a homeostatic property cluster approach just as well. By homeostatic property cluster, I am referring to the idea that while formal stages do not exist, the properties and processes of development may cluster around a certain period in overall development. I say this since the notion of stages of learning is a contested matter amongst those who study

Encounters with science will occur across the lifespan – or at least that is the hope. Contemporary researchers and science educators in formal education are attuned to the ways in which science learning differs amongst children, adolescents, and teens (Vosniadou & Ioannides, 1998). These contemporaries owe a debt to Dewey's notion of progressive education. Dewey (1938a) writes, "The trouble with traditional education was not that educators took upon themselves the responsibility for providing an environment. The trouble was that they did not consider the other factor in creating an experience; namely, the powers and purposes of those taught" (p. 45). In other words, depending on the age of the student, some information, activities, or methods of learning may be more or less appropriate. Science engagement professionals should similarly be attuned to developments across the lifespan since science engagement is a lifelong endeavor. Dewey's theory of experience helps frame this strategy and practices which flow from it.

Dewey (1938a) introduces two principles in his theory of experience (which informs his theory of education). The first is the principle of continuity which holds that every experience an individual has carries forth something from preceding experiences and modifies the qualities of those experiences which follow it. The second is the principle of interaction. The principle of interaction is the combination of internal and external (or objective) conditions of an experience. The objective conditions refer to the environment and its components and objective conditions could consist of "persons with

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human development. In psychology, there are two general approaches to development – those who view development as continuous versus those who take it to be discontinuous. The continuous approach takes development to be a process whereby psychological factors are improved upon over time. The discontinuous approach takes development to occur in stages whereby psychological elements are new abilities based upon changes in underlying mechanisms. What is important for this strategy – as an overall program of developing a rich epistemic toolkit – is recognizing differences in learning across members of the public rather than any commitment to the continuous or discontinuous view.

whom he is talking about some topic or event, the subject talked about being also a part of the situation; or the toys with which he is playing; the book he is reading…or the materials of an experiment he is performing" (pp. 43-44). The internal conditions refer to "personal needs, desires, purposes, and capacities" (Dewey, 1938a, p. 44). In Dewey's theory these principles "intercept and unite" (p. 44) and they define the shape of our experiences. In other words, each experience is the product of an individual, her environment, and informed by previous experiences. The theory of experience informs Dewey's theory of education and informs the role of educators.

According to Dewey, the educator has most control over the objective conditions in which a learner finds themselves. Further, she has a duty to ensure those objective conditions are appropriate to the learner. This is unsurprising given that an educator cannot control the internal aspects of individuals – as in, manipulating their cognitive capacities.[67] Instead, objective conditions are controllable. Dewey (1938a) writes, "Responsibility for selecting objective conditions carries with it, then, the responsibility for understanding the needs and capacities of the individuals who are learning at a given time" (pp. 45-46). The mutual adaptability between (a) the objective conditions designed or structured by the educator and (b) the internal conditions of the student is what recognizing stages of development means in practice in the realm of education.[68] I argue it can be extended to science engagement under a participant-centered approach. The

[67] This is not to say that a teacher cannot guide the interests and desires of students at all; rather, it would be quite anti-Deweyan to engage in internal changes which might encroach on a student's agency.

[68] Experiences can have educative value if there is an alignment of the objective conditions and internal conditions. Experiences lack value to a participant if the content presented (an objective condition) is divorced from where that participant is in their capacities. However, that is not necessarily an indictment of that content in itself. Dewey makes this point writing, "It is no reflection upon the nutritive quality of beefsteak that it is not fed to infants. It is not an invidious reflection upon trigonometry that we do not teach it in the first or fifth grade of school." Dewey, J. (1938a). *Experience and education*. Macmillan.

science engagement professional – through design of exhibits, communications, videos, and so on – wields their epistemic power in shaping the objective conditions of the engagement opportunity.

A unique example of a science engagement opportunity presenting scientific concepts in a developmentally appropriate way is a series of online videos from *WIRED*. In the videos, the editors of *WIRED* invited scientific experts to offer explanations of some complex scientific concept in the expert's field and asked them to do so repeatedly at differing levels of complexity. In the first level, the expert is to explain the concept to a child. In the second level, a teen. The third level, a college student. The fourth level, a graduate student (studying in the scientific discipline where one finds the concept). And, last, a fifth level where the expert explains the concept to a fellow expert (in that same scientific discipline).

Three exemplars of the series are physicist Dr. Jana Levin's explanation of gravity (WIRED, 2019), biologist Dr. Neville Sanjana's explanation of CRISPR technology (WIRED, 2017a), and neuroscientist Dr. Bobby Kasthuri's explanation of a connectome (WIRED, 2017b). At each level (except the expert level), the expert relies on deploying what, in the science education literature, called an instructional explanation (Gilbert et al., 1998) (as opposed to a disciplinary explanation). Disciplinary explanations are those explanations endemic to the sciences. The lexical and mathematical structure of these explanations (or models) are oftentimes complex and can be difficult to grasp on their own to a layperson; however, not impossibly so. Instructional explanations begin with disciplinary explanations and make use of narrative elements (stories, analogies, etc.), decomplexify mathematical or lexical elements of the disciplinary explanation (equations are made simpler or conceptual elements are removed), or introduce a false depiction of the phenomenon/process as a temporary buttress.[69]

Organizing and structuring developmentally appropriate educative experiences requires an intimate knowledge of the latest research in developmental psychology. However, it would be well beyond the scope of this project to present every relevant developmental psychology finding for science engagement professionals. As well, much of the variance regarding cognitive capacities and science engagements occurs in children and adolescents. Adults up to their mid-50s do not have that much variation in higher-level cognitive performance where a drop-off is seen (Salthouse, 2004, 2009). Children show many cognitive developmental changes in very short periods of time, so developmental appropriateness is even more critical for children. The particular practice I introduce under this general strategy is to implement guided discovery programs.

