Measuring Epistemic Weather Curiosity: Initial Development and Validation of an Individual Difference Questionnaire

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Abstract

This paper addresses work at the intersection of meteorology and the psychology of curiosity and learning (Bolton et al., 2020; Stewart et al., 2015, 2018). Specifically, we report on the development and validation of the first self-report measure of epistemic (i.e., information-based) weather curiosity. An 11-item self-report scale (the Epistemic Weather Curiosity Questionnaire; ECWQ) measuring general interest in learning about weather and curiosity for the science behind weather was derived from two studies. The EWCQ demonstrated good convergent validity overall. It was significantly and positively correlated with measures of weather salience and analytical (systemizing) cognitive style in both studies: weather warning awareness and beliefs about one's ability to prepare for severe weather in study 1; and trait epistemic curiosity, trait openness, and interest in learning science in study 2. Psychometric properties and implications of the scale for use by meteorologists, educators, and academic researchers are discussed.

Weather, often considered to have strange and unusual properties (e.g., Ludlum, 1984; Seargent, 2012), has fascinated humankind for centuries. One needs only look to the myriad studies of its nature for evidence of this captivation (e.g., Bjerknes, 1921; De Figueiredo Neves et al., 2017; Helmholtz, 1858; Howard, 1803; Jankovic, 2006; Meleshko & Aref, 2007). What are some psychological variables that might help explain such curiosity for the weather?

We first consider, in the personality domain, openness to experience. Openness sits alongside conscientiousness, extraversion, agreeableness, and neuroticism in the Five Factor Model of personality (Soto & John, 2017). First used by Rogers (1954), the term reflects an individual's predisposition to embrace, in Soto and John's words (2017), "a wide versus narrow range of perceptual, cognitive, and affective experiences" (p. 120). A crucial distinction is that it does not connote openness to *social* experience (this is extraversion; see, e.g., Sneed et al., 1998), but rather to more *inner*, cognitive events. Highly open people tend to be intellectually and aesthetically curious, with tendencies for deep thinking, to value artistic pursuits, and to have creative imaginations.

Weather salience theory (Stewart, 2009) provides another, more directed framework through which to understand this curiosity. As with other individual differences, weather salience–a quantification of the attention an individual directs towards weather–exists along a continuum so that one is more or less attuned to meteorological phenomena. Weather salience is driven by cognitive appraisal of, and physical sensitivity to, the natural environment (Evans & Cohen, 1987; Evans & Stecker, 2004; Stewart, 2009; Stokols, 1979, 1995). Such attunement may predict weather knowledge and information use (Stewart et al., 2012; Williams et al., 2017) and may be enhanced in particular clinical populations and individuals with particular cognitive styles (those with autism spectrum conditions, e.g., Bolton, Blumberg et al., 2020; and see Lau et al., 2020 on the incidence of weather-related anxieties in autistic children). Recent work suggests adult weather salience may stem in part from childhood weather-learning experiences (Bolton et al., 2020).

Cognitive style theories (Kozhevnikov, 2007) such as empathizing-systemizing (Baron-Cohen, 2020) might also help explain weather curiosity. Systemizing, formulated as the drive and ability to identify and generate psychological systems or sets of logical rules used to explain the workings of the physical world, attempts to explain aspects of autism spectrum conditions (Baron-Cohen, 2020). We are interested in the detail-orientation aspects of the systemizing construct and the manner in which it motivates and drives predictions of certainty (Bolton, Blumberg et al., 2020). Ideal systemizing involves keeping variables constant and changing only one parameter at a time (Baron-Cohen, 2006; Bolton, Blumberg et al., 2020) so that each change can be observed relative to the overall system. This allows for the verification of predictability through an understanding of system sensitivity (Bolton, Blumberg et al., 2020; Tullett et al., 2015). It has been suggested (Bolton, Blumberg et al., 2020; Bolton et al., 2020) that systemizing-weather relations are linked to perceptions of chaos and weather-randomness.

Although not measured here, another important theoretical variable is *perceptual* weather curiosity. Stewart created the Weather Curiosity Scale (2017) to measure a type of weather curiosity embodied in sensory-driven curiosity for sights (e.g., beauty appreciation); smells (e.g., of rain); tastes (e.g., of snow); sounds (e.g., wind rustling through trees); and textures (e.g., the supposed feeling of clouds) associated with weather. This relationship with weather entails trait sensitivity to environmental stimulation and the manner in which people experience emotions and manifest their personalities. Stewart (2017) found increased perceptual weather curiosity among those with more intense emotional experiences and in more socially outgoing individuals.

Finally, among the variables considered here, epistemic curiosity (EC) is the naturally occurring drive to seek new information (Litman & Spielberger, 2003). There are two types: Interest (I-type) and Deprivation (D-type). I-type considers that individuals intrinsically enjoy discovering new things and want to learn more about them. D-type is experienced when individuals lack information and are driven to fill a knowledge deficit (Litman, 2008; Litman & Jimerson, 2004). Individuals may thus experience either positive feelings as a result of new learnings or negative feelings due to lack of certainty around knowing about a topic (Litman & Jimerson, 2004; Loewenstein, 1994). Curiosity scholars have posited that desires for new information reflect either a pleasurable anticipation of new learning or feelings of deprivation stemming from lack of access to said information. Lowenstein (1994) suggested curiosity as a feeling of interest would be stimulated when individuals recognize possible enjoyment associated with new information. By comparison, those who perceive suffering a deficiency by not possessing new information, or “missing out” on that knowledge, would feel deprived (Litman & Jimerson, 2004; Lowenstein, 1994; Lowenstein et al., 1992). This deprivation–an unpleasant sensation accompanied by secondary feelings of tension and uncertainty–elicits an impulsive information-seeking which can, in theory, be ameliorated by the acquisition of factual knowledge or problem-solving associated with the curiosity (Litman & Jimerson, 2004; Lowenstein, 1994). I-type curiosity thus positively reinforces exploratory behaviors and fosters pleasure via the increase of intellectual stimulation; D-type curiosity negatively reinforces exploration and involves pleasure through tension reduction.

