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Assessing the Impact of a Weather and Climate Curriculum on Youth Science Comprehension

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Abstract

The researchers developed a youth weather and climate curriculum using a science comprehension model that integrates experiential and inquiry-based learning approaches with developing science knowledge, science skills, and reasoning abilities. The purpose of this study was to pilot the curriculum to determine if it would improve youth science comprehension. Participants were 8th grade, predominately Hispanic and economically disadvantaged youths, at a middle school in Las Vegas, New Mexico served by an innovative Extension youth agricultural science center. Youths were taught five weather and climate science lessons that included setting up experiments and developing and testing hypotheses for local climate trends from online weather station data. After being taught the curriculum, youths improved in overall science comprehension and its subdimensions of science knowledge, science skills, and reasoning abilities. Their science comprehension also improved for four of five lessons. The number of youths preferring learning by doing over other learning modalities also increased from pretest to posttest. Youths most frequently mentioned the experiments, that the earth is getting warmer, and the greenhouse effect and gasses when asked what interested them about the lessons. Pilot test results were used to strengthen the curriculum before making it available to educators online. Further research is recommended to establish the curriculum's impact on science comprehension retention and on science comprehension development when the curriculum is used as part of an elementary to secondary learning progression.

Keywords: experiential learning; inquiry-based learning; youth science comprehension; weather and climate science curriculum; learning mode preference; youth agricultural science center

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Introduction

Different regions of the United States are experiencing various climate changes like overall warming; longer heatwaves; prolonged drought; and more frequent, severe, and unseasonable storms (Lengnick, 2018; U.S. Global Change Research Program, 2014, 2018). The most recent National Climate Assessment (U.S. Global Change Research Program, 2018) stated:

> Rising temperatures, extreme heat, drought, wildfire on rangelands, and heavy downpours are expected to increasingly disrupt agricultural productivity in the United States. Expected increases in challenges to livestock health, declines in crop yields and quality, and changes in extreme events in the United States and abroad threaten rural livelihoods, sustainable food security, and price stability. ("Summary Findings" section, "Agriculture" subsection, para. 1)

The frequency and disruptive nature of extreme weather and climate events on people, environment, economy, and agriculture are pushing many policy makers to address the problem quickly. For example, Hughes (2019) reported that in the United States, "57% of cities plan to take climate related actions in 2019" (p. 2A). Johnson (2019) and Lengnick (2018) presented several potential impacts on agriculture by region of the United States that will likely occur and require attention if current climate and weather trends continue. These include lengthening growing seasons but more stressful and unpredictable conditions for crop and livestock production in all regions. Extreme weather and climate events have created a need to effectively educate the public about what is happening with weather and climate and innovative, resilient solutions to related problems (Dooley & Roberts, 2020). By developing and diffusing STEM-based agriscience curricula (U.S. Department of Education, n.d.), youths learn about weather and climate and how humans can mitigate and adapt to extremes impacting agriculture and natural resources. A scientific understanding of weather and climate will prepare youths to enter STEM careers and function as evidence-based and engaged individuals.

In February 2014, U.S. Secretary of Agriculture Tom Vilsack announced the creation of seven Regional Hubs for Risk Adaptation and Mitigation to Climate Change across the country to serve as clearinghouses for research about the effects of climate change on agriculture and natural resources (U.S. Department of Agriculture, 2014). One of these centers, the Southwest hub, was established at the Jornada Experimental Range, a branch of the USDA's Agricultural Research Service, with its headquarters on the campus of New Mexico State University (NMSU) in Las Cruces (Las Cruces Sun News, 2014). We discussed the idea of developing an experiential and inquiry-based youth weather and climate science curriculum. This project was developed in coordination with the climate hub to advance weather and climate teaching and learning.

Weather and Climate Science Teaching and Learning Literature Review

We conducted a review of youth weather and climate science teaching and learning literature. The review indicated problems with online curricula, youth misconceptions, and teacher knowledge gaps.

