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PREPARING TEACHERS TO TEACH SPATIAL COMPUTATIONAL THINKING WITH IDV VISUALIZATION OF WEATHER DATA

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Preparing Teachers to Teach Spatial Computational Thinking with IDV Visualization of Weather Data

Synopsis:

Funded by the NSF STEM+C program, the 3D Weather project developed instructional modules of using IDV visualization of weather data to help middle and high school students to develop spatial computational thinking. This paper reports the research on the professional development provided to 15 teachers by the 3D Weather project in the second project year.

Preparing Teachers to Teach Spatial Computational Thinking with IDV Visualization of Weather Data[1]

INTRDUCTION

Wing argues in her seminal article of 2006 that computational thinking (CT) is a fundamental skill to be taught to all students alongside reading, writing, and arithmetic. Ever since then, computational thinking has received considerable attention from STEM educators and researchers with continued efforts to teach it to K-12 students as an important problem-solving skill set. In the same year, the National Research Council (2006) published *Learning to Think Spatially* highlighting spatial thinking as the thought process that "is integral to everyday work of engineers and scientists" and "has underpinned many scientific and technical breakthroughs" (p. 5). This publication has sparked a new interest among researchers to examine spatial thinking in STEM education, especially in those spatially demanding STEM disciplines, such as geoscience, chemistry, and mechanics (Hegarty, 2010). Although recent years have seen emerging efforts (e.g., Città et al., 2019; Moschella & Basso, 2020; Ham, 2018) to put computational thinking and spatial thinking under the same lens, they are mostly treated as separate thinking processes in the K-12 STEM education arena.

What's missing in the landscape of computational thinking and spatial thinking research is a discipline-based perspective that recognizes the reliance of computational thinking on spatial thinking in some STEM disciplines, such as meteorology. Meteorologists can envision atmospheric movement, forecast upcoming weather, and predict weather events by analyzing and interpreting two-dimensional weather maps and satellite imagery, and visualizing large scale weather data obtained through a mix of weather satellites and on-the-ground weather sensors. Besides meteorological knowledge, computational thinking alone does not explain how meteorologists make sense of three-dimensional atmospheric processes because the maps, images, and numerical data they use encode a large amount of spatial information that needs to be processed by thinking spatially. The three-dimensional nature of the atmosphere and the consequent spatial nature of the tasks undertaken by meteorologists determine that computational thinking in meteorology takes place in spatial contexts and builds on spatial thinking. This is a special type of computational thinking referred to as "spatial computational thinking" by the authors of the article in the *3D Weather* project.

Funded by NSF STEM+C program, the 3D Weather project designed and developed modules to teach spatial computational thinking through visualization of real weather data with IDV (Integrated Data Viewer, downloadable at https://www.unidata.ucar.edu/software/idv/). Summer workshops were offered to prepare teachers for using the modules to teach spatial computational thinking with IDV visualization of weather data. The research reported in this article was conducted on the teachers who attended the project's 2nd year summer workshop for the purpose of assessing the workshop's impact on these teachers. Specifically, the research focused on answering the following research questions:

(1) How does the summer workshop affect teachers' spatial computational thinking?

(2) How does the summer workshop affect teachers' self-confidence in teaching meteorology through computational thinking and practices?

(3) How does the summer workshop affect teachers' epistemic cognition of teaching meteorology?