Despite research related to the ways in which people perceive, process, respond to, and use weather information and associated environmental stimuli in the world around them (for a broad review, see Bolton, 2021), research has not yet explored the epistemic side of weather curiosity (EWC) related to a need for information about weather. This dearth of research has endured even as an information-based curiosity for the weather has clearly been manifested in the way weather phenomena has long enthralled people (Maddern & Jenner, 2009; Phan et al., 2018; Stewart, 2009; Stewart et al., 2012; Strauss & Orlove, 2003; U.K. Met Office, 2015). Recognizing that a validated measure of EWC could be useful to further study in this area and in, for example, K-12 physical science learning environments (Stewart et al. 2015, Stewart et al., 2018), we designed a short questionnaire enabling its quantification. The study presented next reports our efforts to validate a new questionnaire of epistemic weather curiosity and to correlate it with several existing measures of weather salience, systemizing cognitive style, openness to experience, two components of epistemic curiosity, science curiosity, weather warning awareness, storm preparation self-efficacy (i.e., the belief one holds about being able to prepare for storms), and storm safety behaviors.

Method

Participants and Procedure

Participants were recruited internationally through social media for two online, Qualtrics-hosted surveys,

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with protocols approved by the Saint Leo University Institutional Review Board. Table 1, presented next, shows the participants' demographic composition. Open data, in SPSS and JASP file formats (JASP for CFA), are available on the Open Science Framework website (https://osf.io/74n6w/).

Table 1
Self-reported demographics for both studies.

<table>
<tr><td colspan="7">Study 1 (N = 209)</td></tr>
<tr><td colspan="7">Racial Classification</td></tr>
<tr><td>Caucasian</td><td>Hispanic</td><td>Asian</td><td>Latino/a</td><td>Bi- or Multi-racial</td><td>African American</td><td>Other</td></tr>
<tr><td>172</td><td>10</td><td>8</td><td>8</td><td>4</td><td>1</td><td>6</td></tr>
<tr><td colspan="7">Gender and Age</td></tr>
<tr><td colspan="2">Women</td><td>Men</td><td>Nonbinary</td><td>Mean</td><td>SD</td><td>Range</td></tr>
<tr><td colspan="2">145</td><td>61</td><td>3</td><td>37.10</td><td>16.35</td><td>18-91</td></tr>
<tr><td colspan="7">Weather Interest</td></tr>
<tr><td colspan="4">Weather as Hobby or Interest (n = 208)
Yes (93; 44.7%) | No (115; 55.3%)</td><td colspan="3">Wanted to Be Meteorologist (n = 93)
Yes (34; 36.6%) | No (59; 63.4%)</td></tr>
<tr><td colspan="7">International Distribution by Country</td></tr>
<tr><td colspan="2">United States: 136 (65.1%)</td><td colspan="2">United Kingdom: 48 (23%)</td><td>Canada: 5 (2.4%)</td><td colspan="2">Other: 20 (9.6%)</td></tr>
<tr><td colspan="7">Study 2 (N = 236)</td></tr>
<tr><td colspan="7">Racial Classification</td></tr>
<tr><td>Caucasian</td><td>African American</td><td>Asian</td><td>Hispanic</td><td>Latino/a</td><td>Bi- or Multi-racial</td><td>Other</td></tr>
<tr><td>201 (85.1%)</td><td>9</td><td>8</td><td>4</td><td>1</td><td>4</td><td>9</td></tr>
<tr><td colspan="7">Gender and Age</td></tr>
<tr><td colspan="2">Women</td><td>Men</td><td>Nonbinary</td><td>Mean</td><td>SD</td><td>Range</td></tr>
<tr><td colspan="2">185 (78.4%)</td><td>47 (19.9%)</td><td>4 (1.7%)</td><td>41.14</td><td>16.10</td><td>18-86</td></tr>
<tr><td colspan="7">Weather Interest</td></tr>
<tr><td colspan="4">Weather as Hobby or Interest (n = 220)
Yes (102; 46.4%) | No (118; 53.6%)</td><td colspan="3">Wanted to be Meteorologist (n = 100)
Yes (33; 33%) | No (67; 67%)</td></tr>
<tr><td colspan="7">International Distribution by Country</td></tr>
<tr><td colspan="2">United States: 206 (87.3%)</td><td colspan="2">United Kingdom: 11 (4.7%)</td><td>Canada: 1 (0.4%)</td><td colspan="2">Other: 18 (7.6%)</td></tr>
</table>

Across the two studies, participants responded to the demographic items shown in Table 1 and several individual difference, self-reported Likert-type measures of the constructs discussed above (openness, weather salience, systemizing, storm preparation self-efficacy beliefs and safety behaviors, and trait epistemic and science curiosities; note that they are presented next in the order to which participants responded to them). Cronbach's alpha (α), a standardized measure of item inter-correlation ranging from 0–1, was calculated for all measures to assess internal reliability and suitability for use. For study 1, these were the 7-item version of the Weather Salience Questionnaire (WxSQ; Stewart et al., 2012; α = 0.65); 10-item Systemizing Quotient (SQ; Greenberg et al., 2018; α = 0.74); 4-item Oklahoma Warning Awareness Scale (OKWAS; Allan et al., 2017; α = 0.92); 8-item Hurricane Personal Self-Efficacy Scale (HPSES; Stewart, 2015; α = 0.88, note that the items were modified to reference thunderstorms so we hereafter refer to the scale as the TPSES); and 15 items from the Storm Safety Behavior Scale (SSBS; Krause et al., 2017; α = 0.85).

Study 2 used 13 WxSQ items related to weather-directed attention and sensing as a composite measure (Stewart, 2009; α = 0.81), the 10-item Interest and Deprivation (I-D) Curiosity Scale (Litman & Spielberger, 2003; Interest α = 0.85, Deprivation α = 0.85), 12-item Openness factor of the Big Five Inventory-2 (Soto & John, 2017; α = 0.85); 12-item Science Curiosity in Learning Environments Scale (SCILE; Weible & Zimmerman, 2016; α = 0.92), and 10-item SQ (α = 0.83). Remaining measures assessed convergent validity except the SCILE (used to assess discriminant validity).