Science and agriscience teachers are drawn to shop online for free curriculum resources when operating on a tight budget. Industries and groups produce many online climate science curricula with a stake in maintaining the status quo. Hence, they can lack currency, a factual and science-based foundation, and be misleading (Melia, 2019). Another problem facing science and agriscience teachers is that some groups portray climate science as having two sides (Crayne, 2015; Melia, 2019). In a qualitative study, Crayne (2015) found among middle school science teachers in Western Oregon that "while participating teachers accept the science of climate change and express concern about it, many teachers are reluctant to make the topic a priority in their classrooms. When they do include the subject, teachers frequently address both sides" (p. iv).

Youths have misconceptions about climate science and climate change (Choi et al., 2010; Karpudewan & Mohd Ali Khan, 2017; Shepardson et al., 2017). Choi et al. (2010) grouped middle and high school student misconceptions of climate change from 17 different studies into the four broad categories: (a) basic notions (e.g., confusion about different greenhouse gasses), (b) causes (e.g., climate change causes pollution), (c) effects (e.g., an effect of climate change is skin cancer), and (d) resolution/mitigation (e.g., students lack an understanding of how to control greenhouse gas emissions). They reviewed seven commonly used science textbooks on 18 common student misconceptions about climate change and found that all textbooks addressed three. Misconceptions addressed per textbook averaged 10 (55%), ranging from eight to 15 (44% to 83%). They concluded that science textbooks should be written to address student misconceptions about climate change.

Wang et al. (2020), found that secondary agricultural education teachers from 14 states understood the science underlying global climate change but struggled with such topics as natural versus anthropogenic contributions and climate change models' validity. The teachers agreed that it was important to address global climate change in agricultural education classrooms but used very little class time teaching about it. Plutzer et al. (2016) stated that "most U.S. science teachers include climate science in their courses, however their insufficient grasp of the science may hinder effective teaching" (p. 664). Their national study of 5,000 randomly selected science teachers found that middle school science teachers only spend a median of one to two hours on climate change science instruction. Reasons the authors proposed for this low level of instruction were:

1. They "might experience overt pressure from parents, community leaders, or school administrators not to teach climate change" (p. 664).
2. They "may not be very knowledgeable about a wide range of evidence" (p. 664) for climate change.
3. They "are unaware of the extent of scientific agreement" (p. 665) about climate change.

Their recommendations called for up-to-date, teacher-tested, standards-aligned, and online curriculum resources to address deficiencies in climate science instruction.

With a need to minimize these teaching and learning problems in mind, we set out to develop, pilot test, improve, and diffuse a current, standards-aligned, evidence-based, and online weather and climate curriculum that would improve youth science comprehension.

Conceptual Framework

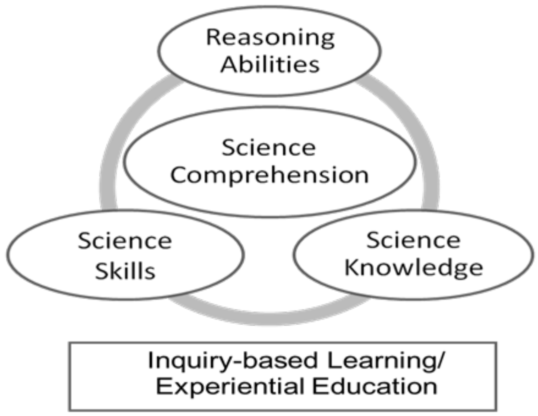
This study utilized a teaching and learning model depicted in Figure 1 intended for use in both formal and non-formal education to improve youth science comprehension (Skelton et al., 2012). Model components tie together in this way:

> Inquiry-based learning and experiential education are the foundation for the process. Inquiry-based learning guides short-term curricular activities, while experiential education guides the long-term teaching and learning process. One can conceptualize the process beginning with the acquisition of new knowledge or the building of prior knowledge either through an Extension program or specific Extension curriculum. While learners are acquiring new knowledge, they may also be developing new skills or refining skills. Examples of skill development/refinement include: asking questions, developing research protocols, decision-making, agricultural and horticultural techniques, communicating, and leadership. This process leads to reasoning abilities, where students are able to explain or demonstrate what they did, how they did it, and what they can conclude about the investigation. Through this process a broader contextual understanding is formed, leading to improved comprehension of subject matter and the

subsequent re-initiation of the process with new information. ("Conceptualizing Youth Development and Education Outcomes" section, para. 2)

