Board 326: K-12 Teachers and Data Science: Learning Interdiscplinary Science Through Research Experiences

Dr. Katherine G. Herbert-Berger, Montclair State University
Dr. Thomas J Marlowe, Seton Hall University

Thomas J Marlowe is Professor Emeritus of Mathematics and Computer Science at Seton Hall University, with PhDs in each discipline from Rutgers University. His research has spanned many areas, including coalgebra theory, algorithms, program optimization and compilers, real-time systems, software engineering, computer science pedagogy, and interdisciplinary studies.

Dr. Vaibhav Anu, Montclair State University

An Assistant Professor of Computer Science at Montclair State University, Dr. Anu co-directs the Software Systems lab at the Center for Computing and Information Science.

Stefan A Robila, Montclair State University

K-12 Teachers and Data Science: Learning Interdisciplinary Science through Research Experiences

Abstract: Data science is now pervasive across STEM, and early exposure and education in its basics will be important for the future workforce, academic programs, and scholarly research in engineering, technology, and the formal and natural sciences, and in fact, across the full spectrum of disciplines. When combined with an emphasis on soft skills and an interdisciplinary focus, such educational experiences have deeper and more meaningful effects. Our Montclair State University NSF Research Experience for Teachers (RET) grant (NSF Award Number: #2206885, IRB Number: 22-23-3003) exposed teachers to a program integrating solar weather, data science, computer science and artificial intelligence, and STEM pedagogy. The cohort comprised nine middle- and high-school teachers with diverse academic backgrounds and demographics from northern and central New Jersey. The teachers interacted with and were advised by faculty from Montclair and two other institutions, and by outside experts, to learn the basics, develop lesson plans, and present these to and interact with a learning-intensive summer camp. As a capstone, teachers developed research projects synthesizing this interdisciplinary content with their own interests and background. As a result, the teachers have submitted several posters with abstracts to the 2024 ACM SIGCSE and IEEE ISEC conferences and will be delivering grant-related lessons in their classes during the current academic year.

1 Introduction and Motivation

Developing and understanding data fluency is increasingly important given the rapid changes related to living, learning, and working in the knowledge society of the 21st century. Meeting this commitment requires well-prepared teachers with proper support, including tools and resources, and yet, professional development and teacher preparation around data fluency is spotty at best and too often absent. As a result, teachers may not be ready to make connections between early education in numeracy, computation thinking, and data analytics as they relate to data fluency and to the knowledge, skills, and dispositions they must develop later. This paper documents a grant-funded, extended professional learning community in which teachers developed these skills, conducted research projects around their interests, and used their findings to develop related lessons and prepare a paper for submission to a conference or publication and presentation at a conference or workshop.

Developing data fluency continues to be scaffolded throughout a student's career where, once they transition into science, applied math, or other relevant classes, they learn to use their skills to analyze an experiment or create a budget, and to apply them as part of critical thinking. As artificial intelligence/machine learning/data science (AI/ML/DS) techniques become a part of everyday life, and as state standards change to encompass CS topics, educators are faced with challenges to integrate these into the K-12 curriculum. As research and development in these fields expands ever more rapidly, both in power and in scope, so does how we interact with it within and across other disciplines.

Many industries face challenges in recruiting, and in trying to match employee skills with these advanced computational skills. The development of these understandings and skills falls to P16 educators even though many have not had sufficient preparation and lack access to tools and

resources needed to ready students to work responsibly in the new digital world. Matching student curriculum to industry needs in AI/DS while retaining an academic focus is particularly hard, especially within the limits of the curriculum. For many educators, CS education, especially AI/DS-related education is new, and the need for CS support for educators is essential if they are to develop and maintain a growth mindset both for themselves and for their students to keep up with changes [1].

Equally important is making the computing sciences appealing and accessible to learners. Ideally, topics should be relevant and novel, but accessible. They should present a learning challenge without seeming onerous or impossible, and steer clear of unnecessary social and personal triggers. Developing such a curriculum, enabling students to see a direct application to their lives increases motivation and fosters interaction. Such inclusion of students' lives can help to break down racial and gender barriers regarding students' beliefs about who can be a data or computer scientist.

NJ is at a crossroads with K-12 Computer Science Education. The state is still developing its computer science education standards and outlining required faculty expertise for school districts, making the student and teacher experience variable across the region and even within districts. While many faculty are taking advantage of services and opportunities from organizations like Code.org the need for high-quality computing sciences content and pedagogy extends far beyond what one group can provide. NJ is one of the largest "tech" economies in the country and it does not have resources available to help teachers gain experience in computer science, let alone meet the needs of the state's diverse educational needs [4,5]. This raises a very significant need for supporting teachers as they now explore trying to integrate computing and data science into the K-12 experience.

Northern New Jersey (NJ), where the grant program is located, is an area of extremes in demographics. Many of these districts have significantly underrepresented minority (URM) populations for CS, coupled with family backgrounds where no parent attended college. It is home to many of the most affluent US zip codes as well as some of the poorest. For example, one partner district has a median household income of $45,000 while another less than 7 miles away has a median income of $200,000. Additionally, Northern NJ is one of the most diverse regions in the country [2, 3].