Implement Guided Discovery Programs

Children's reasoning capacities should not be underestimated – particularly when it comes to the kinds of reasoning strategies one finds in science. While some have held that children lack the needed capacities (diSessa, 1988; Inhelder & Piaget, 1958), others have shown children's capacities are ripe for scientific reasoning (Carey, 1985; Gopnik et al., 1999). An important add-on to the optimism about children's capacities for scientific reasoning; however, is that while their reasoning capacities are well-tuned, their findings are not always sound. Children, many times, absent direct instruction, will come to a

[69] A popular case in the science education literature is the use of Thomson's "plum pudding model" of the atom in primary or middle school introductions to the structure and behavior of the components of atoms. Students are introduced to a simpler model in order to gather some traction on the concept before learning about the Bohr model. See Thomson, J. J. (1904). The structure of the atom. *Proceedings of the Royal Institution, 18*, 1-15.

conclusion which falls outside of what we know about the world to be true (Klahr, 2013; Klahr & Nigam, 2004). For instance, children operating on their own may reach the conclusion that species evolve during their lifespan rather than across an evolutionary timescale. The importance of structure in educative experiences should be unsurprising given that science relies on an accumulated body of evidence – and children do not necessarily have access to it in cases of ‘free play’ activities. Guided discovery, or scaffolding discovery, satisfies a desideratum of providing appropriate objective conditions to the experience (the right materials, experimental procedures, and so on) and a desideratum of recognizing the internal conditions of the participant (their age, their social needs, or so on).

Scaffolding, in the learning sciences literature, is a powerful tool for enhancing learning experiences. Scaffolding, in its original formulation, refers to processes or strategies by which a teacher or more knowledgeable peer provides assistance to a learner. The teacher or more knowledgeable peer manipulates the learning task in a way which allows the learner to solve problems or accomplish tasks that would have otherwise been out of her reach (Wood et al., 1976).

Of course, one might wonder whether it is always feasible in cases where a live instructor or knowledgeable peer is not present. Subsequent iterations of scaffolding have addressed the concern. Contemporary conceptions allow for non-human agents to be the manipulator of the learning task in order that the learner might solve problems or accomplish tasks. For instance, software programs have allowed learners to progress in a science learning task through scaffolding strategies (Reiser et al., 2001).[70] I leave open the possibility that scaffolding be driven by the presence of a human interlocutor, a computer driven simulation (including augmented reality devices), or static prompts with content driven by surveys of general aptitude.[71]

Guided or scaffolded discovery in science engagement contexts may vary by the resources available. One instance of guided discovery from the literature involves assisting children in controlling variables in experimental design. In a simple physical-mechanical experiment, children were given a task to determine the variables effecting how far a ball would roll. Children absent direct instruction performed poorer in controlling for confounding variables while carrying out the experiment. Teaching children about only manipulating the variable of interest while keeping the others constant allowed them to achieve their experimental goals in fewer trials and increased the students' conceptual understanding (Matlen & Klahr, 2013).

In some settings, direct instruction is more difficult than others. For instance, some, but not all museums and other informal science learning institutions do have guided discovery centers, but not all. In some cases, these guided discovery centers are limited to children who attend camps or other special events and are not staffed at all

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[70] The example in this paper was a biological inquiry software which provided learners with a large base of primary data and support tools for analyzing the data and producing explanations. In one unit, students are introduced to the ecosystem of the Galapagos Islands. A second unit introduces the die off of animals on the islands as a problem for investigation. The third unit allows learners to investigate the issues through datasets of the environmental characteristics of the islands, information about plants and animals on the island, and access to field notes and other relevant data. The last unit is where learners present their findings. This software scaffolds the process of inquiry by focusing it on the production of explanations which are tied to observational data.

[71] Children tend to trust digital/internet sources much as they would trust a teacher, so this could defuse a possible worry that they may devalue the testimony of a digital assistant/educator. See Wang, F., Tong, Y., & Danovitch, J. (2019). Who do I believe? Children's epistemic trust in internet, teacher, and peer informants. *Cognitive Development, 50,* 248-260. https://doi.org/10.1016/j.cogdev.2019.05.006

times. In these cases, digital kiosks as mentioned previously, or even recorded/written prompting, may suffice serving as the guide. Children's television programming with scientific import demonstrate guided discovery as the characters or character on-screen explains some concept before pausing and allowing the child to perform a task at home. Regardless, the impact of recognizing the developmental needs of the children participating is crucial. Finding ways to adapt personnel, technology, or other means in order to recognize stages of development in science engagement opportunities is critical.

Scaffolding Metacognition in Science Engagement

This section takes up the strategy of Scaffolding Metacognition in Science Engagement. Metacognition refers to our ability to think about our own minds and what we think we know and think about our own knowledge; its quality, depth, and relevance. Over the past 50 years, cultivating metacognition as a feature of human reasoning has become a best practice in pedagogy studies. In higher education, centers for teaching and learning (or however they are named at different institutions) encourage faculty to incorporate metacognition into in-person courses, online courses, hybrid courses, and in their advising and mentoring practices. In elementary, middle, and secondary education spaces, teachers are similarly encouraged to incorporate metacognitive activities in their teaching. The mechanisms contributing to metacognition develop early, but, on some accounts, attempts to improve metacognition with children under six would be mostly developmentally inappropriate (Davis et al., 2010) and, particularly, under eight in an academic setting (Veenman & Spaans, 2005).[72] The cultivation of metacognition benefits

[72] The age ranges cited could vary learner-to-learner and may be generally debatable, regardless.

learners in many ways and so it is unsurprising that metacognitive strategy instruction has become a popular pedagogical tool across the educational spectrum.