Figure 1

YASC Conceptual Model for Improving Youth Science Comprehension



Inquiry-based learning is a strategy used in classroom instruction to teach students to inquire and think like scientists. In other words, they learn science by being scientists. An inquiry-based approach to teaching science has been shown to increase students' understanding of science (National Research Council, 2000). "In this process, students often carry out a self-directed, partly inductive and partly deductive learning process by doing experiments to investigate the relations for at least one set of dependent and independent variables" (Wilhelm & Beishuizen, 2003, p. 382). To ensure that our curriculum was inquiry-based, we aligned lesson experiments and data analysis activities with the Pedaste et al. (2015) five phases to an inquiry-based learning cycle and "essential features of classroom inquiry and their variations" (National Research Council, 2000, p. 29). Teaching science with an inquiry-based learning approach "is great preparation for future scientists because it matches the scientific method they will employ throughout their career" (Skelton et al., 2012, "Approaches to Teaching and Learning" section, para. 2).

Experiential learning is the process whereby knowledge is created by transforming experience (Kolb, 1984). Effective learning is likely to occur when youths progress through a four-stage experiential learning cycle of concrete experience, reflective observation of the new experience, abstract conceptualization, and active experimentation. Experiential learning creates the necessary learning environment to conduct investigations in real-world contexts in which scientific phenomena occur. Learning in a context provides youths with the opportunity to grasp facts, concepts and relationships. Scientific learning grounded in contexts bridges knowledge and experiences students bring to investigations (Cervetti et al., 2006). Engaging youths through carefully planned educational activities and hands-on projects enhances learning outcomes (Bourdeau, 2004; Skelton & Dormody, 2009). In a study of secondary school students, Karpudewan and Mohd Ali Khan (2017) compared a treatment group taught climate change with an experiential learning approach based on Kolb (1984) to a control group taught by a conventional teacher-dominated teaching and learning approach. They found that "experiential-based teaching and learning improved students' knowledge about climate change" (p. 217).

The Figure 1 model was previously tested by Skelton, Dormody, & Lewis, (2016) and Skelton, Blackburn et al., (2018) with samples of primarily Hispanic and economically disadvantaged middle school youths. A promising result from the Skelton, Dormody & Lewis 2016 study was that students performing below grade level made up considerable ground on students performing at or above grade level after being taught a water chemistry lesson developed based on the model. The researchers concluded that the model "holds promise for improving youth science comprehension" ("Conclusions, Implications, Discussion' section, para. 1). The Skelton, Blackburn et al., (2018) study determined that science reasoning ability and science skills were significant predictors of grade-level expectations for sixth-grade students taught lessons in soil pH and water quality developed based on the model. For eighth-grade students, science skills were a significant predictor of grade-level expectation. The study's overall recommendation was for agriscience teachers to incorporate inquiry-based and experiential methods in their classrooms to improve science outcomes.

Purpose and Objectives

The purpose of our study was to develop and pilot test an inquiry-based and experiential youth weather and climate science curriculum that would improve science comprehension and address the teaching and learning problems highlighted in the Introduction section. Results were used to strengthen the curriculum before making it available online to educators.

Specific objectives were to:

1. Determine if science comprehension scores improve after youths are taught our weather and climate curriculum.
2. Determine if science knowledge, science skills, and reasoning abilities subdimension scores improve after youths are taught the curriculum.
3. Determine if science comprehension scores improve for the water cycle, greenhouse effect, measuring and analyzing precipitation, measuring and analyzing temperature, and mitigating and adapting to weather and climate extremes in agriculture and natural resources lessons after youths are taught the curriculum.
4. Determine youth learning mode preferences and whether they change after being taught the curriculum.
5. Determine youth perceptions of the most interesting thing learned about climate science while being taught the curriculum.

