Come Rain or Shine, School is in Session: A mixed methods study of implementing a weather and climate science curriculum pilot in South Carolina K-12 schools, 4-H, and Agricultural Education programs

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Introduction, Purpose & Objectives

Knowledge is power when it comes to weather, and by learning weather patterns, individuals can prepare for simple or disastrous changes (NCSTC, 2014). The United States Global Change Research Program (2009) stated that citizens who understand climate and can apply their knowledge in careers and their communities are desperately needed. Rogers et al. (2013) suggested that academia should focus more on better understanding the physical and social sciences, as well as quantifying the impacts of weather, climate and water on society. Dooley and Roberts (2020) write, "there is a need for innovation in curriculum and educational practices to help prepare future leaders to address complex problems" (p. 1). Humans' well-being is heavily dependent on plants and animals (O'Hare et al., 2004), so it is imperative that we learn as much about weather and climate as possible.

Within K-12 education, each grade level can incorporate weather and climate science-related topics in the respective curricula developed by each state (The Aspen Institute, 2020). Concerning certain topics or subjects in science, Plutzer et al. (2016) noted 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). Dooley and Roberts (2020) said due to extreme weather and climate events, there is a need to educate the public about weather and climate, as well as solutions to related problems.

Dooley and Roberts (2020) continue there is a need for teaching resources for climate literacy and its impact on agricultural systems. By introducing topics such as climate change and global warming, the deficiencies in atmospheric science and climatology curricula are overcome, and students are made aware of real-world examples (Karpudewan & Mohd Ali Khan, 2017; Dahlberg, 2001). These above ideas led the U.S. Department of Education to suggest a STEM-based agriscience curricula be developed and diffused for youth to learn about weather and climate (Dormody et al., 2021).

Unfortunately, there is not anything like this in South Carolina, an agricultural state that is affected by ice storms and hurricanes alike. South Carolina K-12 standards present many learning opportunities about weather and climate science, but do not point to a specific curriculum or materials to guide educators. Davis et al. (2006) explained that "teachers must devise experiences that will help students construct understandings of natural phenomena, as well as assessments that demonstrate evidence of student learning to numerous constituencies" (p. 3). The creation of a custom weather and climate science curriculum for South Carolina K-12 teachers can aid in facing challenges in learning and achieving learning goals.

The purpose of this study was to design, implement and assess the effectiveness of a weather and climate sciences curriculum pilot for South Carolina educators, both formal and informal. This pilot curriculum aimed to enhance K-12 students' understanding, engagement, and retention of key concepts related to weather and climate science. The curriculum pilot was developed in alignment with South Carolina educational standards and objectives, pedagogical strategies, and by using real-world examples and applications. This study aimed to contribute valuable insights to the field of science and agricultural education.

The following objectives guided this study:

1. Determine students' knowledge acquisition of weather and climate science content by evaluating pre- and post- curriculum assessments.
2. Evaluate curriculum design methods of the weather and science curriculum by assessing the structure based on educator's perceptions and feedback.

Theoretical/Conceptual Framework

This study was undergirded by the Pedagogical Design Capacity (PDC) for teachers and extension agents. PDC describes the skills of seeing the different interpretations of resources and being able to create "deliberate, productive designs" (Brown, 2009, p. 29). It is inevitable that teachers adapt and make adjustments when implementing a curriculum, regardless of their beliefs and experiences (Nalabantoğlu & Bümen, 2024). In Nalabantoğlu and Bümen's (2024) article, it is noted that the teachers who lack the skills to analyze curriculum resources productively may fail to identify the strengths and weaknesses of the resources. This theory will be used to develop teachers' and extension agents' PDC, so the curriculum can be used and adapted more productively.

For the students participating in this study, Experiential Learning Theory (ELT) was used to describe the overall effect of the hands-on activities throughout the curriculum. David Kolb's (1984) theory is based around learning by doing and focusing on the idea that the best way to learn things is by actually having experiences that stand out in the mind and help retain information and remember facts. "Teachers can help create environments where students can learn and have experiences at the same time" (Western Governors University, 2020, para. 2).