In an effort to begin improving weather salience and systemizing measurement, we (following the advice and psychometric recommendations of Wright & Skagerberg, 2012) de-reversed the negatively phrased items for the

WxSQ and SQ questionnaires in Study 2.[1] Save for the 7-item WxSQ in Study 1, all scales were reliable at typical alpha coefficient standards of 0.70. However, the original paper detailing its creation and personal correspondence with Alan Stewart (2019, 2020) indicates low reliabilities tend to occur because of the manner in which it was constructed. It was not intended as a full measure of weather salience tendencies but rather as a very brief indicator of a broadly generalized psychological orientation towards weather. Outlying questionnaire scores ± 2.5 standard deviations (SD), except for the epistemic weather curiosity questionnaire (for which we aimed to examine score distributions), were removed.

Questionnaire Construction. Twenty-three items thought to be relevant to EWC measurement served as the basis for the scale. Consistent with the EC literature, items aligned with the notion that people are driven to understand how the weather works and are curious about weather information and correspondingly interested in acquiring it in a variety of ways.

Item formulations were influenced by the Children's Science Curiosity Scale (Harty & Beall, 1984). We attempted to address that questionnaire's poor construct validity, due to its conceptualization of science curiosity as revolving solely around interest and not involving self-initiated action towards obtaining scientific knowledge (Gardner, 1987), by creating items featuring active engagement in curiosity-driven, weather information-gathering activities. Participants indicated agreement with each item (Table 2), on a 5-point, Likert-based scale from 1 (strongly disagree) to 5 (strongly agree). Summed responses yield total and subscale scores.

Table 2
Original items created to measure epistemic weather curiosity.

Initial Item Pool
1. I would like to read magazines and/or stories about weather.
2. I like to watch television programs about weather.
3. I would like to listen to meteorologists talk about their jobs.
4. I want to know what causes wind.
5. I like to talk about the weather.
6. Movies and pictures about weather are interesting.
7. I like to watch TV news reports about weather.
8. I like to search for answers to questions about weather.
9. I feel drawn to learning about weather.
10. I have some interest in learning how to read computer weather models.
11. I would like to see the inside of a weather radar.
12. I want to know what causes tornadoes.
13. I am interested in learning about the tools meteorologists use to predict weather.
14. It would be interesting to see a weather balloon launch.
15. I like when meteorologists on TV talk about the science behind weather.
16. I would be interested in weather-related science experiments (e.g., creating a cloud in a bottle).
17. I am curious about why the weather changes.
18. TV news reports about weather are interesting.
19. I have some interest in learning how to read weather radar.
20. It is interesting to me that wildfires can sometimes create a type of tornado.
21. Weather easily captures my attention.
22. It would be interesting to tour and see inside a TV weather station.
23. I would like to learn about high and low pressure systems.

[1] For example, on the WxSQ, "If a friend or family member asked me what the weather forecast was for today, I could not tell him or her what to expect" becomes "If a friend or family member asked me what the weather forecast was for today, I could tell him or her what to expect," and on the SQ, "When I hear the weather forecast, I am not very interested in the meteorological patterns" becomes "When I hear the weather forecast, I am very interested in the meteorological patterns."

Data Analysis Plan

An initial factor analysis was conducted on the EWC items in study 1 while confirmatory factor analysis (CFA; Field, 2013) was conducted in study 2. After initial CFA, the items were further refined through systematic elimination based on the factor model uncovered in study 1.[2] Following these tests, correlational and linear regression analyses, with supporting 95% confidence intervals (CI), were used to assess convergent and predictive validity. The determinant coefficient, Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, and Bartlett's Test of Sphericity determined whether the data were appropriate for exploratory analyses (Watkins, 2018). Previous scholarship (Osborne, 2015; Tabachnick & Fidell, 2014) recommends a 10:1 participant-item ratio. Our samples were N = 209 for study 1 and 235 for study 2, yielding 196 and 226 usable datapoints respectively. These sample sizes were deemed sufficient given recruitment difficulties and the preliminary nature of the work.

Study 2 further tested the hypotheses that EWC would predict engagement with weather or weather information and that, based on the aforementioned predictions around D-type curiosity (Lowenstein, 1994), weather-interested participants would be more anxious when induced to think about a situation in which they would be unable to engage in the weather curiosity-based information-gathering behaviors in our questionnaire. Prior to completing the weather curiosity items, 202 participants completed 5 author-generated items (α = 0.71; see Appendix A) to assess engagement with weather information. After completing the epistemic weather curiosity items, 107 participants with either weather as a hobby or a formal meteorology background imagined that they could no longer engage with weather as expressed in those items and to rate their negative affectivity, themed primarily around characteristics of anxiety, on eight items of the Positive and Negative Affect Schedule (PANAS-SF; Watson et al., 1988; *distress, upset, scared, hostile, irritability, nervous, jittery, afraid*; α = 0.90). Although we could not induce impulsive information-seeking, previous research suggests that anxiety motivates responses in line with the theory of D-type curiosity (Litman & Jamerson, 2004; Lowenstein, 1994; see, e.g., Hmielowski et al., 2019; Yang & Kahlor, 2013).

Results

Study 1

A principal components analysis set to load freely, and with oblique rotation, was deemed appropriate based on the determinant of 7.75 x 10-8, indicating a lack of multicollinearity; KMO score of 0.95; and Bartlett's $\chi 2$ of 3053.67 (df = 253), p < 0.001. This analysis yielded a preliminary 3-factor structure (Table 3) with good communalities (i.e., no items inter-correlating either < .2 or > .8).