Metacognition first appeared in the literature in Flavell (1976) and drew upon four extant research traditions in psychology: reflection, executive control, self-regulation, and other-regulation (promoting self-regulation in others) (Brown, 1987). Research on metacognition has demonstrated positive correlations between metacognition and enhanced reading comprehension (Brown et al., 1983; Paris & Oka, 1986); enhanced problem-solving (Kitchener, 1983; Whimbey & Lochhead, 1986); and improved scores on assessments (Casselman & Atwood, 2017; Schraw, 1994). Education and psychology researchers laud the use and training of metacognition, but precisely defining metacognition can be challenging.[73]

Metacognitive skill is said to be a part of overall 'self-regulation' – which is also composed of cognitive control, motivation and emotion, and strategic action (Bromme et al., 2010). The degree to which one is metacognitively, motivationally, and behaviorally active in their own learning processes defines self-regulatory success (Zimmerman, 1989). Self-regulation, in this sense, has been correlated with positive outcomes in formal educational contexts (Kitsantas, 2002) and metacognitive interventions are correlated with positive outcomes in specifically formal science educational contexts (Zepeda et al., 2015). Given this discussion, there are reasons to bet on cultivating metacognitive skill as a part of a rich epistemic toolkit for science understanding. I use the term cultivating

[73] For a critical perspective see Alpert, L. R. (2021). *Rethinking Thinking About Thinking: Against a Pedagogical Imperative to Cultivate Metacognitive Skills* [Unpublished doctoral dissertation, City University of New York].

intentionally here to indicate that metacognitive skill, much like other cognitive processes, does not grow absent explicit instruction.

Research indeed indicates that individuals typically do not spontaneously engage in metacognitive thinking unless they are explicitly instructed to do so through intentionally constructed interventions (Berardi-Coletta et al., 1995; Chi et al., 1989; Lin & Lehman, 1999). Given this – and the claim that metacognitive skill is a valuable tool – it is important that scaffolds be put into place to develop the metacognitive skills needed for science understanding. To put a finer point on this, metacognitive knowledge, on its own, has been demonstrated insufficient for successful learning (Ziegler & Montplaisir, 2014). Given the broad support in the literature for metacognitive interventions and its efficacy in a range of skill domains, one could simply say that all aspects of science engagement adopt metacognitive skill training programs. This is not a bad idea. Informal science learning institutions would do well with increasing their focus on incorporating metacognitive programs. I have been using the term metacognitive scaffolding to refer to metacognitive interventions or metacognitive programs.

The research on metacognitive interventions or metacognitive programs in informal science learning institutions is lacking – and some have extended the criticism to a lack of higher-order thinking in these institutions at all (Gutwill & Allen, 2010; Randol, 2005). Part of this has to do with a historical absence of a focus on whether or not visitors were learning in museums, science centers, and other informal science institutions. Rather, these institutions housed collections and were research-oriented rather than learning or educationally focused. It was not until the 1990s when more attention was paid to learning in a robust sense within informal science institutions

(Feher, 1990). Specific to higher-order thinking and metacognition, some have made calls for such research and practice in informal science learning institutions (Anderson et al., 2003).

The limited research which has been done in informal science institutions indicates that metacognitive interventions can be effective. For instance, Gutwill and Dancstep (2017) found that including exhibit-specific inquiry-based questions in flip labels (boards attached to hinges where participants must raise them to reveal content) led to an increase in speech containing metacognitive elements (an indirect measure of metacognitive activity). The results suggest that these flip labels in museum exhibits can substantially increase visitors' metacognitive activity.

In another study, Thomas and Anderson (2013) found that parent metacognitive knowledge influenced their interactions with their children in a museum setting. The researchers interviewed twelve parent-child dyads immediately following the dyads' participation in an interactive museum exhibit. The researchers' analysis supports two findings. First, "Parents reported metacognitive procedural and conditional knowledge regarding their and their children's thinking and learning processes, and this knowledge influenced their interactions with their children" (Thomas & Anderson, 2013, p. 1253). Second, "Parents were aware that this metacognitive knowledge influenced their interactions, seeing this as appropriate pedagogical action for them within the science museum context and for the child involved" (Thomas & Anderson, 2013, p. 1253). These findings support the participant-centered model's claim that metacognitive awareness interventions in an informal science learning institution promotes more educative experiences in these settings – and, as will be discussed in the next chapter, there is value in promoting social interaction in these settings as well. Aiding participants in developing metacognitive knowledge is a good starting point for skill-building.

An instructive example of metacognitive reflection in an informal science setting is from the United States National Park Service's website for Glacier National Park in Montana.[74] It follows the metacognitive strategy Gutwill and Dancstep (2017) simply refer to as *Question Asking*. In the "Learn About the Park" section of the park's website, visitors can explore information about the Glacier National Park's namesakes and view images of how they have shrunk over time due to global climate change. Most importantly is the text associated with one of the glaciers, Jackson Glacier. The text under dual images of Jackson from 1911 and 2009 reads,

> Although melting glaciers are the most visible indicators of climate change in the mountains, the entire mountain ecosystem is responding. Using both repeat photography and tree-ring studies, scientists have documented that trees are growing faster, becoming taller and filling in the spaces in between trees. Young seedlings have established and are surviving in areas where deep snowpack and harsh weather conditions had previously excluded them. *How do you think this vegetation change will impact wildlife?* (National Park Service, 2021, emphasis added).

Glacier National Park attracts guests from across the United States and worldwide and so glacial recession may not cohere with the average visitor; however, guests are asked to consider a more ubiquitous feature of the human experience, wildlife. Reflecting on this subtle yet challenging question promotes a 'working backward' from what is well-known toward the more challenging (and, perhaps, abstract in a temporal sense) of glacial melt. Pressing participants to reflect on new information (glacial melt and visual evidence of

[74] Based on my own visit to this park, I can say that there is (or, at least, was) a placard in the park which has the same message from the website.

glacial melt) and its fit with existing belief structures (the value of wildlife and stable ecosystems) is an effective metacognitive reflection practice.