The Pedagogical Design Capacity (PDC) and Experiential Learning Theory (ELT) frameworks together created an integrated conceptual model to demonstrate how the educator's capacity drove the design of activities that intentionally moved students through the four stages of the ELT cycle. The educator's PDC was the foundational piece that designed and shaped learning experiences that guided students through each stage of the ELT. The ELT formed the core learning process, with each stage linked to a design task by the educator. The model aided in visualizing and emphasizing how effective experiential learning didn't happen by chance. It was intentionally designed by educators who possess strong pedagogical design capacity.

Methods

This study began with the creation of a weather and science curriculum customized for South Carolina K-12 classroom use, as well as FFA and 4-H use. The curriculum was developed from several sources, many of which come from existing weather and climate science curricula being used in other U.S. states with coastlines. The lead researcher formulated a curriculum matrix that matched lessons with South Carolina College- and Career- Ready Science Standards for grades nine through 12 to aid in modifying lessons and activities to fit South Carolina state standards per grade level. The entire curriculum consisted of five days' worth of lessons that included ageappropriate hands-on activities. Each lesson consisted of an outline, lesson plan and PowerPoint. Each lesson was also accompanied by one or two hands-on activities for the students to further their knowledge of the subject or use to reflect on the lesson.

Implementation of the curriculum took place in two high school agriculture classrooms, two South Carolina Governor's School classrooms (i.e., agriculture and science), two charter middle school science classrooms, and three 4-H programs in varying locations throughout South Carolina. While one county in the Pee Dee Region was predetermined due to the project's funding, the other counties were selected from the Coastal, Midlands, Pee Dee, Piedmont, and Upstate Regions of the state. Within those or surrounding/neighboring counties, one agricultural education teacher or one 4-H agent were selected to participate in the curriculum trial. The trial took place during the Fall semester of the 2025-2026 school year. 4-H agents were given the option to implement the curriculum as part of a late summer break camp or Fall school enrichment for students.

Before educators taught the curriculum in their classrooms or 4-H groups, a one-on-one orientation took place with the educators so they could see what the lessons would look like, as well as ask questions. The project's funding allowed for most of the materials used in the lessons' hands-on activities to be purchased for the educators ahead of time. If the educators could not make a one-on-one orientation work, then a recorded set of instructions could be made available upon request. The educators could also submit questions after viewing the recordings.

Data collection took place in the form of pre- and post-test assessments taken by students and pre-tests only by educators using Qualtrics. Students were asked questions about their knowledge prior to the weather and climate science curriculum, and then their knowledge after. They were also asked about their perceptions of the weather now, after receiving more in-depth lessons, and how they will plan for future weather events. Questions on the student survey questionnaire were adapted from two different weather and climate science-related studies by Christensen and Knezek (2015) and Cartwright et al. (2021). The student questionnaire was checked for its readability to ensure it would be appropriate for middle school readers. Per the Flesch-Kincaid Grade Level scale, the student's pre- and post-test grade was 4.9, well below that of middle school. The Flesch Reading Ease grade was 71.1.

The educator pre-test instrument was modified from a survey of public attitudes and perceptions related to water use (Borisova et al., 2013). Questions were asked about weather and climate science content knowledge, and water science knowledge. The instrument had a total of 26 questions. Several other demographic-type questions relating to teaching experience and lessons about weather and climate science taught over their time in the classroom were also asked on the instrument. Both student and educator questionnaires were evaluated for face and content validity (Salkind, 2012) by four faculty members in agricultural and extension education across three universities.

In addition to the pre-test knowledge content, educators were asked for constructive curriculum feedback and to explain their perceptions and confidence in teaching the materials after using the premade kit. Each educator were asked to submit this constructive criticism through a daily reflection of the lesson and activity via Zoom or some form of voice recording. Because of the distribution of schools and Extension offices, conducting the interviews via Zoom was the easiest method. By conducting reflections with the pre-tests taken by educators, the data were triangulated for accuracy and trustworthiness. Quantitative data was analyzed using a paired samples *t*-test to analyze the differences between students' pre- and post-test scores, as well as educators' confidence before and after implementing the lessons.

