Preparing K-8 Teachers to Teach and Infuse Computer Science Across All Subjects

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November 24, 2024

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Abstract

The rapid advancement of computing technology and increasing dependency on digital information impact the career paths and the lives of all current students. The dynamic nature of technology necessitates ongoing evaluation and adaptation of computer science (CS) curricula and teaching methodologies to prepare a technology-driven workforce. While an abundance of curriculum material is available, this experience paper highlights a project focused on development of resources by teachers to specifically align to the New Jersey Student Learning Standards (NJSLS) for Computer Science and Design Thinking (CSDT). The work was designed by teachers for teachers as part of a professional learning community (PLC). The PLC aimed to provide learning opportunities, resources, and technical assistance to schools and districts. With the diverse demographics of the state, the PLC looked to expand access to equitable high-quality, standards-based computer science education for all K-12 students. The paper describes the methodology to create teacher-focused instructional materials based on a teacher PLC and survey data from 37 respondents, highlighting key insights, limitations, and recommendations for future improvements. This paper thus contributes to the existing literature by reaffirming the need for content resources and underscoring the role teachers play in ensuring computer science instruction is more accessible to teachers new to computer science education.

SIGCSE TS 2025, February 26-March 1, 2025, Pittsburgh, PA, USA

ACM ISBN 979-8-4007-0531-1/25/02.
https://doi.org/10.1145/3641554.3701919

CCS Concepts

Social and professional topics~Professional topics ~ Computing education ~ K - 12 education •Social and professional topics ~ Professional topics ~ Computing education ~ Model curricula •Social and professional topics~Professional topics ~ Computing education ~ Computing literacy

Keywords

K-12 Computer Science Education, Instructional Content, K-12 Teacher Professional Development, Collaborative Design, Computer Science Standards

ACM Reference Format

Angela Williams-Nash, Sumi Hagiwara, Katherine Herbert, Thomas Marlowe, Rebecca Goldstein, Stefan Robila, and Vaibhav Anu. 2024. Preparing K-8 Teachers to Teach and Infuse Computer Science Across All Subjects. In *n Proceedings of the 56th ACM Technical Symposium on Computer Science Education V. 1 (SIGCSE TS 2025), February 26-March 1, 2025, Pittsburgh, PA, USA.* ACM, New York, NY, USA, 7 *pages.* https://doi.org/10.1145/3641554.3701919

1. Introduction

Technological changes and its impact on education, student, and careers prospects require persistent, periodic examination of computer science course content and the instruction necessary to prepare a workforce for a technologically dependent society.

Like many states across the country, the State of New Jersey developed the New Jersey Student Learning Standards (NJSLS) for Computer Science and Design Thinking [15]. The development of these standards was based on the K–12 Computer Science Framework [7], which was led by the Association for Computing Machinery (ACM), Code.org, the Computer Science Teachers Association (CSTA), the Cyber Innovation Center, and the National Math and Science Initiative, in partnership with states and districts.

The standards contain a vision of students who will not just be computer users, but also computationally literate creators. Students will be proficient in the concepts and practices of computer science and design thinking, and knowledgeable in multiple areas of application. By engaging students in computing and human-centered approaches to the study of computer science and technology, educators are preparing students to ethically produce and critically consume technology, and to become technologically informed citizens and consumers.

Teachers are key to ensuring the vision comes to fruition. K-12 computer science (CS) teachers face several challenges that impact their ability to stay current with technology and effectively teach students. One of the primary issues is the knowledge gap due to limited exposure, preparation, expertise, comfort (especially for those without a STEM background) with CS content, CS pedagogical content knowledge (CSPCK), unfamiliarity with newer technologies, and programming languages. K-8 classroom and subject matter teachers are especially in need of more support and guidance.