This particular case highlights a metacognitive strategy worth pursuit in an informal science learning context; however, it also highlights an important worry. The worry might go something like this: Developing metacognitive skill is a desirable goal; however, how does this advance science understanding? In response to the question posed in the Glacier National Park case – How do you think this vegetation change will impact wildlife? – one may not clearly pick out anything related to the ecological effects of climate change. The impulse generated by the metacognitive prompt does not necessarily direct one's habits in any particular direction. One may find a solution which makes sense of the indeterminate situation but is not cogent in a scientific sense. This is a fair concern, but I want to stress that this is an example in isolation. What this example does is demonstrate a consequence of climate change through observational evidence and promote reflective questioning. Additional prompts could utilize similar comparative imagery with probing questions – with the questions increasing in their complexity and appeal to abstract reasoning.

For instance, the questions could direct participants to consider how wildlife changes in this case might have impacts in other ecological niches. We could suppose an interactive kiosk would allow participants to manipulate the climatic features of an environment through carbon reduction schemes with concomitant ecological changes simulated. Further, the simulation would propose questions to the participant as she manipulates the environment – perhaps the simulation asks the participant to achieve a particular goal (perhaps: what reductions in carbon would be needed to achieve a particular ecological outcome?) and provides some reflective questions along the way. In the process, the participant could be introduced to ecological models of climate change with references to the model's construction. In this proposal, metacognitive reflective questions, conceptual knowledge, and a bit of 'how science works' is integrated into a single experience.

To this point, I have introduced metacognition and surveyed its efficacy to learning. Specifically, I have focused on metacognitive skills, but this is not to demean metacognitive knowledge as it can be seen as a foundation from which to develop metacognitive skill. I also want to emphasize that the approach outlined thus far should be recognized as distinct from a purely deficit approach where participants are presented with scientific facts in hopes of belief-revision. One could imagine the Glacier National Park example as a strictly deficit case. Instead, the approach put forth here requires attentiveness to skill-development in participants. The addition of metacognitive skill development shows an attentiveness to the psychological properties of the participants.

Mindfulness Interventions in Informal Science Learning Contexts

I turn now to the particular practice of interest in this section. I propose mindfulness interventions in informal science learning institutions as fruitful. I will show that mindfulness has the capacity to address an impediment to science understanding – the resilience of intuitive theories. Science understanding may be impeded by the resilience of intuitive ontologies – or sometimes called folk beliefs, naïve theories, or just intuition (Carey, 2009; Vosniadou, 1994). The idea here is that humans navigate the world using a set of innate presumptions about the way in which the world is structured and the way in which the world functions. It is often the case that these presumptions do not cohere with scientific explanations of natural phenomena, however. The discord between a persistent intuitive explanation and a scientific explanation presents a challenge for science learning which metacognitive skill interventions have the potential to ameliorate and facilitate what researchers call "conceptual change".

Conceptual change refers to the ability to revise one's intuitive beliefs or theories about the natural world in light of scientific evidence.[75] As an area of research, two overarching theoretical approaches to conceptual change emerge – one holds that conceptual change is possible (Limon & Mason, 2002; Murphy & Mason, 2006) while the other holds that it is not (Shtulman & Lombrozo, 2016). On the former approach, proponents argue that intuitive concepts (sometimes referred to as parent concepts) are replaced by the scientific concepts (sometimes referred to as descendant concepts) through a process of transformation. At the very least, transformation means that the intuitive structures within one's cognitive architecture are amended in some way. On the latter approach, there is no transformation – there is instead a proliferation of concepts (Shtulman & Lombrozo, 2016). The critical skill needed in order to cultivate science understanding regardless of the view one takes is executive function (tamping down the impulse to rely on an intuitive theory over a scientific explanation or re-appraising one's

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[75] The germ of this approach in education studies and cognitive development stems from an interest in Thomas Kuhn's *Structure of Scientific Revolutions.* For Kuhn, and very briefly, mature sciences have progressed through pre-paradigmatic stages into more sophisticated and complex stages. Kuhn, T. S. (1996). *The structure of scientific revolutions* (3rd ed. ed.). University of Chicago Press.

This view of conceptual change in scientific communities was seen as a possible analogy to individual cognitive conceptual changes in science understanding. Gruber, H. E. (1973). Courage and Cognitive Growth in Children and Scientists. In M. Schwebel & J. Ralph (Eds.), *Piaget in the Classroom* (pp. 73-105). Basic Books. , Hewson, P. W. (1981). A Conceptual Change Approach to Learning Science. *European Journal of Science Education*, *3*(4), 383-396. https://doi.org/10.1080/0140528810304004 , Kitcher, P. (1988). The Child as Parent of The Scientist. *Mind & Language*, *3*(3), 217-228. https://doi.org/10.1111/j.1468-0017.1988.tb00144.x .

theoretical stance).[76] I argue for incorporating mindfulness interventions as a metacognitive scaffolding intervention in informal learning opportunities in order to address this hindering feature of efforts to cultivate scientific understanding.

The literature on mindfulness shows some promise for harnessing the mechanisms of executive function (Bishop et al., 2004; Holas & Jankowski, 2013). In the literature, mindfulness is conceived of as a two-component process – one is attention to internal and external experience and two is a non-judgmental appraisal of emotions or thoughts experienced. The former component of mindfulness has shown positive correlations with increased attention to perceptual cues – which facilitates conflict monitoring, both internal and external (Anicha et al., 2012; Sternberg, 2000). Additionally, the first component has been associated with switching and updating working memory (Jha et al., 2010). The latter component of mindfulness has been associated with improvement in inhibition (Sahdra et al., 2011; Teper et al., 2013).

Studies demonstrate that mindfulness trainings (either brief introductions or sustained trainings) do aid in inhibitory tasks (Chan & Woollacott, 2007; Heeren et al., 2009; Wenk-Sormaz, 2005). A recent metanalysis found gains across a number of cognitive domains (Gill et al., 2020). Similar to other metacognitive strategies, individuals do not independently engage in mindfulness without prompting. In informal science learning settings, mindfulness interventions can be incorporated into entry signs,

[76] It could be hypothesized that the cognitive structures underlying the intuitive theories are cognitively impenetrable. This would mean that no forethought or other cognitive intervention would affect their activation. They would be like perceptual illusions which are cognitively impenetrable. Much as one would like to not see the illusion, it cannot be "overridden" by a cognitive process. This is not a fruitful avenue since the underlying theories are cognitive and not perceptual. For a discussion, see Shtulman, A., & Harrington, K. (2016). Tensions Between Science and Intuition Across the Lifespan. *Topics in cognitive science*, *8*(1), 118-137. https://doi.org/10.1111/tops.12174

exhibit design and labels, post-visit online resources, and so on. Research and practice in this potentially fruitful area is underdeveloped; however, very recently some in the museum and curatorial studies literature have put forth mindfulness as a possible strategy, but with no empirical evidence available just yet (Pedretti & Iannini, 2021).