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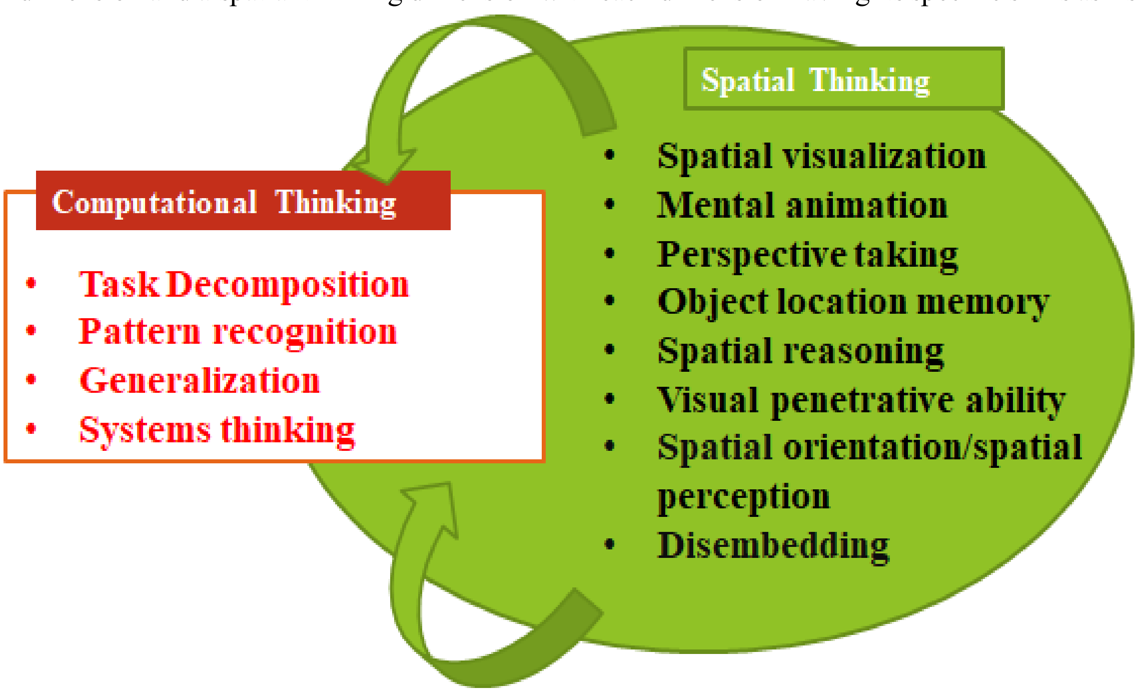
BACKGROUND

3D Weather Modules and Spatial Computational Thinking

The *3D Weather* project developed four modules on the topics of Temperature, Moisture, Wind & Pressure, and Mid-latitude Cyclone & Fronts. Each of the four modules include three themes for using IDV visualization of weather data to teach spatial computational thinking as listed in the following table:

Module	IDV Visualization Themes
Temperature Module	➢ Global Temperature Patterns ➢ Seasonal Temperature Cycle ➢ Diurnal Temperature Cycle
Moisture Module	➢ Global Moisture Distribution ➢ Visualizing Clouds ➢ 3D Structure of Moisture Transport
Wind & Pressure Module	➢ Global Pressure and Wind Patterns ➢ Pressure and wind fields at different levels ➢ The Jet Stream
Mid-latitude Cyclone & Fronts Module	➢ Temperature Structure of a Mid-latitude Cyclone ➢ Wind and Pressure Patterns in a Mid-latitude Cyclone ➢ Evolution of a Mid-latitude Cyclone

The spatial computational thinking in the 3D Weather modules consists of a computational thinking dimension and a spatial thinking dimension with each dimension having its specific skills as listed below:



3D Weather Summer Workshop

The workshop reported in this article was a two-week summer workshop offered in Summer 2021. Fifteen 5th – 12th grade teachers attended the workshop. The first week of the workshop was virtual through a

Canvas course mostly focused on meteorology content of the modules and the second week was in person focusing on IDV visualization of weather and spatial computational thinking.

RESEARCH METHODOLOGY

A survey was administered to the fifteen summer workshop teachers before and after the workshop. The survey includes 13 items measuring the teachers' spatial computational thinking, 7 items measuring their self-confidence in teaching meteorology through computational thinking and practices, and 23 items measuring their epistemic cognition of teaching meteorology. All items in this survey use 6-point Likert type scale. The 23 items for measuring epistemic cognition consist of three subscales: epistemic cognition of teaching meteorology with traditional method (10 items); epistemic cognition of teaching meteorology with scientific practices (6 items); and epistemic cognition of teaching meteorology with computational thinking approach (7 items).

RESULTS

Spatial Computational Thinking

The teachers' pre and post responses to the 13 items measuring spatial computational thinking were analyzed with a Wilcoxon signed rank test. The test indicated that spatial computational thinking scores were significantly higher after the workshop (MD = 5.00, n = 15) than before the workshop (MD = 4.18, n = 15), z = 3.06, p = .002.