Item themes clustered around active engagement in weather-learning (Factor 1, explaining 51.07% of the variance), curiosity for the science behind weather phenomena (Factor 2, explaining 7.53% of the variance), and multimedia-driven curiosity and engagement with weather (Factor 3, explaining 4.45% of the variance). However, 1 item loading < .4 was removed (Osborne, 2015), as were 3 cross-loading items (see Table 3 for items, including those removed which are denoted with asterisks). These were removed since the difference between cross-loading items should be at least .2 in order for them to be retained (Kline, 1998). Repeating the factor analysis with the 4 items removed (also Table 3, see parentheses for the second analysis) merged the previous second and third factors, resulting in a general Curiosity about Weather Science factor. It also revealed two more cross-loading items, which were removed. The remaining items were subjected to a final analysis, which yielded 17 strongly reliable items across the two factors (Table 4; total α = 0.94; Factor 1 = 0.90; Factor 2 = 0.90) and accounted for 59.52% of the variance (Factor 1, 50.47%; Factor 2, 9.06%).

This left-skewed solution approximated a normal distribution (Figure 1) and was supported by one major inflexion point in the first analysis' scree plot (Figure 2; Kanyongo, 2005), lending credence to the two-factor structure as most parsimonious and interpretable. These items are henceforth referred to as the Epistemic Weather Curiosity Questionnaire (EWCQ). Pearson bivariate r correlations showed good convergence with the accompanying measures (Table 5).

[2] CFA-supporting computations included the comparative fit (CFI), Tucker-Lewis (TLI), and goodness of fit (GFI) indices; standardized room mean residual (RMR); and the root-mean-square error of approximation (RMSEA).

Table 3

Results of the first two exploratory factor analyses.

Epistemic Weather Curiosity Questionnaire Items After First (and Second) EFA Factor Loadings from Principal Components Analysis					
	Item	Factor Loadings > .4			
		1	2	3	Communality
1.	I have some interest in learning how to read computer weather models.	.953 (.500)			.759 (.513)
2.	I feel drawn to learning about weather.	.655 (.655)			.670 (.613)
3.	I like to search for answers to questions about weather.	.646 (.473)			.579 (.510)
4.	**I have some interest in learning how to read weather radar.	.637 (.528)	(.425)		.754 (.711)
5.	I would like to see the inside of a weather radar.	.593	(.507)		.662 (.619)
6.	I would like to learn about high and low pressure systems.	.583	(.506)		.639 (.602)
7.	*I am interested in learning about the tools meteorologists use to predict weather.	.539	-.419		.731
8.	*I would like to read magazines and/or stories about weather.	.422		.409	.492
9.	**It would be interesting to tour and see inside a TV weather station.	.405 (.473)	(.430)		.646 (.638)
10.	I would be interested in weather-related science experiments (e.g., creating a cloud in a bottle).		-.882 (.869)		.714 (.664)
11.	It is interesting to me that wildfires can sometimes create a type of tornado.		-.795 (.789)		.628 (.599)
12.	I am curious about why the weather changes.		-.723 (.735)		.692 (.667)
13.	I want to know what causes tornadoes.		-.712 (.721)		.557 (.542)
14.	I want to know what causes wind.		-.672 (.766)		.492 (.521)
15.	I like when meteorologists on TV talk about the science behind weather.		-.459 (.507)		.589 (.582)
16.	It would be interesting to see a weather balloon launch.		-.443 (.400)		.497 (.478)
17.	*I would like to listen to meteorologists talk about their jobs.				
18.	I like to watch TV news reports about weather.	(.949)		.926	.747 (.693)
19.	TV news reports about weather are interesting.	(.873)		.867	.751 (.677)
20.	I like to watch television programs about weather.	(.830)		.704	.660 (.653)
21.	Movies and pictures about weather are interesting.	(.619)		.564	.570 (.527)
22.	Weather easily captures my attention.	(.639)		.521	.625 (.607)
23.	*I like to talk about the weather.	.435		.509	.566
Eigenvalues		13.478 (11.415)			
% of variance		58.601 (60.082)			

Table 4

Results of the third exploratory factor analysis.

Epistemic Weather Curiosity Questionnaire Items After Final EFA Factor Loadings from Principal Components Analysis			
Item	Factor Loadings Ordered Greatest-Least > .4		
	1	2	Communality
1. I would be interested in weather-related science experiments (e.g., creating a cloud in a bottle).	.876		
2. It is interesting to me that wildfires can sometimes create a type of tornado.	.795		
3. I want to know what causes wind.	.771		
4. I am curious about why the weather changes.	.747		
5. I want to know what causes tornadoes.	.729		
6. I would like to learn about high and low pressure systems.	.521		
7. I like when meteorologists on TV talk about the science behind weather.	.519		
8. I would like to see the inside of a weather radar.	.518		
9. It would be interesting to see a weather balloon launch.	.407		
10. I like to watch TV news reports about weather.		-.946	
11. TV news reports about weather are interesting.		-.870	
12. I like to watch television programs about weather.		-.824	
13. I feel drawn to learning about weather.		-.641	
14. Weather easily captures my attention.		-.628	
15. Movies and pictures about weather are interesting.		-.617	
16. I have some interest in learning how to read computer weather models.		-.473	
17. I like to search for answers to questions about weather.		-.465	
Eigenvalues	10.12		
% of variance	59.524		

Figure 1

Distribution for the 2-factor, 17-item Epistemic Weather Curiosity Questionnaire derived through exploratory factor analyses in study