Methodology

Study Context

We used the NMSU Extension and Research Youth Agricultural Science Center (YASC) located at Memorial Middle School in Las Vegas, New Mexico, as the curriculum development and testing site (Skelton & Dormody, 2009). The description of the center is as follows:

> The YASC is a youth science center emphasizing inquiry-based learning and experiential education. A basic premise of the mission is to develop a teaching and learning model of excellence for agriculture and natural resource science that complements in-class instruction by providing context to content through hands-on learning opportunities. The YASC is engaged in earth, life and physical science teaching and learning. STEM-based education is delivered through teaching the principles and applications of sustainable agriculture, renewable energy, and local food systems. (New Mexico State University, n.d.)

The YASC was founded in 2005 through a special legislative appropriation and is administered through the NMSU Cooperative Extension Service in partnership with the Las Vegas City Schools. All youth enrolled at Memorial Middle School are served by the YASC. The center's director partners with teachers to enhance science outcomes for the primarily Hispanic and economically disadvantaged youths it serves. In 2014, Skelton et al. found that 8th grade students at Memorial Middle School who had experienced three years of science enhancements from the YASC, achieved higher state-mandated science test scores (i.e., total score and scientific investigation, physical science, and science and people subdimension scores) than students at a comparison middle school.

Research Design and Participants

The study employed a one-group pretest-posttest design (Campbell & Stanley, 1963) to pilot test our weather and climate science curriculum. We controlled history and maturation threats to internal validity for this design by immediately administering the treatment after the pretest, followed by the posttest's immediate administration. We controlled for the testing threat to internal validity by making the treatment robust (e.g., six 50-minute class periods of teaching), covering all of the questions on the test during the treatment, and instructing the students on both pretest and posttest to read each question carefully and give their best answer. The same test was used as the pretest and posttest to control the instrumentation threat to internal validity. Caution should be exercised when generalizing the results beyond this study because only one school's 8th graders were used for the pilot test.

The pilot test target population was 120 8th grade students grouped into five science classes at Memorial Middle School in Las Vegas, New Mexico. The accessible population was 96 students (80%) who submitted informed consent and assent forms to participate in the study. Eighty-eight students completed the pretest and posttest and hence, were included in data analyses. Of these, 78 (88.64%) were Hispanic, six (6.82%) were Caucasian, two (2.27%) were Asian, one (1.14%) was African American, and one (1.14%) was Native American. Thirty-eight (43.18%) were female and 50 (56.82%) were male. Thirteen of the students (14.77%) were categorized as special needs, with two students listed as gifted.

Instrumentation

The pilot pretest and posttest contained two multiple-choice science knowledge (tied to the content taught in each lesson), science skills (tied to the scientific skills taught in each lesson), and reasoning abilities (tied to the hypothesis development and testing completed in each lesson) questions for each of the five lessons for a total of 30 questions. Ten questions represented each of the science comprehension subdimensions. We wrote questions to match lesson objectives, PowerPoint slides, and worksheets to ensure content and face validity. We then broke the test into equivalent halves for split-halves reliability testing. Applying the Spearman-Brown Prophecy Formula to pretest and posttest data (n=88) yielded split-halves reliability coefficients of .68 for the pretest and .74 for the posttest. The test also contained a question on students' learning mode preference to determine if our inquiry-based and experiential lessons increased preference for learning by doing. A final posttest question determined student perceptions of the most interesting thing learned about climate science during the lessons. We asked this question to determine if the students were interested in content and activities from every lesson.

Treatment

One of the developers taught the curriculum to five classes over six 50-minute periods per class after administering the pretest. Curricular content was derived from government agency websites and research reports and from research-based materials taught by the New Mexico climatologist in a university course and outreach education programs (Dormody & Skelton, n.d.). Lessons were aligned with middle school Next Generation Science Standards (n.d.) for weather and climate science. Each lesson integrated the five components of science comprehension in Figure 1 (Skelton et al., 2012). The lessons featured a few introductory PowerPoint slides shown on a Smart TV, an activating strategy, setting up an experiment or conducting local weather and climate data analyses, worksheets, and a summary activity.

