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ASSESSING MIDDLE SCHOOL AND COLLEGE STUDENTS' CONCEPTIONS ABOUT TORNADOES AND OTHER WEATHER PHENOMENA

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1. INTRODUCTION

Weather impacts society on a fundamental level. Many people inquire about the weather conditions in their region every day. When the weather is extreme, it dominates the local and sometimes the national news media. Although people care about the weather, they may not understand the concepts involved in weather processes. In schools, meteorological content is weaved throughout K-12 educational standards and curricula, and in general education (GE) courses at the college level. After exposure to meteorological content, it would be useful to know: (1) What conceptual understanding of weather does a student possess? (2) Do these concepts align with scientific understanding, or are they part of an alternative framework? (3) How do students' conceptual understandings change across multiple cognitive levels?

The aim of this research is to explore the question: what are students conceptions of tornadoes, wind, and fog, and how do they compare across multiple cognitive levels—middle school, university non-meteorology major, and meteorology major level? This paper will present an overview of the methodology of my study, and will present some preliminary results.

2. HISTORICAL OVERVIEW OF RESEARCH ON STUDENT CONCEPTIONS OF WEATHER

Educators tend to overestimate or misinterpret students' understanding of the content presented in their classes (Driver 1985; Schneps 1997). Teachers commonly perceive that, because they presented the material and the students heard it, the students understand it (Fisher and Moody 2000). Research in science education, however, has shown that students are not blank slates, but instead already possess conceptions of how the world works (Driver 1985). The process of learning, as stated by Posner et al. (1982), is a "process of conceptual change," where students need to be convinced to let go of their previous conceptions and accept a more scientific viewpoint. For teachers to effectively teach toward conceptual change, they must first understand the conceptions that their students already possess. In this way, science education research focused on discovering students' common misconceptions or "wrong answers" can help instructors better formulate learning experiences that will shift student conceptions towards more scientifically accepted explanations of natural phenomena (Tanner and Allen 2005).

Conceptual research in science education has advanced during the past 50 years, with many scientific disciplines participating. A bibliography of publications about scientific and alternative conceptions held by students and teachers are collected in the Students' and Teachers' Conceptions and Science Education (STCSE) database, which can be separated by discipline (Duit 2008). There is a minimal amount of published work about conceptual research in the earth sciences, and the majority of these earth science education research publications focus on geological research. Only three articles have been identified by STCSE that are about alternative conceptions in meteorology (Aron et al. 1994; Stepans and Kuehn 1995; Dove 1998), and one of those is a literature review.

Conceptual research in meteorology is clearly lacking. For example, there are apparently no research articles about alternative conceptions of weather in the Journal of Geoscience Education, the main publication for educational research in the geosciences (Henriques 2000). Thus far, I have been able to identify only a few research publications that investigated students' understanding of weather at various educational levels. These few publications are briefly summarized below.

Stepans and Kuen (1985) conducted audio-recorded interviews with elementary-aged students in grades 2 and 5, (ages 7–11) to categorize their level of weather comprehension. They asked students to explain concepts such as wind, clouds, lightning, thunder, rain, snow, and rainbows. The students' responses were placed into developmental categories established by Piaget (Stepans and Kuen 1985). Few student responses were categorized as true causality (or fitting into a scientific viewpoint), whereas most student responses were categorized as a non-scientific response (Stepans and Kuen 1985). They found that most second graders gave a religious response to explain weather concepts, whereas fifth graders gave a non-religious response (Stepans and Kuen 1985). This study only focused on elementary students and not older students.

In a study published by The Science Teacher, Aron et al. (1994) posed questions about weather to pre-service teachers and students at middle school, high school, and university levels. Students were given a short multiple-choice survey covering a range of meteorological content, like lightning, pressure, humidity, coriolis effect, cloud composition, and

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seasons. This study found that, across all age levels, people did not understand weather concepts. For example, 85% of the participants thought that water draining in sinks was due to the coriolis effect and that water always drained in the same direction, which is an alternative conception (Aron et al. 1994). They also found that certain questions showed a lack of knowledge as opposed to a misconception. General understanding increased with age, the exception being future elementary school teachers who scored lower on the survey than the middle school students. This study did not go beyond survey methods, and as such did not provide a way for the students to explain why they chose a particular response.