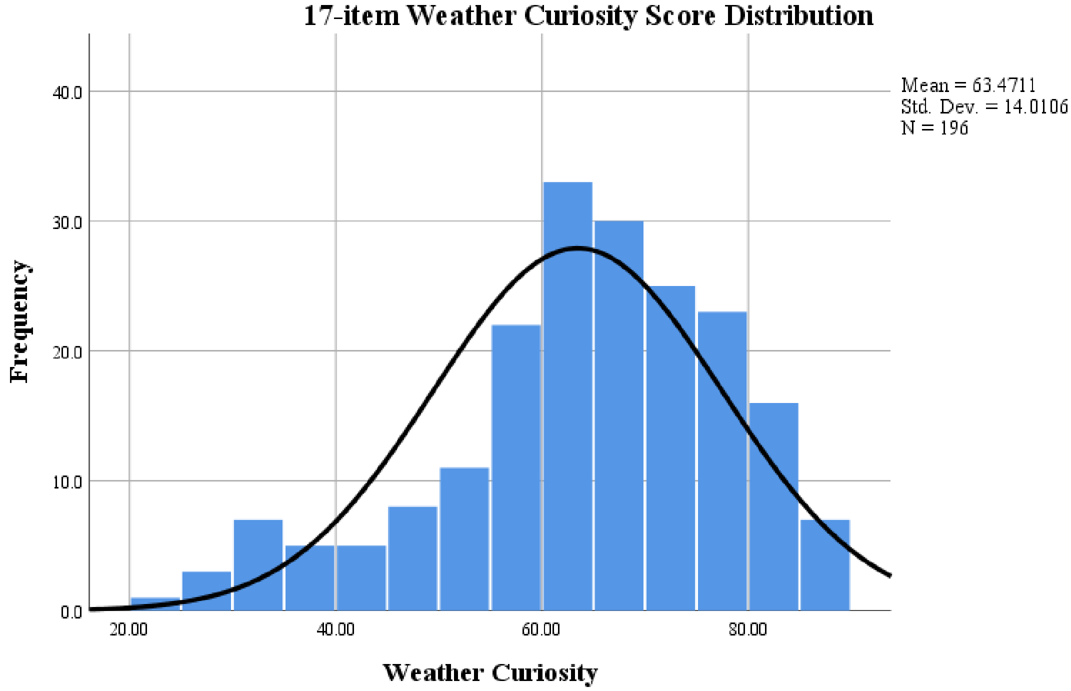


Figure 2

Scree plot from first exploratory factor analysis in study 1.

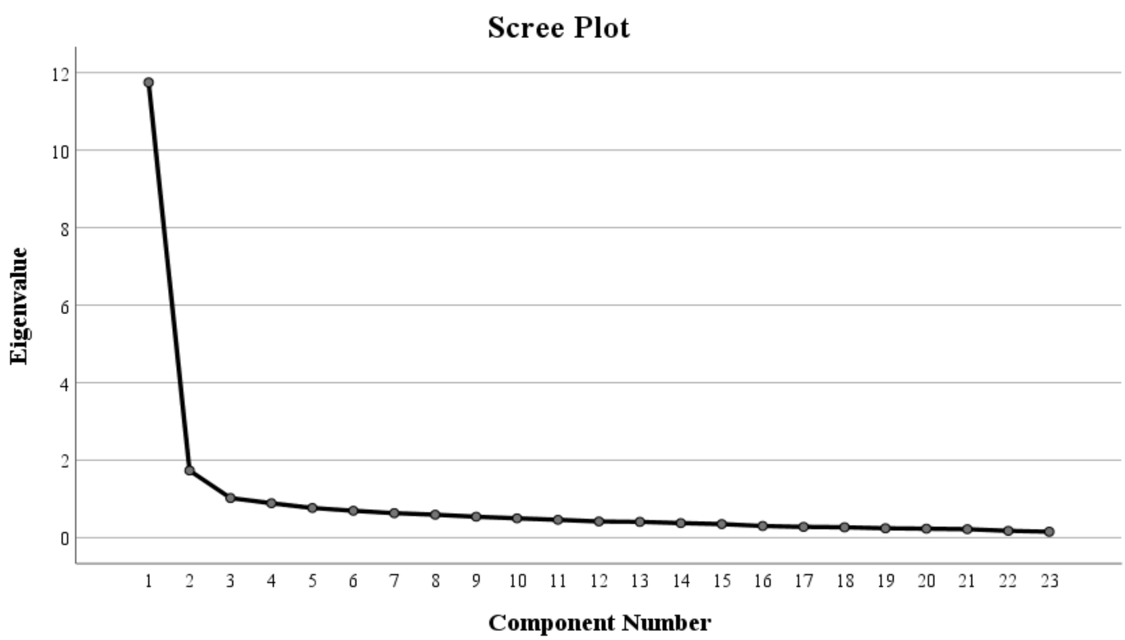


Table 5
Pearson bivariate r correlations for study 1.

Variable		WxSQ	SQ	OKWAS	TPSES	SSBS	EWxCQ-17
WxSQ	*n*	-					
	Pearson's *r*	-					
	p-value	-					
	Lower CI	-					
	Upper CI	-					
SQ	*n*	196	-				
	Pearson's *r*	.51	-				
	p-value	< .001	-				
	Lower CI	0.40	-				
	Upper CI	0.61	-				
OKWAS	*n*	188	184	-			
	Pearson's *r*	.38	.385	-			
	p-value	< .001	< .001	-			
	Lower CI	0.25	0.22	-			
	Upper CI	0.50	0.47	-			
TPSES	*n*	185	181	188	-		
	Pearson's *r*	.36	.26	.42	-		
	p-value	< .001	< .001	< .001	-		
	Lower CI	0.22	0.12	0.30	-		
	Upper CI	0.48	0.39	0.54	-		
SSBS	*n*	183	179	186	183	-	
	Pearson's *r*	.11	.08	.14	.11	-	
	p-value	0.149	0.292	0.063	0.133	-	
	Lower CI	-0.04	-0.07	-0.007	-0.03	-	
	Upper CI	0.25	0.22	0.28	0.25	-	
EWCQ-17	*n*	193	188	190	187	185	-
	Pearson's *r*	.53	.52	.44	.36	.10	-
	p-value	< .001	< .001	< .001	< .001	0.163	-
	Lower CI	0.42	0.40	0.32	0.23	-0.04	-
	Upper CI	0.63	0.61	0.55	0.48	0.24	-

Note. Dunn-Bonferroni confidence intervals (CI) estimate the range in which the correlation could be expected to fall if the study were conducted multiple times with the same sample size drawn from the same population.