Strategies for inducing mindfulness in experimental conditions vary. Mindfulness induction is a single and typically brief session of mindfulness training, designed to induce a temporary state of mindfulness (Creswell, 2017). One common approach is 'eating a raisin mindfully' (Heppner et al., 2008). In this inducement, participants are given a raisin to eat and guided through mindfulness prompts to direct their attention to the perceptual and cognitive features of eating a raisin. Other approaches rely on attentional focusing by less concrete means and can similarly be effective in mindfulness induction (Dahl et al., 2015). In informal science learning institutions, an approach like the raisin mindfulness training may not be possible – or may viewed as intrusive or just plain odd. Instead, an approach relying on textual cues or pre-recorded instructions might be more appropriate.

A learning environment structured to induce a mindful state increases participants' attention to the details of the learning space and their own internal states. One mindfulness training session at the outset could be effective per the mindfulness literature, but additional exercises in transitions between exhibits would make for an improved experience for participants. Overall, a participant-centered approach might go something like this. As participants enter the institution, they would be informed that the institution has taken on a 'mindful approach to discovery'. A mindful approach to discovery, it would be explained, aids individuals in increased attention, deeper reflection, and ability to see the big picture – and this is how a scientist approaches discovery, so the introduction would go. The participants would then proceed to the mindfulness induction. The induction would use a prompting strategy and participants would be instructed to reflect on their thoughts as they experience the spaces. Throughout the exhibits, participants would have the chance to scan codes on their smartphones with reflective prompts on the content they just experienced.[77]

Referring to the challenges introduced earlier, those of resistance and those of accommodation, we can imagine an exhibit like the one at the North Carolina Museum of Natural Sciences on race could pose some issues of both. The exhibit, "Race: Are We So Different?, was developed by the American Anthropological Association (AAA) (later turned into a book) (Goodman et al., 2020). The exhibit integrates natural science, historical, and social science perspectives on race to probe some cultural and individual assumptions about race – for instance, that race is a natural kind.

Mindfulness in this context could aid in the kind of problems associated with intuitive theories introduced earlier in this chapter. Intuitive theories may drive some of the social categorization and race construct thinking we encounter (Rhodes, 2013), so a mindful participant may be more open to conceptual consideration in a museum setting. But, also, some participants may be made uncomfortable in other ways. Black participants may find images or historical depictions as unsettling and cause emotional distress (and Black participants are due spaces of care in these kinds of emotionally

[77] It must be said that some exhibits are more challenging than others, so context will drive the implementation of the mindfulness strategy and how it might be incorporated. Further, exhibits may be more challenging in conceptual ways (of matters of content) or in personal ways (of matters of personal identity). Mindfulness prompts may be more effective in directing participants to reflect in different ways depending on the context.

taxing museum settings). White participants may be made uncomfortable by discussions of race as well, but for different reasons. This discomfort could provoke feelings of resistance, but in a space of comfort, this resistance could be tamped down. I would appeal to the arguments that discomfort with discussions of race deserves attentiveness and care to allow participation and personal growth (Applebaum, 2017).

This last point about the potential for mindfulness (or other metacognitive scaffolds) to address matters of resistance is important to consider further. There may be some ways in which metacognitive skill aids in diffusing some of the traps of identity protective cognition as well. This is speculative; however, metacognitive skill shows a positive correlation with cognitive flexibility and political partisanship has been negatively correlated with cognitive flexibility (Buechner et al., 2021; Zmigrod et al., 2020). Could it be possible that metacognitive skill interventions in informal science learning settings have an effect on diffusing identity protective instincts? There are several assumptions built in here. One is a causal direction issue. If the causal direction is from cognitive inflexibility to political partisanship, then attenuating cognitive inflexibility could reduce partisanship. Two is another causal direction issue. If the causal direction is from political partisanship to a propensity to engage in identity protective cognition, then, if both causal direction issues point in the ways discussed here, the metacognitive intervention program could work as hypothesized.

Conclusion

I have defined science engagement in a wide sense – inclusive of informal learning and participatory science – so I want to acknowledge evidence that participatory projects (citizen science projects, in particular) with embedded metacognitive interventions have been successful in developing metacognitive skill in adolescents (Hiller & Kitsantas, 2015). The evidence demonstrating learner success when metacognitive scaffolding is included in informal science learning opportunities forms the basis for the central argument in this section. Metacognitive scaffolding aids in cultivating science understanding and promotes active engagement in informal science learning spaces. The thrust of this section has been focused mostly on the kinds of metacognitive skill development one can observe in individual participants; however, the literature in museum studies does oftentimes refer to the relational aspects of participants – studies on parent and child interactions, for instance (Thomas & Anderson, 2013).

This chapter addressed the psychological properties of participants and outlined and assessed three participant-centered strategies. The three strategies, taken together, form a framework for aiding participants in developing a rich epistemic toolkit for engaging science. Many particular practices could be inferred from the three strategies taken individually and I imagine some practices could well be informed by overlaps in the strategies. The cognitive focus of this chapter does filter over into the next chapter in some ways. The next chapter takes up the social aspects of science engagement in more depth.

CHAPTER V

ENCOURAGE SOCIAL BONDS

Introduction

In this chapter, I argue for promoting social bonds in science engagement. Research in developmental and social psychology as well as education studies show the cognitive benefits of social interaction to individual learning – or, in other words, the social cognition of learning and engagement. As well, research on sociality and social bonds in science engagement settings has shown positive results. Across the lifespan, social cooperation is key to learning, and this should be unsurprising given the social nature of our species.