Teachers reported issues of insufficient knowledge of CS subject matter and inadequate planning time [8]. Addressing these challenges requires more comprehensive and ongoing PD that equips teachers not only with technical skills but also with pedagogical strategies tailored to CS education. Effective PD should include collaborative learning opportunities, real-world applications, and continuous support from peers and mentors to ensure long-term growth in teachers' abilities to integrate new technologies effectively [19].

While there are many resources available for educators, communication of how those resources apply across diverse classrooms can be difficult for teachers. Research shows that while schools are increasingly offering PD programs, most teachers receive only brief training (often less than 8 hours) on integrating technology into classrooms. This leaves them to independently figure out how to select and use the best tools for their students. Furthermore, PD programs often focus more on technology use than on effective pedagogical strategies, which limits their impact on improving teaching practices. An informal survey of members of the Montclair State University (MSU) PLC, indicated that while teachers were aware of accessible resources through organizations like Code.org and Learning.com; there exists discomfort in CS, CSPCK, and an understanding of how resources align with state standards. This was especially true for K-5 general education teachers charged with the responsibility of teaching and/or infusing CS across all core content areas.

This paper discusses one ongoing effort by the MSU Hub/PLC to provide a comprehensive, online library of resources (instructional videos, Slide Decks, Pre-Post Tests, and word wall posters) aligned to state disciplinary concepts that are designed to build confidence both in CS content and CSPCK for teachers in Grades K-8.

The rest of this paper is structured as follows. Section 2 offers a review of the relevant literature. Section 3 provides background information on the Montclair State University (MSU) PLC Grant, together with a brief summary of the New Jersey (NJ) CSDC. Section 4 addresses the development of a library of teacher resources with teacher notes and guidelines for their use, and identifies and describes the methodology used to create resources, along with a link to the said library. Section 5 presents the results of a survey of teacher reaction, which identifies a gap in the rollout of the CS education, the need for teacher resources and guidelines to unpack the standards. This documents an awareness by teachers of the problem and the benefit of resources in the library. Section 6 presents an evaluation of the video content, also based on a teacher survey, inherent survey limitations, and recommendations to extend what was learned. Finally, Section 7 describes further directions, open questions, and future work.

2. Related Work

A review of current literature related to preparing teachers to teach computer science yielded articles covering three key areas: (1) teacher professional development, (2) survey and questionnaire data from pre-service and in-service programs, and (3) a comparison of different approaches in teacher training. Current New Jersey state standards for education in technology, computer science, and design thinking can be found in [15] gives the current technology standards for the State of New Jersey. An overview of the state of K-12 computer science in the United States is presented in the Code.org annual report [23], and an evaluation of data from nationwide teacher surveys in [6,10].

Teacher development for elementary (generally K-5) levels is discussed in [11,19,24]. McGill looks at emerging practices for integrating CS in across K-5 subjects [11], Yadav assesses teachers' understanding of computational thinking in elementary schools [24], and Rich examines elementary school teacher's confidence in teaching coding and computational thinking [19]. Articles [1,3,9] explore teacher's readiness, experiences, and self-efficacy with CS content in grades K-8.

Three different approaches to programs for pre-service CS teachers are analyzed in [18,20,22]. Smit focuses on a field-based internship program [18], a University of Texas news story looks at a CS certification program there [22], and Ozogul offers a case study of an undergraduate CS licensure program [20]. Articles [2,4,8,11,14,16,18,25,27] investigate the components, strategies, and impact of providing CS professional development. Of these, articles [2,4,25] are enhanced by additional discussions related to pedagogical content knowledge, equity, and formative assessment literacy, respectively. Going beyond the US, Yadav et al [26] review international models for teaching CS content.

Turning to content, Herbert [5] examines data science as an interdisciplinary concept for K-12 teachers. Finally, Stromberg [21] focuses on solar weather and the computer science used to evaluate the potential damage from a massive solar storm.