Findings

The student pre- and post-tests were assigned with a score value of 30 total available points. To know if each individual student gained knowledge after the lessons, a linker ID number was assigned to each student to match pre- and post-tests, and each pilot group had a custom Qualtrics link. Each group had a varying number of participants (i.e., 7 to 99), in multiple grade levels (i.e., 6–12), that participated in 4-H, FFA, or neither. Pre- and post-test scores were compared to designate an increase, decrease, or no change in knowledge. Across all groups ($N = 9$) within this pilot study, a gain in knowledge was demonstrated between the pre- and post-test assessments, ranging from a 28% increase to an 82% increase, with an average increase of 54.8%.

Paired *t*-tests were used to analyze the test scores of each student group (six total). The results of these tests were based only on the pairs from the pre- and post-tests of those student participants who had matching linkers. Prior to data analysis, the assumptions were met for five of the six pilot groups. Instruction did not lead to statistically significant improvement in student scores in five out of six groups that fully implemented the curriculum.

Educators (i.e., teachers and Extension agents) were asked to submit video recordings of their feedback about the lessons based on their experience, rating on a scale of one, very bad, to five, very good, on how the lessons and activities were, and how their students reacted to the lesson and materials. Educators rated each of the five daily lessons and corresponding activities. Lesson One resulted in an average rating of 4.0 with an activity rating of 4.0. Lesson Two had a lesson rating of 4.2, with an activity rating of 4.6. Lesson Three resulted in an average rating of 3.6, with the activity being ranked a 2.6. A lesson rating of 3.6 for Lesson Four was achieved with an activity rating of 4.2. Lesson Five resulted in a 4.2 with an activity score of 4.4.

The series of open, axial, and selective coding of qualitative data resulted in four overall themes: 1) Behavioral shifts of the weather and climate science curriculum pilot; 2) The importance of user experience; 3) The organization and customization of curriculum implementation; and 4) Overall impression of the weather and climate science curriculum pilot.

While the educators were complimentary of the work that went into this project, they provided rich, descriptive, and constructive feedback to further improve it. They mentioned making the lessons more applicable to the Southeast rather than the British or Costa Rican examples in videos. One agricultural teacher noted his Spanish-speaking students were more engaged than he had ever seen in a particular lesson that involved a Spanish-speaking person in a video about sustainable agriculture practices in Costa Rica. Educators also noted that some of the lessons were too long or "discussion-heavy" for their students and should have included more active learning components to keep the students engaged.

Conclusions/Discussion/Implications/Recommendations

Prior to implementing the weather and climate science lessons in South Carolina classrooms and 4-H programs, students demonstrated knowledge of topics relating to weather, climate, greenhouse gases, and more through pre-test assessments. After the five lessons and activities, students not only retained but demonstrated knowledge gain through post-test assessments. Educators donated valuable class time to implement the lessons and activities to provide feedback on lesson structure, connectivity, and relatedness to South Carolina weather and climate science. They also gathered feedback from their students by watching them participate in activities and lesson discussions. Due to the "complex problems" Dooley and Roberts write about, it is clear the lessons and activities displayed a level of "innovation in curriculum" (2020, p. 1).

Each lesson included a hands-on activity to engage students in the topic of discussion. Kolb's (1984) Experiential Learning Theory was demonstrated heavily in every lesson but number Three, as shown by the educators' rankings based on their own and students' feedback. That particular activity was described as "a lot" and "hard to absorb for the kids and the educator." Educators mentioned in the recordings which activities engaged their students the most and which the students were least pleased with. One group of students asked their agriculture teacher if they could modify a set of instructions that asked to write a paragraph comparing their assigned region to a different region in a climate model activity to instead draw a Venn diagram to compare and contrast the two regions. The teacher noted her students are more visual learners than writers.