Lesson 1 was on the water cycle. It featured a water cycle role-play and an experiment to depict the effects of flooding, drought, and typical precipitation events on corn growth. Students formulated hypotheses after setting up the experiment. Lesson 2 was on the greenhouse effect. It featured a greenhouse effect role play followed by setting up a greenhouse effect bean growth experiment and formulating hypotheses. Teaching the water cycle and greenhouse effect lessons first prepared students for Lessons 3 and 4 to measure and analyze precipitation and temperature. In these lessons, students were taught about weather stations and how to navigate the National Oceanic and Atmospheric Administration (NOAA) Regional Climate Centers database (National Oceanic and Atmospheric Administration, n.d.). Students used I-Pads to find local weather station precipitation and temperature data for single days and one year, and develop and test hypotheses for 70-year local precipitation and temperature trends. Lesson 5 covered how to mitigate and adapt to weather and climate extremes in agriculture and natural resources. It featured measuring surface temperatures using handheld infrared thermometers, followed by setting up an experiment to measure temperatures and moisture levels of potting soil covered by different colored garden mulches placed under heat lamps. Students formulated hypotheses on their predicted temperature or moisture gradients. We put the students in teams of four to set up the three experiments (Lessons 1, 2, and 5), and teams of two to share an I-Pad and complete precipitation and temperature protocols (Lessons 3 and 4). The fifth lesson was followed by a 10-minute unit summary and administration of the posttest.

The three experiments had been pilot-tested in earlier years of the project with middle school students not included in this study to ensure the experiments could be set up during a class period and yield differences between treatments and controls when completed (Dormody et al., 2016; Skelton et al., 2017). Questions on the pretest and posttest did not go beyond setting up the experiments because they had lengthy incubation periods after setting up. The temperature and precipitation data analysis activities were also pilot tested in an earlier year with middle school students not included in this study to ensure they could be completed in a class period on the I-Pads (Skelton & Dormody, 2018).

Data Analysis

Overall science comprehension test scores (Objective 1); science knowledge, science skills, and reasoning abilities subscale scores (Objective 2); and lesson subscale scores (Objective 3) were analyzed separately using the F statistic for a mixed model with a fixed effect for the test occasion (pretest, posttest). The mixed model fitted a variance structure that accounted for correlations among observations clustered within classes and students and the higher variance observed at the posttest occasion. To achieve this, the mixed model fitted random effects for class and class x test occasion to account for correlations among students within the same class and used an unstructured variance structure to account for the repeated measures within students. Effect sizes were determined by dividing the mean difference estimate between the pretest and posttest by the difference standard deviation. Students' learning mode preference (Objective 4) was descriptively summarized using a cross-tab with the proportion of students who changed their preference from pretest to posttest estimated with a 95% confidence interval. Objectives 1 through 4 were analyzed using SAS® version 9.3 software (SAS Institute Inc., 2011) and significance was defined as $p \leq 0.05$.

Objective 5 was analyzed by organizing qualitative responses into themes after the administration of the posttest. Frequencies and percentages of responses were determined by theme and cross-referenced with corresponding lessons. A few students gave two answers in their response that were loaded into two themes.

Findings

Overall, Subdimension, and Lesson Science Comprehension

For the overall test (Objective 1), students improved, on average, 3.13 points on the 30 questions from pretest to posttest after being taught the curriculum (Table 1). The difference was significant and, following Cohen's (1988) guidelines for effect sizes in the social sciences (i.e., small, d=.2; medium, d=.5; and large, d=.8), yielded an effect size of 0.82 (large). For the 10 science knowledge questions (Objective 2), students improved, on average, 1.02 points from pretest to posttest. The difference was significant with an effect size of 0.49 (low to medium). Students improved, on average, 1.33 points for the science skills questions from pretest to posttest. The difference was significant with an effect size of 0.67 (medium to large). Students improved, on average, 0.78 points for the reasoning abilities questions from pretest to posttest. The difference was significant with an effect size of 0.42 (low to medium).

For the six questions on the water cycle lesson (Objective 3), students improved, on average, 0.15 points from pretest to posttest (Table 1). The difference was not significant. Students improved, on average, 0.55 points for the greenhouse effect lesson questions from pretest to posttest. The difference was significant with an effect size of 0.38 (low to medium). Students improved, on average, 0.83 points for the measuring and analyzing precipitation lesson questions from pretest to posttest. The difference was significant with an effect size of 0.56 (medium to large). Students improved, on average, 0.70 points for the measuring and analyzing temperature lesson questions from pretest to posttest. The difference was significant with an effect size of 0.50 (medium). Students improved, on average, 0.95 points for the mitigating and adapting to weather and climate extremes in agriculture and natural resources lesson questions from pretest to posttest. The difference was significant with an effect size of 0.57 (medium to large).