Study 2

The two factors had a poor initial model fit in CFA: $\chi 2$ = 460.49 (118), $p < 0.001$, CFI = 0.85, TLI = 0.82, RMSEA = 0.11 (CI [0.10, 0.12]), SRMR = 0.08, GFI = 0.80. Modification indices and correlation and covariance matrices indicated several strongly-cross-loading and highly-covarying items.[3]

An 11-item model (Table 6, Figure 3) yielded by a series of systematic, data-driven item reductions carried out on the 17 items was significantly improved over the initial fit and had excellent psychometric properties: $\chi 2$ = 56.92 (43), p = 0.076, CFI = 0.99, TLI = 0.99, RMSEA = 0.038 (CI [0.000, 0.06]), SRMR = 0.04, GFI = 0.96. These

[3] The strongest cross-loaders, with the following item number mentions referencing Table 4, were items 10 (with 11 and 12). We incrementally tested the effect of removal on model fit by first removing items 11 and 12, which were redundant and did not, in our opinion, enhance face validity over item 10. The modification indices then revealed items 4 and 8 as high cross-loaders among the remaining items. Since item 8 was a much more specific manifestation of curiosity unlikely to be experienced by all but the most curious (and perhaps previously knowledgeable about weather), we opted to remove it. Covariance/correlational analyses at this point showed items 3 and 4, 1 and 2, and 10 and 15 as the highest cross-loaders. To reduce redundancy and in the interest of item clarity and guided by theoretical parsimony, we decided to remove item 14. Finally, we removed items 2 and 4 due to their high correlations with items 1 and 3, respectively.

items also demonstrated strong reliability (Total α = 0.90; Factor 1 = 0.88; Factor 2 = 0.86). The data again skewed left (Figure 4), suggesting most people are at least somewhat weather-curious in an epistemic sense. Note that out of a possible score range from 11–55 this final factor solution had a mean of 40.46 (SD = 8.84, range: 14–55).

Table 6
Pearson bivariate r correlations for study 1.

Final Epistemic Weather Curiosity Questionnaire Items After CFA Number in parenthesis indicates factor
1. I would be interested in weather-related science experiments (e.g., creating a cloud in a bottle). (1)
2. I am curious about why the weather changes. (1)
3. I want to know what causes tornadoes. (1)
4. I would like to learn about high and low pressure systems. (1)
5. I like when meteorologists on TV talk about the science behind weather. (1)
6. It would be interesting to see a weather balloon launch. (1)
7. I like to watch TV news reports about weather. (2)
8. I feel drawn to learning about weather. (2)
9. Weather easily captures my attention. (2)
10. I like to search for answers to questions about weather. (2)
11. I have some interest in learning how to read computer weather models. (2)

Note. Factors are denoted in parentheses. Factor 1 assesses Curiosity for Weather Science; Factor 2 assesses a general, Information-driven Curiosity for Weather. Scale scores are the sum of the items.

Figure 3
Confirmatory factor analysis model plot for 11-item EWCQ solution.

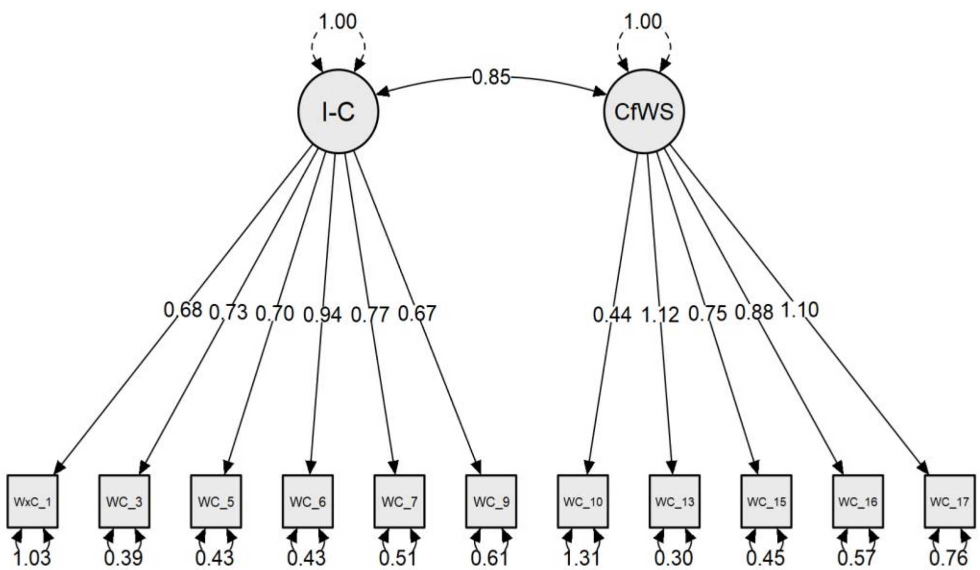
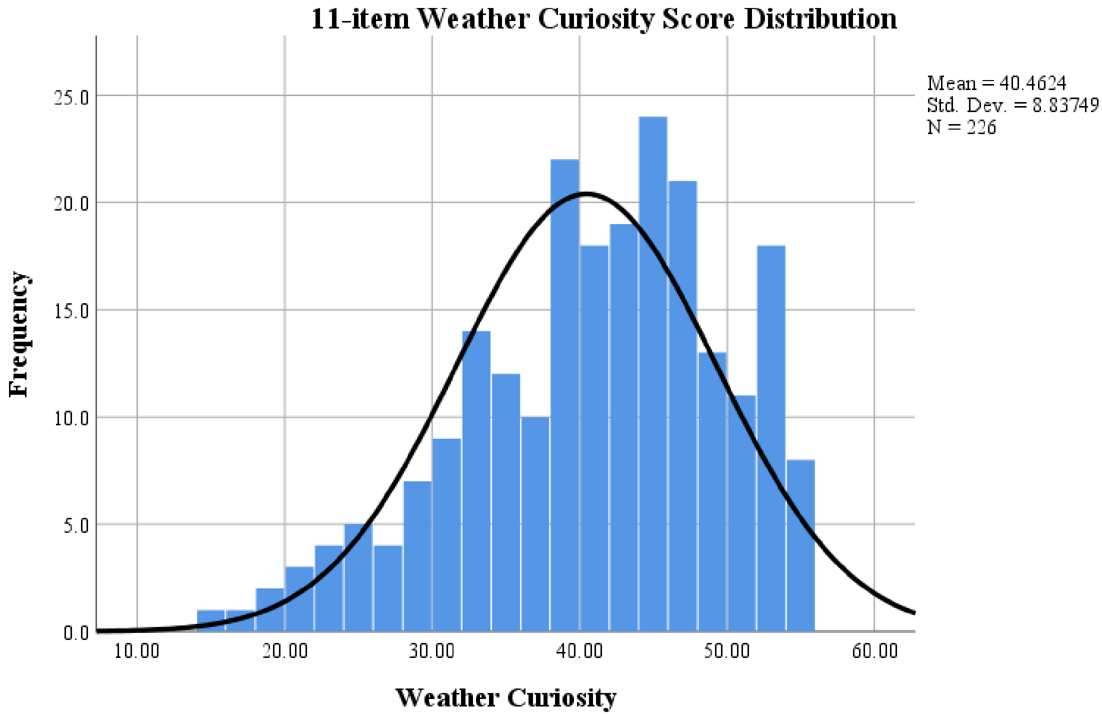