2 The Program

The DATA3 experience, a partnership between Montclair State University (MSU) and New Jersey Institute of Technology (NJIT), is offering the local K-12 teacher community the opportunity to participate in applied DS and AI research. We support teachers through research and pedagogical experiences at MSU's Grades K-12 EpiSTEMic Camp, a summer STEM camp where instruction is thematic, project-based, and inclusive to support students who are English learners (students who may have English not as their first language) and have an Individualized Education Programs (IEPs). Teachers develop and test instructional modules in the camp that can be taught later in their classrooms. Teachers also meet for office hours and professional development and special sessions

for additional training and support. A culminating experience is participant presentations of their work to our larger MSU Network for Education Renewal (MSUner) and PRISM Institute, an already established education network at MSU servicing over 3000 teachers in northern NJ that reaches 260,000 students [2,3,6] and over 50 school districts. Finally, participants have access to additional professional learning experiences through our partnerships with the New Jersey Educational Computing Cooperative (NJECC,) the largest collaboration of NJ School District Computing professionals to deliver professional development, and the Montclair State University Education Hub and Standards Program, which has a reach of over 500 teachers impacting 50,000 students. These state resources are where educators can meet and discuss the pressing issues facing CS Education in NJ.

We have completed the first phase of our program with 9 teacher participants from northern and central NJ middle and high schools. These teachers completed a six-week summer experience.

Table 1: Summer Workshop Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	Review of Weekend/ Research	Research	Lesson Debrief	Research	Synchronous Meeting
Afternoon	Pedagogy and Lesson Development	Work with Campers	Research	Guest Research Speaker/ Experience	Asynchronous Reearch

Table 1 provides a partial overview of the structure, in the form of a typical week's activities during the summer experience. Lessons, embedded in research discussions or read asynchronously, were highly interdisciplinary and included discussion of solar weather and some of the underlying physics, computer science topics and programming, machine learning and artificial intelligence, tools for data analysis and some of the mathematics behind it, and computer science pedagogy. As indicated, the experience included learning this pertinent content, working with the inclusion summer camp, meeting data science professionals from industry, and participating in a solar observation activity with the North Jersey Astronomy Group.

From this experience, each teacher created a plan for research and a plan, influenced by their own interests and educational specializations, for modifying the lessons piloted with the camp to bring to their students. Research topics included finding the intersections between special education and inclusion education and AI and DS content, examining historical documents to further understand solar cycles and enrich the solar weather data set, creating solar weather sensors with Arduino processors and sensor packs, and using linear regression to model various attributes collected in solar weather observations to enhance the EarthCube Data Capabilities Group research tools.

3. Update and Future Work

Participants continue to expand their learning, their research, and the lessons presented to their classes. They have submitted a total of four posters to ACM SIGCSE 2024, with one accepted,

and six short work-in-progress papers to IEEE ISEC 2024, with final decisions in most cases currently pending, from multiple perspectives including space weather, pedagogical perspectives and problem-solving, and the use of programmable sensor devices. One group of high-school students advised by one of the students has also submitted a poster to ISEC based on independent research on data analysis of solar sunspot cycles.

Table 2: Academic Year Participant Schedule

Activity	Participation	Products
Office Hours with PIs	Weekly but optional	Classroom/ research issues discussion
Quarterly PDs	Quarterly Required	Completed Lesson Plans, Plans for Further Work on Research, In Progress Work Papers
Special Events	Optional	none - Additoinal PDs for RET teachers
Statewide Conference	Once Required	Poster and Presentation
Professional Development for other Teachers	Once Required	Professional Development Content (developed in Teams) delivered to 35 regional teachers

During the academic year, the teacher participants have continued to interact with the PI team (Table 2). Several regularly attend weekly online office hours, and others less frequently, for help and review of content, or to continue discussions and collaboration. Participants are required to attend professional development (PD) sessions in October, December, January, and March. These PD sessions work towards meeting research milestones and generating reproducible lessons for teachers to integrate into their classrooms. As of February 2024, eight teachers remain in the program, with one leaving for personal reasons. Those teachers will be presenting the statewide NJECC conference and giving a PD experience for regional K-12 teachers, and most will be invited to continue, effectively as senior students and sometimes mentors for new members of the team. Finally, the MSU Hub has events that serendipitously align with our objectives. We are creating ad hoc opportunities for these teachers as these opportunities come about. For Year 2, we will integrate a graduate data science class into the experience, where those students will work with the teacher participants to implement more challenging DS and AI work.

Acknowledgement

We acknowledge the support of our fellow MSU RET DATA 3 Program members, our colleagues in our respective districts and institutions, and our families. This work was funded by the NSF Research Program #2206885 Collaborate RET SITE: Data Sciences and Data Fluency in Scientific Data Sets (DATA3) Program and under the oversight of IRB-FY21-22-2607.

References

[1] O. Hazzan and K. Mike. “Ten Challenges of Data Science Education”, Communications of the ACM, https://cacm.acm.org/blogs/blog-cacm/246219- ten-challenges-of-data-science-education/fulltext.

[2] National Center for Education Statistics (NCES), Institute of Educational Sciences, US Department of Education, “Search for Public School Systems”, https://nces.ed.gov/ccd/districtsearch/.

[3] National Center for Education Statistics (NCES), Institute of Educational Sciences, US Department of Education, “Education Demographic and Geographic Estimates (EDGE)”, https://nces.ed.gov/programs/ edge/Home

[4] State of New Jersey Department of Education, “2020 New Jersey Student Learning Standards – Computer Science and Design Thinking”, https://www.njdoe.gov/education/cccs/2020/2020%20NJSLS-CSDT.pdf,

[5] State of New Jersey Department of Education, “ Office of Educational Technology & School Innovation: Computer Science FAQ”, https://www.NJ.gov/education/techno/csfaq.htm.

[6] K. G. Herbert, V. K. Anu, K. Z. Sultana, S. Robila, J. R. Miller, S. Hagiwara, R. A. Goldstein, and T. J. Marlowe, "Professional and Capacity Building in K-12 Computer Science Education: A Multi-Faceted Approach”, *ACM SIGCSE '23: Proceedings of the 54th ACM Technical Symposium on Computer Science Education*, Toronto, Canada, March 2023.