Table 1

Summary of Model-Based Estimates and Inferences for Objectives 1-3

Variable	Test Items	Pre Est.	Pre SE	Post Est.	Post SE	Dif. Est.	Dif. SE	Effect Size	$F_{1,4}$	*p*
Overall Test	30	13.53	0.71	16.66	0.78	3.13	0.32	0.82	98.39	< 0.001*
Science Knowledge	10	4.50	0.26	5.52	0.28	1.02	0.16	0.49	38.69	0.003*
Science Skills	10	4.71	0.20	6.04	0.23	1.33	0.15	0.67	80.72	< 0.001*
Reasoning Abilities	10	4.33	0.32	5.12	0.31	0.78	0.21	0.42	14.41	0.019*
Lesson 1	6	2.89	0.14	3.04	0.14	0.15	0.15	0.10	0.93	0.389
Lesson 2	6	2.16	0.16	2.71	0.16	0.55	0.19	0.38	8.69	0.042*
Lesson 3	6	2.70	0.19	3.53	0.20	0.83	0.16	0.56	27.38	0.006*
Lesson 4	6	3.13	0.16	3.83	0.17	0.70	0.11	0.50	42.07	0.003*
Lesson 5	6	2.66	0.14	3.61	0.18	0.95	0.09	0.57	121.03	< 0.001*

Note. N = 88. Pre = pretest, Post = posttest, Dif. = difference, Est. = estimate, and SE = standard error.
*p < 0.05.

Learning Mode Preference

Student learning mode preference changed significantly between pretest and posttest. A 95% confidence interval estimated between 38.78% to 60.04% would change learning mode preference. Of the 85 students that answered this pretest and posttest question, 49.41% (n=42) changed learning mode preference on the posttest. Table 2 contains frequencies and percentages of 16 possible pairings of responses between pretest and posttest. Learning by doing was preferred by 50.59% (n=43) of students on the pretest and 75.29% (n=64) on the posttest. It was the only learning preference to go up from pretest to posttest.

Table 2

Self-reported Change in Learning Mode Preference

Pretest Preference		Posttest Preference				
		Doing	Reading	Observing	Lecturing	Totals
Doing	*n*	37	0	5	1	43
	%	43.53	0.00	5.88	1.18	50.59
Reading	*n*	5	0	3	1	9
	%	5.88	0.00	3.53	1.18	10.59
Observing	*n*	19	1	6	2	28
	%	22.35	1.18	7.06	2.35	32.94
Lecturing	*n*	3	0	2	0	5
	%	3.53	0.00	2.35	0.00	5.88
Totals	*n*	64	1	16	4	85
	%	75.29	1.18	18.82	4.71	100.00

Note. $N = 85$.

Most Interesting Thing Learned About Climate Science

Eighty-one student responses to the most interesting thing learned about climate science during the lessons were categorized into 12 themes and an unclassifiable category (Table 3). Statements related to the three experiments and the earth getting warmer had the highest frequencies (n=18), followed by the greenhouse effect and greenhouse gasses (n=12). Responses spanned all five lessons with themes from the greenhouse effect and measuring and analyzing precipitation and temperature lessons being most common. Students were interested in local climate trends and accessing the NOAA Regional Climate Center database (National Oceanic and Atmospheric Administration, n.d.) to perform analyses.

Table 3

The Most Interesting Thing I Learned About Climate Science During the Lessons

Statement Theme	Lesson Numbers	*n*	%
Statement related to one of the three experiments	1, 2, 5	18	22.22
The earth is getting warmer	2, 4	18	22.22
Greenhouse effect or gasses	2	12	14.81
Local precipitation trend over the last 70 years	3	7	8.64
Using I-Pads to access NOAA Regional Climate Center database	3, 4	7	8.64
Different surface colors absorb different levels of thermal energy	5	6	7.41
Local temperature trend over the last 70 years	4	6	7.41
The climate is changing	All	6	7.41
Weather stations and their instruments	3, 4	6	7.41
Water cycle related statement	1	5	6.17
General weather or climate statement	All	3	3.70
Mitigation related statement	5	2	2.47
Unclassifiable		3	3.70

Note. $N = 81$.