After introducing and assessing the literature on sociality and social bonds, I move to thinking about a particular practice which aligns with the strategy of promoting social bonds. I propose the use deliberative mini-publics regarding issues of scientific import. This is a practical suggestion for inclusive and effective science engagement. The hope with this practice is that it increases science engagement, science understanding, and aims toward solving society's complex problems.

Social Cognition and Engagement

The notion that social interaction is important for learning is relatively uncontroversial.[78] From a macro timescale, sociality and learning are tied together in cognitive evolutionary frameworks – the notion that human beings are a social, cooperative species. Proposals differ as to how to integrate evolution, development, and culture, but there is wide agreement that prosocial behavior and modes of information transfer are important (Csibra & Gergely, 2009; Kaplan & Robson, 2002; Sterelny, 2012; Tomasello, 2021). From a micro timescale, one similarly finds research demonstrating the importance of sociality. While the two dominant approaches in developmental psychology (cognitive constructivist and social constructivist) differ in their views on how to frame development, both have come to appreciate the positive effects of social interaction on developmental processes across the lifespan (Powell & Kalina, 2009).[79]

People learn from one another in myriad ways. For instance, in the teacher-student relationship, the teacher may use a method of scaffolding learning where an easier task is used to build up a student's skill with more difficult tasks presented just outside the reach of the learner's ability. The learner is given strategies or the problem-solving method modeled for her in order for her to acquire the new knowledge (Wood et

[78] The extent to which it is important is a matter of debate, however. For instance, some of the massively modular theorists in the Santa Barbara school of evolutionary psychology would deny the extent of social learning as a satisfactory explanans instead opting for the presence of innate domain-specific cognitive modules. See Barkow, J. H., Cosmides, L., Tooby, J., Barkow, J. H., Cosmides, L., & Tooby, J. (1992). *The Adapted mind : evolutionary psychology and the generation of culture*. Oxford University Press.
[79] The cognitive constructivist framework did not historically appreciate the impact of social interaction for developing skills; however, later theorists have.

al., 1976). Further, peer-to-peer interactions can be fruitful particularly when there is a difference in knowledge between the two – where one peer takes on the role of teacher to the other. The practice of explaining a concept to another aids in more fully understanding that concept (Palincsar & Brown, 1984).

Across the lifespan, sociality remains critical. Some of the general lessons gleaned from the literature about learning already – that it is social, that it involves active construction of meanings relevant to the learner, and that it is a self-regulating process – are generalizable to the case of adult learning as well (Merriam et al., 2007). The most important differences refer to ensuring content is relevant (since different age groups will deem different information or examples relevant or irrelevant) and the complexity of the information (assuming children can handle less complexity). In informal learning and participatory science contexts, the sociality of learning should, then, be harnessed across the lifespan.

Some ideas from the formal educational literature for active social learning which I take to be transferrable to informal contexts include the following,

- Think-Pair-Share: Students individually think for a moment about a question posed on the lecture, then pair up with a classmate beside them to share/discuss their thoughts.
- Concept mapping: Students draw a concept map (a graphic representation such as a web) depicting the relationships among aspects of a concept or principle.
- Problem Posing: Individual students make up a real-world problem regarding a particular concept or principle, then exchange problems with a classmate for solving (King, 1993, p. 31).

These pedagogical strategies could be translated into informal spaces whether through mediated means (use of digital kiosks, prompts within an app, a live mediator in an informal learning scenario, or so on) or used in spaces where participants can freely interact with one another.

Interactive exhibits at informal learning institutions like museums, aquaria, and zoos can and do already incorporate these active social learning activities and with positive results. For instance, in one study, researchers promoted within-family social interactions during a minimally guided interactive exhibit with positive results (Franse et al., 2021). The experiments studied the conversations of 104 families and found that completely unstructured experiences in the interactive museum exhibits were not as effective as minimally guided ones – meaning that a science engagement professional was present to prompt discussion and problem-solving. Other museum studies have similarly focused on family interactions as a boon to learning. Benjamin et al. (2010) studied the effects of providing conversation instruction to caregivers and children on task performance (a building engineering interactive exhibit) in a museum setting. Their study of 121 child/caregiver units found that content instruction and conversation instruction (asking more who/what/why questions) increased children's learning and remembering abilities versus those who did not receive such instruction.

In another study, Gutwill and Allen (2010) harnessed findings in the formal education literature on the value of collaborative inquiry for learning and applied them to museum exhibits. Well aligned with the participant-centered approach, they found that families who received instruction in inquiry skills, interacted with museum staff, and worked collaboratively with others demonstrated increased inquiry behaviors, had a more positive museum experience, and that collaborative inquiry led to increased content knowledge versus those in control groups. The efficacy of inquiry as a social phenomenon in each of these experiments lends credence to the participant-centered model's Deweyan framework for collective inquiry.

Peer-to-peer interactions are similarly important and should be harnessed in the context of informal learning institutions or other science engagement contexts where possible. One way to increase peer-to-peer interactions is to use prompting – whether the prompts are live communicators, digital additions to the environment, or just written placards. A particularly interesting application of prompting using a live communicator is controversy-based exhibitions and educational programs (Eikeland & Frøyland, 2020). These structured exhibits and educational programs are designed by science engagement professionals to elicit peer-to-peer deliberations through the use of emotional stimulation (Hodson, 2013). Examples of the contents of such controversy-based exhibitions have included climate change (Allen & Crowley, 2014) and teenage pregnancy (Navas-Iannini et al., 2017). In both examples, the exhibit curators presented visuals, audio, and text to elicit responses from participants within the exhibit (and to promote dialogue between participants) and collected feedback through post-visit surveys.[80] The use of deliberative prompts and follow-up survey research as an institutional feedback tool are valuable lessons for a participant-centered approach.