Figure 4
Distribution for the 2-factor, 11-item Epistemic Weather Curiosity Questionnaire derived through confirmatory factor analyses in study 2.



Pearson bivariate *r* correlations showed the 11-item iteration of the EWCQ converged well with the accompanying measures (Table 7). Notably, the SCILE, intended as a discriminant measure, positively correlated with EWC.

The first linear regression (DV: DoWx_regression and IV: WxCuriosity_total) showed that EWCQ score was a significant predictor of engagement with meteorological content and information, $F(1,200) = 54.93$, $p < 0.001$, with an adjusted-R^2 of .21 and unstandardized B of 0.17. Thus, EWCQ score accounted for 21% of the variance in our measure of weather-engagement behaviors. Participants' predicted curiosity equaled 13.90 [CI: 12.09, 15.71] + 0.17 [CI: 0.12, 0.21] weather engagement behaviors so that there was a 0.17-point increase in the number of engagement behaviors for every point-increase in curiosity.

The second regression (DV: WxCuriosity_total and IV: PANAS_regression) showed that imagining an inability to engage in EWC-driven thinking and information-gathering was significantly predictive of negative affect in the subset of the sample interested in weather, $F(1, 105) = 14.73$, $p < 0.001$, with an adjusted-R^2 of .12 and unstandardized B of 40.40. Hence, 12% of the variance was explained in this relationship. Predicted negative affect equaled 40.40 [CI: 37.39, 43.40] + 0.31 [CI: 0.15, 0.47] negative emotions, indicating there was a 0.31-point increase in negative affect for every point-increase in imagined lack of curiosity and information-gathering.

Discussion

This paper contributes to the psycho-meteorological literature by presenting the first validated self-report measure of EWC, the Epistemic Weather Curiosity Questionnaire (EWCQ). In two studies we validated, from an initial candidate pool of 23, 11 items which had excellent psychometric properties and fit to two factors measuring an information-driven curiosity for weather and curiosity for the science behind weather. The EWCQ demonstrated good convergent validity overall. It was significantly and positively correlated with measures of:

- weather salience and systemizing across both studies;
- weather warning awareness and beliefs about one's ability to prepare for severe weather in study 1; and

- trait epistemic curiosity, trait openness, and interest in learning science, in study 2.

Table 7

Pearson r bivariate correlations for study 2 variables.

Variable		WxSQ	IC	DC	Openness	SCILE	SQ	EWCQ-11
	n	–						
	Pearson's *r*	–						
WxSQ	*p*-value	–						
	Upper CI	–						
	Lower CI	–						
	n	212	–					
	Pearson's *r*	.28	–					
IC	*p*-value	< 0.001	–					
	Lower CI	0.15	–					
	Upper CI	0.40	–					
	n	212	221	–				
	Pearson's *r*	.25	.59	–				
DC	*p*-value	< 0.001	< 0.001	–				
	Lower CI	0.12	0.50	–				
	Upper CI	0.38	0.67					
	n	208	215	215	–			
	Pearson's *r*	.21	.58	.32	–			
Openness	*p*-value	0.003	< 0.001	< 0.001	–			
	Lower CI	0.07	0.48	0.20	–			
	Upper CI	0.33	0.66	0.44	–			
	n	205	209	209	208	–		
	Pearson's *r*	.25	.67	.49	.56	–		
SCILE	*p*-value	< 0.001	< 0.001	< 0.001	< 0.001	–		
	Lower CI	0.11	0.59	0.38	0.46	–		
	Upper CI	0.37	0.74	0.59	0.65	–		
	n	190	194	194	193	195	–	
	Pearson's *r*	.43	.47	.42	.36	.51	–	
SQ	*p*-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	–	
	Lower CI	0.30	0.36	0.29	0.23	0.39	–	
	Upper CI	0.53	0.58	0.53	0.48	0.60	–	
	n	211	219	219	213	207	192	–
	Pearson's *r*	.60	.38	.31	.22	.33	.64	–
EWCQ-11	*p*-value	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	–
	Lower CI	0.51	0.26	0.19	0.09	0.20	0.54	–
	Upper CI	0.68	0.49	0.43	0.34	0.45	0.71	–

Note. Dunn-Bonferroni confidence intervals (CI) estimate the range in which the correlation could be expected to fall if the study were conducted multiple times with the same sample size drawn from the same population.

