2021 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
SCIENCE, TECHNOLOGY & ENGINEERING, ARTS, MATHEMATICS
ARTS, HUMANITIES, SOCIAL SCIENCES, & EDUCATION JUNE 9 - 11, 2021
HAWAII PRINCE HOTEL WAIKIKI, HONOLULU, HAWAII

PREPARING TEACHERS TO TEACH COMPUTATIONAL THINKING WITH 3D WEATHER DATA VISUALIZATION

SUN, YAN ET AL
MISSISSIPPI STATE UNIVERSITY
MISSISSIPPI STATE
MISSISSIPPI

Dr. Yan Sun
Dr. Pat Ko
Department of Instructional Systems and Workforce Development
Dr. Jamie Dyer
Department of Geosciences
Mr. Jonathan Harris
Northern Gulf Institute
Dr. Jean Mohammadi-Aragh
Department of Electrical & Computer Engineering
Mississippi State University
Mississippi State, Mississippi

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Synopsis:

The 3D Weather Analysis and Visualization (3D Weather) project is being funded by the NSF STEM+C grant to develop secondary science learning modules and teacher workshops for teaching computational thinking through 3D visualization of weather data using Unidata's Integrated Data Viewer (IDV). This paper reports on the design-based research study in the first project year on the iterative process of developing, revising, and improving the modules and the teacher workshop.

Preparing Teachers to Teach Computational Thinking with 3D Weather Data Visualization[1]

Introduction

Following Wing's (2006) call to teach computational thinking (CT) as a fundamental skill alongside the three R's (i.e., reading, writing, and arithmetic), the education community has been challenged to incorporate computational thinking into K-12 subject areas. While efforts have been made to integrate computational thinking into non-STEM subject areas such as language arts, history, and music (e.g., Bell & Bell, 2018; Nesiba et al., 2015; Settle et al., 2012), STEM classrooms have always been the focus for computational thinking integration. This is primarily because mathematics and engineering are becoming computational endeavors with advanced computing technologies making bolder leaps of innovations across a spectrum of human inquiries and fields. Although a primary motivation for introducing computational thinking into STEM classrooms is the rapidly changing nature of these disciplines as they are practiced in the professional world (Henderson, Cortina, & Wing, 2007), computational thinking as taught and learned in K-12 classrooms may not reflect how it is practiced by real-world STEM professionals.

A common practice of STEM and CT integration is using STEM activities as the contexts for developing some preselected computational skills, such as abstraction, algorithmic thinking, pattern recognition, and problem decomposition (e.g., Angeli et al., 2019; Cateté et al., 2018; Mensan et al., 2020; Rich et al., 2020). This common practice, although having the merit of

[1] The research in this article is being funded by the NSF STEM+C program, under award # *1934194*. Any opinions, findings, and conclusions expressed in the article are those of the authors and do not necessarily reflect the views of the National Science Foundation.

helping students develop certain generic computational thinking skills inherently valuable for professionals in STEM fields, is problematic because it fails to capture: (1) the idiosyncrasies of computational thinking as anchored in specific STEM disciplines; and (2) the authenticity and relevance of how computational thinking is infused in STEM endeavors. To improve the educational practices of integrating computational thinking into STEM classrooms, the K-12 STEM education community needs to explore new computational thinking integrated STEM learning pathways that reflect the varied and applied use of computational thinking by STEM professionals. The *3D Weather Analysis and Visualization (3D Weather)* project, funded by the NSF STEM+C program, is a collaborative effort by a team of educational researchers, practitioners, and STEM faculty members to explore the pathway of promoting computational thinking through 3D visualization of weather data. Reported here is the first-year study conducted by the *3D Weather* project team on four secondary science teachers who participated in the 2020 summer workshop of the project.

Background

The 3D Weather Project

In atmospheric science, large weather datasets such as the North American Mesoscale (NAM) modeling system, Global Forecast System (GFS), and North American Regional Reanalysis (NARR) are publicly available and offer exciting educational possibilities. However, they may be difficult for secondary science teachers and students to access, make sense of, and use in meaningful ways that reflect how atmospheric scientists work in the real world. The *3D Weather* project is a three-year project involving developing unique and exciting computational thinking-embedded science learning experiences by utilizing publicly available large-scale weather data. Specifically, these activities include developing secondary science learning modules that teach computational thinking through 3D visualization of weather data using open-source visualization software such as Unidata's Integrated Data Viewer (IDV; downloadable at https://www.unidata.ucar.edu/software/idv/), developing and conducting summer workshops preparing secondary science teachers for teaching the learning modules, and conducting design-based research to iteratively revise and improve the learning modules and the summer workshops.

Year-1 3D Weather Learning Modules and Summer Workshop

The *3D Weather* learning modules focus on four atmospheric science themes: Temperature, Atmospheric Moisture, Pressure and Wind, and Mid-latitude Cyclones and Fronts. In the first project year, the project team developed the *Temperature Learning Module* and the *Pressure and Wind Learning Module* and offered a teacher summer workshop for these two learning modules. The *Temperature Learning Module*, while including lectures on six temperature-related topics (i.e., Global Energy Balance; Energy Balance Over Oceans and Land; Vertical Temperature Patterns; Understanding Sun Angle; Seasonal Temperature Cycles; and Diurnal Temperature Cycles), focused on using IDV to visualize global temperature patterns, the seasonal temperature cycle, and the diurnal temperature cycle, respectively, using data from the Global Forecast System (GFS) and the Rapid Update Model (RAP). The *Wind and Pressure Learning Module* covered six topics (i.e., What Is Pressure, What Causes Changes in Pressure, What Causes wind, Surface Pressure and Wind Patterns, Changes in Wind Speed with Height, and Atmospheric Jets) and used IDV to visualize global pressure and wind patterns, pressure-wind fields at different levels, and the jet stream, respectively, using global weather data from the GFS model. Originally, the year-1 summer workshop for teachers was planned to be a one-week online course for the topics covered in the two modules and one-week face-to-face training on computational thinking through IDV visualization. But due to the COVID-19 pandemic, the face-to-face training was replaced with a virtual series of lessons conducted using the Zoom teleconferencing program.

