Scientists' Experiences of Awe and its Relation to Learning and Discovery

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Purpose

The emotion of awe has been the subject of increasing attention in psychology research over the past 15 years. Awe is classified as an epistemic emotion – that is, an emotion that plays a critical role in the process of knowledge acquisition (Morton, 2010). Recent research suggests that the emotion of awe is particularly well aligned to the teaching and learning of science (Valdesolo, Shtulman, & Baron, 2017). Additionally, psychologists have found evidence to support the notion that experiences of awe play a role in orienting us toward the wellbeing of the collective (e.g., Piff et al., 2015). Such findings raise compelling pedagogical implications for science educators who seek to frame instruction in a way that underscores the role of humans as participants within a variety of vast, complex, interconnected systems.

However, the existing research on awe is primarily laboratory-based and domain general, which limits the extent to which we can infer concrete implications for science learning. The present study builds on prior literature to investigate authentic experiences of awe in scientific learning and discovery. In this paper, I present findings from an interview study of expert scientists (n=30) about moments of awe experienced throughout their professional trajectories and the perceived impact of those moments. The emergent themes illuminate disciplinary-specific features of awe experiences in science and suggest both challenges and opportunities for science educators who wish to leverage students' feelings of awe in their instruction.

Theoretical Framework

The most commonly cited definition of awe in the psychology literature comes from Keltner and Haidt (2003), who proposed a cognitive model consisting of two key features: the *perception of vastness* and the *need for accommodation.* Vastness often refers to physical size, but it can also refer to other scales such as time, complexity, or power. Accommodation refers to the notion that when new information does not fit within a learner's existing schema, the learner must modify the schema or develop a new one (Piaget & Inhelder, 1969).

Awe has been classified as an *epistemic emotion*, or an emotion involved in the process of knowledge acquisition (Morton, 2010; Schindler et al., 2017). Awe is differentiated from other epistemic emotions by its tendency to provoke the learner to revise his or her existing mental model. This experience of disruption followed by accommodation suggests that "the condition of being in awe plays an important unsung role in the learning process" (Rowen, 2006, p. 216).

Research from cognitive development and neuroscience has underscored the importance of emotional engagement for facilitating learning and transfer (Bianchi, 2014; D'Mello & Graesser, 2011; Immordino-Yang & Damasio, 2007; Taylor, 2001). Researchers have posited that awe may be an especially powerful emotion for facilitating science learning (e.g., Valdesolo, Shtulman, & Baron, 2017). The first component of awe, perception of vastness, is a logical fit for science, given that scientific concepts often involve extreme magnitudes of scale (whether in space, time, quantity, or complexity).[1] Moreover, as science learning often involves expectation violation and conceptual change, awe is valuable in its capacity to motivate accommodation (Valdesolo, Shtulman, & Baron, 2017).

[1] Indeed, "scale, proportion, and quantity" is one of seven crosscutting concepts identified in the Next Generation Science Standards (NGSS Lead States, 2013).

Building on the existing literature, this study is guided by the following research questions:

1) What are some prevalent features of transformative awe experiences in the context of science?
2) In what ways, if at all, do scientists see their awe experiences as transformative or otherwise impactful?

Methods

Sample

Professional scientists (n=30; 13 female, 17 male) were recruited using a purposeful sampling method across a range of fields in the natural sciences, including biology, chemistry, physics, earth science, and astronomy. The participants' institutional affiliations represented 20 different organizations across a variety of sectors (i.e., universities, industry, government, K-12 education, and independent research organizations).

Procedure

Interviews lasted approximately one hour and were semi-structured. The interview protocol included questions about the participant's early experiences with science, definition of awe and examples of awe in the context of his or her work, and response to a short video clip from the film *Overview*.[2] I conducted interviews in-person and via video conferencing platforms as necessary. All interviews were audio-recorded and transcribed.

Analytic Approach

I took a phenomenological approach to the analysis, which relies on the epistemological assumption that investigating how individuals experience and make meaning of a concept or

[2] *Overview* is a film about the overview effect, the well-documented cognitive shift that astronauts experience upon seeing earth from space.

phenomenon can help us understand the "essence" of that concept or phenomenon (Polkinghorne, 1989; Moustakas, 1994). As such, I conducted an emergent thematic analysis of all interview transcripts to identify prominent themes and concepts in the data. A second researcher who was not an expert in the theoretical framing of the research coded a subset of the data in order to "cast a wider analytic net" (Saldaña, 2009, p. 27).