Self-confidence in Teaching Meteorology through Computational Thinking and Practices

The teachers' pre and post responses to the 7 items measuring self-confidence in teaching meteorology through computational thinking and practices were analyzed with a Wilcoxon signed rank test. The test indicated that self-confidence scores were significantly higher after the workshop (MD = 4.50, n = 15) than before the workshop (MD = 4.00, n = 15), z = 2.59, p = .010.

Epistemic Cognition of Teaching Meteorology

The teachers' responses to the three subscales (epistemic cognition of teaching meteorology with traditional method; epistemic cognition of teaching meteorology with scientific practices; and epistemic cognition of teaching meteorology with computational thinking approach) in the pre-workshop survey were analyzed with a repeated measures analysis of variance (ANOVA). But the assumptions of normality and sphericity were violated. Therefore, a Friedman rank-sum test was conducted instead. The result indicated a significant difference in the scores of the three subscales, $\chi^2(2) = 20.51$, $p < .001$. Three subsequent Wilcoxon signed rank tests were conducted for pairwise comparisons of the three subscale scores with a Bonferroni adjusted α level of .017. The results of the Wilcoxon signed rank tests indicate that scores of epistemic cognition of teaching meteorology with scientific practices and epistemic cognition of teaching meteorology with computational thinking approach were not significantly different but were both significantly higher than epistemic cognition of teaching meteorology with traditional method.

The teachers' responses to the three subscales (epistemic cognition of teaching meteorology with traditional method; epistemic cognition of teaching meteorology with scientific practices; and epistemic cognition of teaching meteorology with computational thinking approach) in the post-workshop survey were analyzed with a repeated measures analysis of variance (ANOVA). But the assumptions of normality and sphericity were violated. Therefore, a Friedman rank-sum test was conducted instead. The result indicated a significant difference in the scores of the three subscales, $\chi^2(2) = 21.75$, $p < .001$. Three subsequent Wilcoxon signed rank tests were conducted for pairwise comparisons of the three subscale scores with a Bonferroni adjusted α level of .017. The results of the Wilcoxon signed rank tests indicate that scores of epistemic cognition of teaching meteorology with scientific practices and epistemic cognition of teaching meteorology with computational thinking approach were not significantly different but were both significantly higher than scores of epistemic cognition of teaching meteorology with traditional method.

CONCLUSION

The data analysis results indicate that: (1) the summer workshop is effective in improving teachers' spatial computational thinking and self-efficacy in teaching meteorology through computational thinking and practices; and (2) the summer workshop does not change teachers' epistemic cognition about how meteorology should be taught and teachers' preference for teaching meteorology with scientific practices and computational thinking approach over traditional method is evident both before and after workshop.

References:

Città, G., Gentile, M., Allegra, M., Arrigo, M., Conti, D., Ottaviano, S., Reale, F., & Sciortino, M. (2019). The effects of mental rotation on computational thinking. *Computers & Education*, *141*, 103613. https://doi.org/10.1016/j.compedu.2019.103613

Ham, D. A. (2018). *Spatial Thinking as a Path Towards Computational Thinking* [Chapter]. Teaching Computational Thinking in Primary Education; IGI Global. https://doi.org/10.4018/978-1-5225-3200-2.ch006

Hegarty, M. (2010). Components of spatial intelligence. In B. H. Ross (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 265–297). Elsevier Academic Press. https://doi.org/10.1016/S0079-7421(10)52007-3

Moschella, M., & Basso, D. (2020). Computational Thinking, spatial and logical skills. An investigation at primary school. *Ricerche Di Pedagogia E Didattica. Journal of Theories and Research in Education*, *15*(2), 69–89. https://doi.org/10.6092/issn.1970-2221/11583

National Research Council. (2006). Learning to think spatially: GIS as a support system in the K–12 curriculum. Washington, DC: National Academic Press.

Wing, J.M. (2006) Computational Thinking. *Communications of the ACM*, *49*, 33-35. https://doi.org/10.1145/1118178.1118215