While issues and emphases within these references varied, several points remain very clear, (1) there is not a single, unified approach across the United States to help teachers secure the content knowledge and confidence needed to teach CS, (2) K-8 teachers need more support tailored to their specific needs, and (3) survey data taken at the end of a course or program provides a snapshot, but the long term impact after teachers re-enter classrooms post training requires follow-up. Most importantly (4) professional development, resources, collaboration, and ongoing coaching all play an integral role as teachers learn how to teach and/or infuse computer science across different subjects.

3. Background

A roadmap for providing K-12 CS education to New Jersey students includes the following priorities:

- *Adopt* computer science standards to provide a framework for equitable access to a coherent, robust computer science program across K-12 grades.
- *Implement sustainable* professional learning for educators and educator preparation providers.
- *Strengthen the teacher pipeline by* increasing the number of educators teaching computer science. Note that this may also entail modifying the content of teacher education programs, or the development of tracks and additional service courses in university computer science and related programs.
- *Build capacity through partnerships includin*g families, educators, higher education, school boards and other community stakeholders to execute the state plan.
- *Establish a data-driven decision-making approach informed by metrics* to evaluate progress and address gaps.

The Computer Science Disciplinary Concepts (CSDC) target four distinct grade bands: Grades K-2, 3-5, 6-8, and 9-12. Each grade band requires instruction in progressively more detail in the following five target areas:

1. ***Computing Systems,*** which examines how people interact with technological devices.
2. ***Networks and the Internet,*** which examines how computing devices share information and resources.
3. ***Impacts of Computing,*** which examines how computing devices and the flow of information can affect people both positively and negatively, influencing societal practices and behavioral norms.
4. ***Data and Analysis,*** which examines the generation, processing, and evaluation of information.
5. ***Algorithms & Programming,*** which provides foundational information on creating the programs and programming.

In response to this call, the State awarded Montclair State University (MSU) a pair of two-year state-funded grants to address these priorities. The MSU CS for Everyone Everywhere (CSEE) Program is a professional development (PD) program to support district partners in aligning the existing CS curriculum to the NJSLS-CS standards. The Computer Science Education Hub program aims to enhance teacher preparation, understanding, competence, confidence, and comfort by creating learning opportunities through workshops; fostering networking opportunities; and providing access to free, teacher-created resources for self-learning and classroom delivery. CSEE and MSU Computer Science Education Hub programs have curated a collection of practitioner-oriented resources and research for open access. These two initiatives recognize that teacher participation alone is not enough. Teachers work within a framework of, and benefit from, support by school leaders (administrators overseeing curriculum delivery and resources) and counselors to inform students' short- and long-term CS trajectory. Additionally, there is a significant need for ongoing professional development (PD) [16]. Furthermore, most PD programs focus more on technology use and programming languages rather than on effective pedagogical strategies, which limits their impact on improving teaching practices.

A diverse population of teachers from Title I districts in northern New Jersey (many students who attend are on free- or reduced lunch) was assembled in both the CSEE and Hub programs to serve as members of a Professional Learning Committee (PLC). A goal of the PLC was to share and unpack the "in trench" issues being faced with adopting CS into their curriculum. The grants programs included two cohorts of teachers, year one and year two. Each cohort had a total of 50 teachers from 11 school districts with a 30% attrition rate between the two years. Six teachers were identified to participate in State level PLC with teachers from across the state.

In addition to monthly meetings and working sessions, training workshops with faculty from Montclair State University and industry professionals were also provided. Workshop duration varied from 2-hour evenings, 4-hour morning sessions, and 6-hour or full day sessions. 11 required meetings (one hardware event and 10 PLC collaborative meetings) were held each year. Additionally, between the CSEE and Hub programs, over 50 public facing professional development events were held each year, and these participants could elect to attend those and get preferential registration. PLC members were required to interact with higher education faculty and industry experts in Computer Science and Education, generate lessons, give feedback on challenging lessons, and do lesson studies. Additionally, more funding was provided if teachers agreed to perform these lessons in the classroom and allow CSEE and Hub personnel to observe them teach. All teachers received computing hardware kits and classroom resources for the lessons.