Results

The complex findings emerging from this analysis cannot be fully addressed within the scope of this paper. Here, I present a limited set of three key themes that were prevalent across the dataset.

1. Awe is closely tied to the process of discovery.

In the limited existing literature referencing awe in science, the examples tend to focus on conceptual knowledge (e.g., ideas such as deep time, the interconnectedness of species, etc.). Contrastingly, most of the examples generated by scientists in the study were centered on the experience of conducting scientific work rather than on the nature of the findings themselves**.** Many stories of awe were about moments of discovery, often focused on the sensation of contributing to human knowledge; quite a few participants described moments of waiting in anticipation for an experiment to work or for new data to come in. When participants' examples did focus on conceptual understandings, they were often from moments early in their careers (e.g., learning about the human genome for the first time).

Additionally, scientists overwhelmingly described awe as an initial and ongoing motivator for their work. This was a key component of their definitions and also seemed to be the primary way in which they saw their awe experiences as transformative (i.e., the main impact of awe experiences is to drive scientists to keep pursuing science). While some participants

attributed their career trajectories to powerful early experiences, others felt that they were inherently the "type of person" who finds science to be awe-inspiring.

In relation to Keltner and Haidt's (2003) definition, the data reflected the "need for accommodation" component of awe much more strongly than the "perception of vastness." These findings do seem to be in line with the idea of awe as an epistemic emotion. Multiple participants included explanation-seeking behavior in their definitions of awe, and some described a feeling of "wanting to know more" that suggests an ongoing search for knowledge. Novelty also seemed to play an important role in eliciting awe; scientists frequently described the experience of learning something new or seeing something for the first time. This could be one reason why the examples are largely process-driven (i.e., at this point in their careers, it is plausible that expert scientists are more likely to experience novelty by generating new data than by learning a new concept). If that is the case, novices' awe experiences in the context of science might look quite different.

2. *Awe is relational and positioned in the context of prior experiences.*

Participants situated their moments of awe in relation to the experiences leading up to them and the people involved. Often, scientists attributed the sense of awe to the long, hard work leading up to that moment. Some scientists expressed their desire to share the experience with others (e.g., by calling a colleague over to see new data emerging), while others emphasized the sensation that comes with being the only person privy to a new piece of knowledge. For instance, an astrophysicist likened the experience of discovering distant stars through a powerful telescope to stumbling upon a *"secret garden."*

Metacognition also seemed to play a role in the impact of an awe experience. The act of reflecting on a moment of awe and its importance appeared to contribute to the transformative

nature of the experience, but participants said that their daily work does not present regular opportunities to engage in this type of thinking. Interestingly, this finding was revealed in part through the methodology itself, as the interview process seemed to serve as an intervention that provided participants with an opportunity for reflection. Participants often generated new examples toward the very end of the interview, frequently saying things like *"I never thought about this before!"*

It is notable that the examples generated by scientists when asked to think of impactful awe experiences look very different than the awe-eliciting stimuli used in lab studies. As one epidemiologist said, the initial sensation of an awe experience *"dissipates a little bit, but it doesn't go away … I think the moments collectively build up."* A neuroscientist referred to the *"low-level, ever-present"* sense of awe that is at the heart of her work.

3. In the context of education, scientists saw awe as both highly valuable and highly elusive.

Finally, when asked about the pedagogical role of awe from their own experiences as both students and teachers, many participants agreed that awe is an objective of instruction. Participants emphasized the importance of exposing learners to authentic science (rather than "cookbook" labs), and many highlighted the human aspect of the discipline and the value of personal relationships. However, many also expressed that these authentic experiences are hard to manufacture. These intuitions are in line with existing research about effective science instruction and the value of authenticity.

Scholarly Significance

It has only been in the past decade that the field of psychology has attended to awe as a major object of interest, but in this short time, researchers have already made strong assertions about the emotion's effects on learning, personal health, and collective wellbeing. However, the

prevailing methods tell us little about how individuals actually respond to awe-inducing experiences in their own lives. Critically, while the suggestion that awe may be a powerful pedagogical tool in the context of science education is compelling, we lack the necessary information to make useful curricular recommendations. This study contributes to our conceptual understanding of the relationship between awe and science and identifies concrete examples of awe-eliciting experiences in the context of scientific learning and discovery. In addition to contributing to the scholarly literature, the examples of authentic awe experiences in science generated by this study can begin to inform curriculum development and the process of cultivating learning environments where opportunities for awe are present.

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