The results of our two studies suggest EWC is related to information-gathering behaviors during severe weather situations, beliefs about weather hazard preparedness, and EC more generally, as well as to an analytical cognitive style. Non-significant storm-safety behavior associations suggest the primarily learning/education-based construct captured by the EWCQ does not translate into protective action despite associations with protective action self-efficacy beliefs. This latter result, however, *does* suggest that learning more about weather is associated with an increased confidence that one can keep themselves safe if needed. We can take this as a further sign of predictive validity for the epistemic weather curiosity construct (Stewart et al., 2012). The association between storm safety behaviors and weather warning awareness trended towards significance, however; this linkage makes sense and is one topic which could be explored in future research with larger sample sizes.

The EWCQ's association with both I- and D-type EC suggests people seek out weather information both because they are curious to learn more about and understand it conceptually and because they do not wish to be deficient in knowing what the weather is doing. Considering these elements of curiosity, the consistent left-negative skew to the EWCQ data makes sense and supports the statement that weather salience takes multiple forms and is predicated in part on a need for information (Stewart, 2009; Stewart et al., 2012). Epistemic weather curiosity score was positively associated with weather-hobby behaviors, demonstrating predictive validity that those with weather interest are motivated to engage in different behaviors associated with that interest.

Moreover, epistemic weather curiosity and total weather salience score in study 2 were both, as one might expect, associated with trait openness. Thus, those who value creative pursuits, a variety of intellectual, and cognitive experiences are more likely to pay attention to the weather and to be curious about it. This replicates work by Bolton et al. (in preparation, based on 2018 archival data), who found scores on Stewart's (2009) Weather Salience Questionnaire positively associated with trait openness. Stewart (2017) similarly found perceptual weather curiosity associated not with trait openness, per se, but rather generalized *trait* perceptual curiosity which involves a certain openness to different and novel *sensory* experiences. These findings altogether suggest weather curiosities may be associated with wider individual differences and differ due to person-situation interactions (Jach et al., 2021). That is, people will express different curiosities and different, associated behaviors and cognitions in relation to weather threats as opposed to needs for more general planning-related, or educational/learning-related, information (also see Stewart, 2009; Stewart et al., 2012; Stewart & Bolton, 2021).

Lowenstein (1994; also see Lowenstein et al., 1992) put forth the notion that deprivation-based curiosity is associated with psychological sensations of tension. We operationalized this affective property as an anxiety-rooted tension and showed that those induced to imagine an inability to engage in EWC-driven thinking and information-gathering had a significantly higher degree of negative affectivity in this manner. This adds to the literature quasi-experimental evidence supporting the hypotheses set forth around D-type curiosity and is also consistent with research linking subjective wellbeing with the ability of individuals of varying neurotypes to pursue personal interests and meaningful and engaging endeavors (Grove et al., 2018; Schueller & Seligman, 2010; Vella-Brodrick et al., 2009). Although the SCILE was included as an indicator of discriminant validity, it too was positively correlated with the EWCQ. This was unanticipated but is actually unsurprising; it suggests EWC is just one sub-type in a larger set of overarching science curiosities, perhaps related to a "scientific" personality type (Billington et al., 2007; Bolton et al., 2018; Bolton et al., 2020; Feist, 2006; Zeyer, 2010, 2018; Zeyer & Wolf, 2010; and see Adeyemi, 1989 and Idika, 2017 for evidence from biology and chemistry). One interpretation is that various types of science curiosity may share common causal mechanisms (e.g., detail-orientation and pattern recognition induced by systemizing tendencies). The positive correlation between EWCQ score and systemizing tendency, as well as wider work on need for cognition and introspective personality (Feist, 2006, 2012; van Seggelen-Damen, 2013), supports such a link. However, this means the EWCQ's discriminant validity is still in question. Perhaps discriminant validity would best be demonstrated by less science-related individual differences (e.g., in trait nature connectedness).

Conclusions, Limitations, and Future Work

This study presents the first validated epistemic weather curiosity measure. The scale–featuring excellent psychometric qualities including evidence of predictive validity and convergent validity with measures of weather salience, weather warning awareness, and epistemic and scientific curiosity–consists of 11 items assessing informational curiosity for weather on two factors related to general weather interest and curiosity for learning the science behind weather.

However, these studies are not without limitations. Self-report always involves concerns including item understanding and participant honesty. Further psychometric replication and testing (including test-retest reliability, discriminant validity, and existence of floor and ceiling effects when administered to different populations) is needed before we can most confidently infer results and the scale's stability. One concern that occurred to us late in this project is that one item initially included deals with "reading" rather than "interpreting" computer weather models. This may cause subtle functioning differences in responses by different groups, given laypeople likely would not "read" a weather model as might a meteorologist or weather enthusiast. A future change in the item's wording item may produce better psychometric attributes and strengthen the scale's construct validity through its re-introduction to the EWCQ. Another consideration of future research is to further investigate the factor structure of the scale and examine the relative predictive capabilities of the two subscales on their own, with respect to other psycho-meteorological constructs. This may prove fruitful to scale expansion efforts.

Finally, with respect to the experimental support for D-type curiosity provided by the curiosity-affect-interest regression, our results were limited by the small sample. This method should be replicated in a larger sample to more confidently assess its validity and associated findings. These concerns notwithstanding, the EWCQ is a promising measurement tool. It could be helpful to meteorologists participating in outreach activities, allowing

EWC-quantification in weather-interested individuals with whom they interact. Further, given its brevity and straightforwardness of administration (simply sum the items to produce a total score), educators and researchers could quickly assess EWC in classroom or other settings, including in the context of grade school-level, physical science curriculum assessment. With respect to future work, the scale could be expanded; possible investigation of cut-points to establish quantified levels of EWC and the inclusion of other possible EWC item factors would be useful to those interested in measuring EWC individual differences. Finally, nature-connectedness is a candidate discriminate construct, as there is overlap but less scientific emphasis between nature and technical weather interest.

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Appendix A

Weather Engagement Items Used in Regression

How likely would you be to do each of the following?

a. Mention to a friend in conversation how nice or bad the current weather conditions are.
b. Share weather information with a friend or family member.
c. Post about weather on social media.
d. Take photos of clouds or other atmospheric phenomena.
e. Check the weather forecast at least three times per week.