Finally, Lewis (2006) questioned university students and K-12 teachers about tornadoes in New England. Lewis (2006) employed an awareness survey—a survey that tries to determine if participants know that tornadoes are a threat to their community and if they know how to respond to a tornado occurring in their area. The survey focused on tornado climatology of the region and tornado preparedness. Lewis (2006) found that university students and teachers alike thought that tornadoes rarely occurred in the region, a region that, in fact, has a high annual frequency of tornadoes.

Given the paucity of research literature on student conceptions of weather at any cognitive level, my research is both novel and widely relevant. To our knowledge, this will be the first research study that will systematically collect data on weather concepts at multiple cognitive levels—middle school, and university non-meteorology majors, and meteorology majors—using a multiple-phase data-collection process that will probe student ideas using both written assessments and videotaped interviews.

3. METHODS

To address the questions posed in this research, a mixed-method research design that will involve data collection using both quantitative and qualitative methods is utilized. The data-collection process will take place in two distinct phases—multiple written essay assessments, and videotaped interviews.

Subjects	Middle School Students	University non-Meteorology Majors	University Meteorology Majors/Recent Alumni (2003-2008)
Phase I: Written Essay Assessments	n = ~65	n = ~70	n = ~15
Phase II: Videotaped Interview	n = ~10	n = ~10	n = as many as possible

Figure 1. Overview of participant population

The subject population consists of 6th grade students in a middle school in a large, urban school district, university non-meteorology students in meteorology classes at a large, urban university, and university meteorology majors currently enrolled at or recently graduated from this same university (Figure 1).

The meteorological content chosen for this project—wind, fog, and tornadoes—is deliberate. Wind is a fundamental process on our planet and has the potential to cause great damage. Students have direct experience with wind on a daily basis. Fog is a dominant feature of San Francisco climatology, and a familiar phenomenon to students living in our region. Tornadoes are associated with devastating winds and represent a destructive weather phenomenon that students in our region have likely only experienced indirectly through movie representations and other media outlets. To gain a deeper understanding of students' conceptions, the two-phase approach is optimal, allowing to sample from a larger population of students using a quantitative approach and from a smaller population of students using a qualitative, more in-depth interview approach. The two phases are explained in greater detail below.

3.1 Phase I of research: Written Essay Assessments

In phase I—written essay assessments—participants will be given three sets of questions for each of the three weather topics (nine total questions). There is a specific structure to the question sets presented to the participants. The first question is classified by Bloom's taxonomy as a high-order application question (Bloom 1956). This question is in the form of a challenge statement—a statement that asserts a common misconception or a truism—and asks the participant to rank their level of agreement on a scale (Strongly Agree, Agree, Disagree, Strongly Disagree, Don't Know). Once the participant ranks their agreement to the statement, they are given five minutes to write about why they chose their response. Once the five minutes is completed, they are then given two questions that would be classified by Bloom's taxonomy as low-level knowledge questions (Bloom 1956). Each of the two questions asks the student about the underlying content from the original challenge statement (Figure 3).

Question/Prompt Structure	Question/Prompt
1. High Order Application Question in the form of a challenge statement	T1: Without thunderstorms, there would be no tornadoes. W1: Without the sun, there would be no wind on earth. F1: Fog is a kind of cloud.
2. Low-Level Knowledge Question	T2: What is a tornado? W2: What is wind? F2: How do clouds form?
3. Low-Level Knowledge Question	T3: What is a thunderstorm? W3: What is air pressure? F3: What is condensation?

Figure 2. Structure of question sets, with each prompt/question represented. "T" stands for tornado prompts, "W" stands for wind prompts, and "F" stands for fog prompts.

The structure of these question sets first challenges the student to take a stand about a complex topic and explain their response. The follow up questions probe the extent to which they are familiar with basic physical process that underlies the initial question. If for some reason the student is unable to grapple with the first question, the two follow up questions give the student the opportunity to see if they have knowledge in this area, but just could not apply it.

Written essay responses provide greater insight into why students choose a particular answer and have the potential to reveal gaps in knowledge and misconceptions. Data obtained from the written essay responses will be analyzed using a conceptual rubric we will develop and that will enable us to quantify this qualitative data set. Figure 4 shows how the qualitative data obtained in the written assessments will be quantified. Post-hoc quantification of written essay responses will be performed by multiple observers and inter-rater reliability calculated. Results from this phase will help to structure the interview protocol for Phase II of this project.