Beyond family interactions and peer-to-peer interactions, participant-to-expert interactions should be promoted in the context of informal science learning and participatory science as well. Science engagement opportunities should incorporate the notion of feedback from members of the public to science engagement professionals,

[80] Another popular example is the use of post-it notes in museums to allow participants to provide instant feedback to curators, educators, and other professionals.

science communicators, and scientists themselves. Productive exchanges between members of the public and those in the realm of science and science engagement are crucial for the democratic aims of the overall project.

Deliberative Mini-Publics as Sites of Change

Deliberative mini-publics as spaces for science engagement are a promising mechanism for science engagement. Living out democracy as Dewey envisioned it is not merely taking in some scientific finding and making life decisions in accordance with it; however, it is participating in science as a social institution. Participants should be invited into direct deliberations with experts. Participants then may express their standpoints, interests, aims, and so on. Appealing to Dewey (1927), recall that he writes, "The man who wears the shoe knows best that it pinches and where it pinches, even if the expert shoemaker is the best judge of how the trouble is to be remedied" (207). One space for this is within what have been broadly termed deliberative mini-publics.

The idea of mini-publics was first proposed by political scientist Robert Dahl (1989). For Dahl, mini-publics (or, as he called it 'minipopulus') are mechanisms for involving citizens in addressing public issues. The idea of a minipopulus is to draw together demographically representative assembly of citizens to learn and deliberate on a topic to inform a decision-making body (a representative legislative body, say). Deliberative mini-publics have been proposed to solve a number of issues in representative democracies – like overcoming hyperpartisanship in constituencies, counteracting self-interest in representative bodies, and increasing public interest in a particular issue (Setälä, 2017).

Several different proposals have been put forth regarding the structure and aims of deliberative mini-publics. For instance, consider two proposals – the Citizen Jury and Deliberative Polling. In the former, the result of the deliberative mini-public is to produce a collective position report on the issue under consideration. In the latter, the result is to poll each individual and aggregate results of the deliberation.[81]

Consensus conferences are one such deliberative mini-public which have been deployed in cases of scientific import. Originally, consensus conferences were primarily a function in the field of medicine whereby a panel of experts would meet behind closed doors in order to debate findings and come to a consensus on some specific domain of medicine (Joss & Durant, 1995). One might think of these as one of the regulative deliberative ideals in science as discussed in the previous section. Over time, these consensus conferences moved toward more open practices and eventually invited non-experts to participate – members of the public, broadly. The result is a dialogue of scientific expertise paired with non-expert knowledge of the perceptions of practice, what issues publics do not see as resolved, and where future research would be beneficial for everyday life (Joss & Durant, 1995). A specific outgrowth has been an interest in not only participation in science as the practice of what is typically called "basic science" (or bench science), but on science policy. Similarly, the Deliberative Polling approach developed in the US has focused on this policy element.

Deliberative Polling begins with traditional survey research methods – sample selection, questions, etc. – and then brings together the respondents for, typically, a weekend of discussing partisan issues in a non-partisan environment alongside experts

[81] For a review of deliberative mini-publics, see Smith, G. (2011). *Democratic innovations : designing institutions for citizen participation* (Reprinted. ed.). Cambridge University Press.

and competing proposals (Fishkin, 1991). The random sampling procedures of Deliberative Polling seeks to avoid selection biases. Respondents, or, participants, really, engage over the facts (informed by what are taken to be experts in the fields of interest in the particular session) and then are prompted to discuss values during their time together. Different policy proposals are introduced relative to the problem under consideration. At the end of the participants' time together, they are re-surveyed to determine movement on their positions. The research indicates that during these deliberative polling events individuals move on their positions in light of discussing factual evidence and deliberating on public values (Fishkin, 2018). This approach of pulling together citizens, experts, and policymakers proves effective for it presents an opportunity to deliberate in a context where social bonds are emphasized – over some of the more corrosive features of politics and political communication. As discussed in the previous chapter, motivated or sham reasoning can impact a participant's reasoning strategies in a domain where affective cues take over; however, the social cues in the Deliberative Polling strategy attenuate this bias. In a recent study, researchers found that deliberative mini-publics can have the effect of increasing public-spiritedness (or, the consideration of matters of the common good versus individual interests) (Wang et al., 2020).

Bringing together experts with the public is a valuable strategy; however, there is also value in local communities conversing with one another in productive dialogue. Pedretti and Iannini (2021) detail an initiative by the museum Espaço do Conhecimento in Belo Horizonte, Brazil. The initiative, called *Controversial Science Café*, invites participants to engage in dialogue with one another about contentious issues in science with social consequences. For instance, some of the Controversial Science Café topics have included the challenges of urban mobility, the underrepresentation/historical exclusion of women in STEM fields, recent environmental disasters involving mining, and fake news/media literacy (Pedretti & Iannini, 2021). A gap in this burgeoning literature is qualitative or quantitative studies of participant attitudes and attitudinal shifts before and after such roundtable events. While Controversial Science Cafes are a museum-sponsored initiative, I could see local groups organizing informal discussions outside of an institutional setting as well – science engagement opportunities are not limited to institutions. Having this kind of rich, public dialogue on issues is central for constructing and strengthening social bonds and for participants to recognize the possibility of common social goals and how science can inform these.[82]

Deliberative mini-publics tend to randomly sample individuals in such a way that they are demographically representative of a larger public and this could be seen as a logistical challenge. In the picture of deliberative mini-publics as sites of science engagement I am articulating, I could envision informal science learning institutions and even formal educational settings (universities or schools) as hosts of these events; however, they need not be institutionally bound. Finding ways to get individuals to participate; having the research background to draw up survey questions and the requisite statistical work; and then enact these mini-publics is a tall order. The result is worth the effort; however, a more modest version could similarly work.[83]

[82] From a philosophical perspective, my colleagues and I organized a series of informal discussions about justice, patient rights, and other topics in Philosophy in a series we called “Philosophy on Tap”. We called them “on tap” since we had them at local beer tap rooms. We found these to be engaging and there were discussions where opposing viewpoints emerged. We did not, however, perform any studies on these events. I do think these informal events should have experts in attendance lest there be confusion or omissions of scientific findings relevant to the conversation.