Methodology

The participants of this study were four secondary science teachers who attended the year-1 summer workshop. A survey questionnaire was administered to the teachers before and after the workshop. The questionnaire included three six-point Likert-type subscales: knowledge of computational thinking and practices in atmospheric science (14 items), epistemic cognition of teaching atmospheric science (19 items), and self-efficacy of teaching computational thinking with weather data and IDV (7 items). Additionally, post-workshop interviews were conducted with the four teachers. The survey data and interview data were analyzed to answer the following research questions:

(1) What is the effect of the summer workshop on the secondary teachers' knowledge of computational thinking and practices in atmospheric science?

(2) What is the effect of the summer workshop on the secondary teachers' epistemic cognitionof teaching atmospheric science?

(3) What is the effect of the summer workshop on the secondary teachers' self-efficacy of teaching computational thinking with weather data and IDV?

(4) How was the secondary teachers' experience in the summer workshop?

Results and Discussion

The mean scores of the teachers' knowledge of computational thinking and practices in atmospheric science were 4.16 and 4.18, respectively, in the pre-workshop and post-workshop surveys, indicating little impact of the summer workshop on the teachers. Of the 19 items in the subscale of epistemic cognition of teaching atmospheric science, eight items revolved around traditional science teaching pedagogy and 11 items reflected inquiry-based and scientific practice-oriented pedagogy of teaching atmospheric science. The mean score of the eight items decreased from 3.30 in the pre-workshop survey to 3.01 in the post-workshop survey, and the mean score of the remaining 11 items increased from 4.82 in the pre-workshop survey to 5.27 in the post-workshop survey. This result indicates that the summer workshop had a positive effect on the teachers' epistemic cognition about teaching atmospheric science, pulling them further away from traditional science teaching pedagogy to lean more towards an inquiry-based and scientific practice-oriented method of teaching atmospheric science. The result of the self-efficacy subscale showed that the teachers' self-efficacy of teaching computational thinking with weather data and IDV increased after the summer workshop, with 3.86 being the mean score from the pre-workshop survey and 4.50 being the mean score from the post-workshop survey.

To understand the teachers' experience in the summer workshop and to improve the workshop based on their feedback, the project team coded the interview data into two categories: (1) difficulties or problems the teachers had in the summer workshop, and (2) suggestions for improving the workshop. The difficulties or problems experienced by the teachers include:

(1) It was a challenge to use IDV and understand IDV visualizations

(2) There was confusion and misconceptions about computational thinking involved in visualizing weather data with IDV

(3) The workshop did not do well in expanding the teachers' understanding of computational thinking

(4) The teachers didn't feel ready to teach computational thinking with IDV visualization of weather data.

These difficulties and problems voiced by the teachers helped to explain: (1) why the summer workshop didn't improve the teachers' post-workshop mean knowledge score of computational thinking and practices, and (2) why the mean scores of their self-confidence of teaching computational thinking with weather data and IDV remained low for both pre-workshop survey and post-workshop survey, although there was an increase from the pre-workshop score (= 3.86) to the post-workshop score (= 4.5).

The suggestions offered by the teachers in the interviews include:

(1) Conducting the IDV training face-to-face instead of virtually

(2) More practice time and hands-on experience with IDV

(3) Giving more explanation of the visualizations on IDV

(4) Providing sample assignments

(5) Modeling how to teach computational thinking using IDV visualization of weather data

(6) Tying IDV visualization of weather data with learning standards.

These suggestions served as the basis for improving the workshop for the second project year.

Conclusion

The survey results from this study indicated that the Year-1 summer workshop of the *3D Weather Project* had positive effects on the secondary science teachers' epistemic cognition about teaching atmospheric science and their self-efficacy of teaching computational thinking with weather data and IDV. But their self-efficacy scores were relatively low on a six-point Likert scale (with 3.86 for pre-workshop mean score and 4.50 for post-workshop mean score). Additionally, the teachers' knowledge scores of computational thinking and practices in atmospheric science remained low and almost the same in both pre-workshop and post-workshop surveys. The teacher interview data offered insights for understanding the survey results and improving the workshop. The year-2 summer workshop will enroll 20 science teachers and cover two more modules (i.e., the *Moisture Learning Module* and the *Mid-latitude Cyclone and Fronts Learning Module*) in addition to the *Temperature Learning Module* and the *Pressure and Wind Learning Module*. Based on the teachers' feedback from the interview data, the project team will develop and incorporate the following activities and materials into the year-2 summer workshop:

(1) developing and offering a training session focused on computational thinking contextualized in atmospheric science and visualizing weather data with IDV

(2) designing and developing computational thinking integrated IDV visualization activities tied with appropriate learning standards

(3) developing and providing detailed Teacher Guide with step-by-step guidance of how to

teach these activities with the “Engage, Observe, and Explain & Communicate” instructional model

(4) offering face-to-face instructor-guided hands-on experience with IDV visualization of weather data

(5) offering the culminating experience in the workshop of engaging teachers in creating, discussing, and sharing their own lessons plans for teaching computational thinking with visualization of weather data.

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