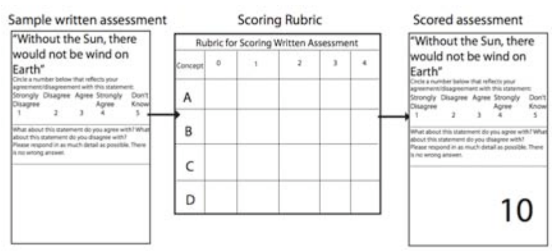

Figure 3. Schematic representation of the process of quantifying qualitative data using a conceptual rubric.

3.2 Phase II of research: Videotaped Interview

Phase II consists of videotaped, semi-structured interviews with a small subset of the total population—10-15 students from each cognitive level. The participants will be determined by who volunteers. These interviews will be videotaped for analytical purposes. The participants will be asked questions similar to the ones they responded to in Phase I, and follow up questions will be asked to further probe students' understandings of fog, wind and tornadoes.

4. PRELIMINARY FINDINGS

This project is currently in phase I, with a portion of the written data collected from non-meteorology majors and middle school students. Preliminary findings from initial data are reported here.

4.1 Preliminary findings about wind from middle school students and non-meteorology majors

Preliminary results from phase I probing student conceptions of wind *("Without the sun, there would be no wind on earth.")* show that over 54% of 6th grade students (n=64) do not see any connection between the sun and wind. Middle school students instead offer that the moon, clouds, and the ocean are key contributors to wind development. One student asserted,

> *"I disagree because the sun creates heat and energy, but the moon create (sic) wind, rain, clouds, and all the other cold types of weather."*

This student makes the connection that sun provides heat and energy to earth, but cannot make the connection of what that heat and energy do for the planet, pointing instead toward the moon as the primary cause for weather on earth. 13% of middle school students conclude that because wind happens at night, the sun could not play a role in wind generation.

For non-meteorology university students (n=38), 50% of students actively disagree with the statement in question 1 *("Without the sun, there would be no wind on earth.")*. Similar to middle school students, these university students assert many ideas about the primary cause of wind, including ocean currents, clouds and the moon. One student asserts,

> *"I see no connection between sun and wind. Wind occurs because of sea current and nothing about the sun."*

This student has a clear idea about wind, and feels strongly about it, even though it is an incorrect notion. Similar to middle school students, 10% of university students assert that because we experience wind at night, the sun does not have a roll in wind development. 21% of non-meteorology university students offer explanations that contain pieces of the puzzle, but still have gaps in understanding. One student is clearly working through the ideas in writing,

> *"I don't necessarily agree that the wind is caused by the sun; wind is caused by changing pressures in the atmosphere which is caused by changing temperature. So, in essence, the sun does affect wind. But there are planets extremely far from the sun that still have wind—planets can be warmed by their own core and mass."*

The student is able to apply his knowledge of wind and make the connection to the sun, but grapples with how planets farther from the sun have wind.

4.2 Preliminary findings about tornadoes from non-meteorology majors

At this time, only the university non-meteorology majors (n=38) have responded to the prompts on tornadoes, and only responses to Question 1 *("Without thunderstorms, there would be no tornadoes.")* have been analyzed at present time. Preliminary analysis shows that 46% of university non-meteorology major students state that tornadoes and thunderstorms can occur independently from each other, and that a tornado can occur by itself. One student at first agreed, and then became doubtful as the response was being written,

> *"I think tornadoes are a precursor to thunderstorms so if there is nothing to lead up to them they won't happen. But I know in California we have thunderstorms without tornadoes, so maybe they're not connected."*

The logic presented here is also faulty, with the student stating that a tornado will occur first, and then the thunderstorm. Once the student begins to write about California—believing that tornadoes do not occur in the state—the student becomes doubtful of the response, and begins to assert the most common response, that there is no connection between thunderstorms and tornadoes.

5. SUMMARY

During each phase of this research project, we are able to explore how San Francisco students conceptualize the meteorological world around them. This information will be valuable to meteorologists—to help them understand how to better communicate their science—and for educators—to help them create classroom experiences that will foster conceptual change in their students.

6. FUTURE WORK

This research is currently underway, and written data still needs to be obtained from multiple populations. Videotaped interviews will begin in the coming months, and will be completed in May 2009, with a goal of publishing the findings of this study in a peer-reviewed journal.

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