[83] A word of caution is that policy implications or scientific recommendations cannot be reasonably inferred from deliberative events where there is exclusion. What I mean by this is to say that if a museum

Conclusion

In this chapter, I have argued that social bonds are important to scaffold individual learning and I showed how this unfolds in the informal science education literature. Whether the interactions are familial, peer-to-peer, or peer-to-expert, the sociality of learning is hardly controversial and should be structured in productive ways. As well, I have argued that these findings support a particular practice which increases public engagement – deliberative mini-publics. I used the framework of consensus conferences (or Deliberative Polling) as actualizations of the deliberative democratic vision of science engagement. Social bonds and social communion are central notions for Dewey's vision of democracy as a way of life, so deploying these concepts within the participant-centered model of science engagement makes sense.

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of natural history in a suburban neighborhood holds a deliberative mini-public event on a matter effecting the entire city, those from other parts of the city may not be present. There may be transportation barriers to that area of the city which prevent some from attending and participating. While there are challenges, the results are worth the effort given that it has the capacity to increase science engagement and enrich our scientific understanding.

CHAPTER VI

CONCLUSION

In an intellectual landscape dichotomized by a deficit approach and a contextualist approach, I have offered an alternative which harnesses the virtues of both approaches through a Deweyan inspired approach to science engagement. The deficit approach prizes the factual content of science, its epistemic authority, and its unidirectional communication to the public. The contextualist approach recognizes the sociocultural embeddedness of science in society, how publics receive science, and how local knowledges intersect with science. The synthesis I have put forth incorporates the factual content of science and its epistemic authority, but in a way that is sensitive to context. By sensitive to context, I mean this in two ways. First, that the findings of science are communicated in ways which acknowledge and engage with the belief-value systems of members of the public. Second, that scientific knowledge in the realm of science engagement is constructed in contexts.

Chapter I surveyed the motivations for the project and framed the problem-space this project occupies. I outlined the dominant approaches in public understanding of science and public engagement with science – the deficit model approach and the contextualist model approach – and argued each has limitations. Regarding the deficit model, the problem I identified was the non-epistemic factor exclusionary problem. The problem is that the deficit model does not adequately account for reasons why individuals might not accept scientific findings upon receipt of those theories. Research in the brain and behavioral sciences show that there are social and political predictors which intervene on the acceptance of scientific findings. Regarding the contextualist model, the problem I identified was the scientific authority deflation problem. The problem is that a contextualist model approach undermines the epistemic authority of science by placing equal value on knowledge claims even when those other knowledges lack the constitutive and institutional mechanisms for critical appraisal and self-correction.

In Chapter II, I argued that the participant-centered model of science engagement adopts a Deweyan-inspired deliberative democratic framework. I argued that science engagement should aim to forge the epistemic tools needed to use science for practical ends and that science engagement should be a space for feedback between science and the public. In this way, science engagement cultivates science understanding but also brings science and the public into productive contact. To actualize the deliberative democratic aims, the participant-centered model adopted principles and strategies inspired by learner-centered approaches to teaching and learning. The six participant-centered strategies are: (1) Re-Think Power Structures, (2) Value the Participants, (3) Engage with Belief-Value Systems, (4) Recognize Stages of Development in Learning, (5) Scaffold Metacognition, and (6) Encourage Social Bonds.

The remaining chapters outlined and assessed each of the strategies and offered particular practices which would fall under each general strategy. Chapter III took up the first two Re-Think Power Structures and Value the Participants as they conceptualize the relationship between the participants and the science engagement professional or science communicator. To Re-Think Power Structures is to flatten the implicit or explicit hierarchy between participant and professional in order to facilitate more productive exchanges. The particular practice associated with Re-Think Power Structures was to train science engagement professionals in researcher/practitioner positionality. The idea is that reflecting upon one's potential biases allows for more productive interactions with members of the public. Furthermore, it ensures that professionals have considered how their background assumptions may influence the way they construct, share, and disseminate knowledge. To Value the Participants is to trust in their epistemic agency and see value in their background knowledge and social identities. The particular practice I offered under the strategy of Value the Participants was to decolonize science engagement. The idea here was to make science engagement more relevant and increase contact with marginalized identities.

Chapter IV took up the next three strategies as they collectively covered the psychological properties of participants. The strategy of Engage with Belief-Value Systems directed science engagement professionals to recognize the background beliefs and unique experiences of participants when designing science engagement opportunities. I offered two practices for this strategy. One was to use survey research as a method of gathering feedback and determining where members of the public were coming from. Two was to forefront how science works in science engagements. The idea is that the methods of science as an engagement strategy can reduce polarization. The strategy of Recognize Stages of Development in Learning directs professionals to ensure engagements are developmentally appropriate for the target audience. The particular practice I suggested was to implement guided discovery programs in science engagement. The strategy of Scaffold Metacognition directed professionals to harness the power of metacognition in structuring engagements. The particular practice I identified was the use of mindfulness interventions as way to harness and sharpen executive functioning.

Chapter V addressed the final strategy of Encourage Social Bonds. Sociality had been a major thrust of the entire project, but this chapter rounded out the dissertation by directing science engagement professionals to leverage social interactions in the design of engagement opportunities. The particular practice I recommended in this case was to use deliberative mini-publics to have experts and the public come together and deliberate over values, policies, research programs, and other matters of scientific import within informal science education venues.

The participant-centered model of science engagement opens new avenues for research and theorizing in the realm of science engagement. It invites researchers in informal science education, philosophy of science, social studies of science, and psychological and brain science to converge on this critical space between science and society. I am particularly interested, as a philosopher, in *philosophy of science engagement* as a particular field of study emerging from this synthetic project. Extant projects in philosophy probe values in science and the science and society relation; however, no philosophical research program has sought to substantially engage with the rich ecosystem that is informal science education and participatory research taken together as a dynamic space of science engagement.

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