Conclusions, Implications, and Recommendations

Overall, science comprehension improved from pretest to posttest for this mostly Hispanic sample of 8th-grade youths taught our weather and climate curriculum. Science knowledge, science skills, and reasoning abilities all improved from pretest to posttest. Science comprehension improved for the greenhouse effect, measuring and analyzing precipitation, measuring and analyzing temperature, and mitigating and adapting to weather and climate extremes in agriculture and natural resources lessons. Science comprehension did not improve during the water cycle lesson. This could partially be a result of it being the first lesson taught by the researchers.

The number of youths with a preference for learning by doing increased from pretest to posttest, while those with a preference for learning by observation and reading decreased. These results indicate that our inquiry-based and experiential lessons likely increased preference for learning by doing. Consistent with these findings, aspects related to the three experiments had the highest frequency among the most interesting things learned from the curriculum, tied with comments related to the earth's warming. The experiments and activities to determine local precipitation and temperature trends emphasized experiential and inquiry-based approaches. They focused on developing science skills and reasoning abilities by having the youths practice both. Other most interesting things learned were the greenhouse effect and gasses, using I-Pads to access the NOAA Regional Climate Centers database (National Oceanic and Atmospheric Administration, n.d.) on the Internet, aspects of weather stations, how surface color affects surface temperature, that the climate is changing, and the water cycle. In summary, youths were interested in learning new knowledge and skills related to all curriculum lessons.

We used the pilot test results to make final improvements to strengthen lesson plans, worksheets, and PowerPoint slides. All documents were edited to make them adaptable to different states and regions. We discovered that more than 50 minutes per lesson would be ideal during the pilot test and modified the curriculum to allow for more time. The additional time could be used by youths to explore topic content further. For educators, the additional time could enhance the science knowledge, skills, and reasoning abilities covered in each lesson. Because the experiments have different incubation periods, the three lessons with experiments should be revisited over several weeks.

These lessons have directions for data collection and hypothesis testing as the experiments progress. We edited the curriculum files for accessibility and made them available to educators on a NMSU webpage (Dormody & Skelton, n.d.). The curriculum can be used for formal classrooms, county educator-led school enrichment programs, afterschool and summer special interest programs, and home-schooled youths.

Additional research is needed to establish the impact of the curriculum on science comprehension retention. Another potential line of research is developing and testing a weather and climate learning progression (Breslyn et al., 2017; Salinas, 2009) for science comprehension development starting with elementary-age youths to build simple understanding and progress to more complex understanding for middle school-aged youths taught this curriculum. In keeping with the mission of the YASC mentioned in the Study Context section (New Mexico State University, n.d.), the learning progression should integrate weather and climate science with agricultural and natural resources and critical thinking about sustainability. Developing and testing a weather and climate science learning progression would further establish the three-dimensional nature of science comprehension when addressed by consistently applying the Figure 1 model across age groups (Skelton et al., 2012, Skelton, Dormody, & Dappen, 2016). Although this study further validates the science comprehension model's utility as a foundation for developing youth agriscience curricula, the model should also be applied to curricula developed for other agriscience content areas.

"Multiple lines of independent evidence confirm that human activities are the primary cause of the global warming of the past 50 years" (U.S. Global Change Research Program 2014, "Climate Change: Present and Future" section, para. 2). Youths need to know this. They need to be informed about weather and climate and understand how to interpret weather and climate data. They are interested in knowing how to mitigate and adapt to weather and climate-related problems. Ultimately, we need youths interested in STEM careers and an informed populace to make evidence-based decisions leading to sustainable solutions. As stated in the Introduction section, our goal was to develop, pilot test, improve, and diffuse a current, standards-aligned, evidence-based, and online youth weather and climate curriculum that would improve science comprehension. The results from the pilot test contributed significantly to this goal.

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