After listening to educators' daily recordings, one particular phrase stood out to the researcher: "I adlibbed a little based on my personal knowledge of this topic of…." According to Brown (2009), Pedagogical Design Capacity (PDC) describes the skills of seeing the different interpretations of resources and being able to create "deliberate, productive designs" (p. 29). The educators who knew extra pieces of content added them to the lessons to make them more relevant to their students. It was evident which educators took the time prior to implementation to review the materials and become familiar with the content. Their feedback was slightly more critical saying things like, "I didn't know this activity was going to require empty water bottles" or "I wanted to do the algae activity but didn't know it needed to be prepped a month in advance." This observation is supported by Nalabantoğlu and Bümen's (2024) article noting the teachers who lack the skills to analyze curriculum resources productively may fail to identify the strengths and weaknesses of the resources.

The development of this curriculum has provided an opportunity to fill the gap where there is not currently anything like this in South Carolina. With climate change being a growing scientific topic, there will continuously be opportunities for growth and development of this curriculum in the future. Going forward, all of the lessons should be revamped and written from scratch to be explicitly based on weather and climate science. Educator feedback called the curriculum more of "sustainability or energy with a little bit about weather and climate." They expressed some lessons are not well connected and do not all fit South Carolina, or even weather or climate science.

The primary researcher is not a certified, formal educator, so she does not have any formal training in curriculum development. For the pilot project, modified lessons were used to gauge interest. That being said, it is recommended a team of trained professionals in curriculum development create a more South Carolina-focused weather and climate science curriculum for future use. The existing materials can be listed on the Clemson Extension/South Carolina 4-H site as supplemental materials in the topics of weather, climate and human population, renewable resources, biomass and biogas. Because the existing lessons were written for South Carolina high school-level science students and met Next Generation Science Standards and South Carolina Science Standards, the materials could still be used during other appropriate times of the school year. The lessons and activities do not have to be taught synchronously or close together in time.

It is recommended that Clemson Extension waits to publish this curriculum until new lessons are created. However, if an educator (formal or informal) requests a digital file of the existing materials, they will be made available with the disclaimer that they are not the official end product. Clemson Extension has already created a Canvas homepage for the curriculum to be launched on the Extension website upon completion and approval, but it is recommended the existing materials not be housed there permanently. When the new materials are published, South Carolina 4-H, FFA, and schools can have free access for up to one year to gauge interest again. If enough traffic is generated and the curriculum is well-received, work will be done with the Clemson University College of Education to have Continuing Education Credits applied for certified teachers to pay for course credits.

A common factor that surfaced upon approaching public school teachers to conduct research in their classroom was that they were unaware of school district policies either requiring an application process to conduct research or simply not allowing outside research to be conducted at all. Some school districts would allow for research to be conducted with teacher data but not student data. It is highly recommended that public school districts make this information more publicly available and make their teaching staff more aware. Many teachers, and some principals, were extremely excited to pilot the materials when approached but were sorely disappointed to learn their district would not allow it and they had no idea of such rules.

Future research should be done in the area of PDC specifically in 4-H agent/educators. These leaders are not always certified teachers or do not have a formal education background. As 4-H agents teach lessons, how much or little do they modify lessons? Do they avoid certain program areas because of a lack of knowledge or resources? If they do avoid those program areas, are they affected in their annual reviews? It would also be of interest to study how much time is put into preparation of lessons and activities by 4-H agents. Is there a correlation between preparation time and PDC?

In the end, the South Carolina educators enjoyed teaching some of the weather and climate science curriculum lessons, but not all. They expressed gratitude and excitement over the materials and kits they were able to keep for their continued use as an incentive for participating in the research. They also expressed a level of pride in being recommended by South Carolina FFA State Staff, Clemson Extension District Directors, or Clemson University faculty to pilot the project. The researcher will strive to continue to create a product that educators can use for years to come that best represents South Carolina.

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