Over the two-year period, participants examined the NJCSDC, clarified language within the standards, generated lists of key vocabulary words and terms, gathered Slide Decks from workshop presenters, and then revisited the road map developed by MSU. These steps helped explain content migration from Grade K through 12. The wealth of somewhat disjointed information became the inspiration for development of the library of teacher resources described below in Section 4.

4. The Development of Teacher Resources

Instructional resources are organized by grade bands K-2, 3-5, and 6-8. Materials are aligned to the NJCSDC and include the following: (1) instructional videos and teacher notes, (2) slide deck presentations, (3) pre- and post-tests, and (4) word wall posters. All materials are available for free at the Montclair State University K-12 Computer Science Education.

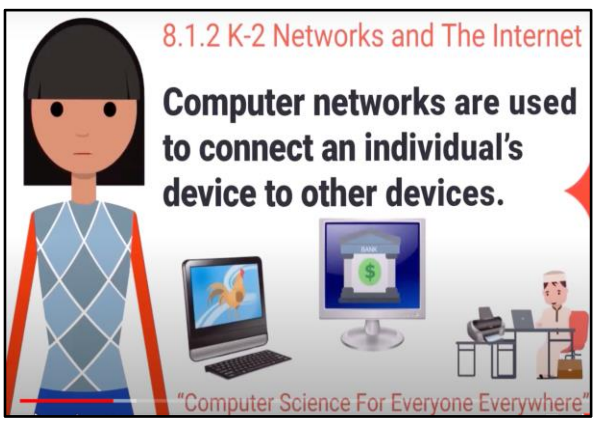
4.1 Teacher Instructional Videos and Teacher Notes

Storyboards aligned to the New Jersey CSDC were generated then used to create a script. Scripts and voice narrations by PLC teachers were translated into videos using Canva.com, Toonly.com and Camtasia Studio. Each video was divided into an overview of the content, preparation for instruction in the classroom, and scaffolding for students at different levels. Videos can be viewed in sections or as a whole. The partitioned approach affords teachers an opportunity to examine or refer back to individual parts instead of the entire video. The intent is to provide a readily available, accessible resource for ongoing training.

The content of all subsequent videos were reviewed by the teacher-narrator, PLC workshop participants made up of teachers and administrators, and MSU faculty and staff. Figure 1 below provides a screenshot of a frame from the K-2 Networks and the Internet video.

A video library along with a Teacher's Notes text document aligned to it exist on the MSU website for each grade band for the following topics, *Computing Systems*, *Networks and the Internet*, *Impacts of Computing*, *Data and Analysis*, and *Algorithms & Programming*.

Figure 1. Instructional Video Snapshot



4.2 Slide Deck Presentations

Slide Decks were developed for teachers and students. These modifiable presentations, aligned to the NJCSDC provide a structured approach within which to learn and teach computer science material. Each presentation includes a description of the standard, review of key vocabulary words and concepts along with real-world examples. Figure 2 below shows a screenshot of one slide (produced in Google Slides) from the K-2 Impacts of Computing presentation. The image explains and provides an example of the central concept of standard IC 8.1.2 *Impacts of Computing* (IC).

The Slide Decks can be modified by expanding or contracting content, adding activities (questions, writing tasks and drawing exercises), and shifting information between grade bands; whatever is needed to meet the needs of learners. Lastly, automation of the presentations for asynchronous learning can be accomplished using most learning management systems.

Figure 2. Slide Deck Screenshot

4.3 Assessment Pre/Post Test

Each Slide Deck has a companion Pre/Post Test created using Google Forms which is also modifiable. It can be used to assess what students already know (Pre Test) and what they have learned at the conclusion of the segment (Post Test). Each assessment covers beginning, intermediate, and advanced topics. The formative assessment is intended as one measure to evaluate CS content knowledge.

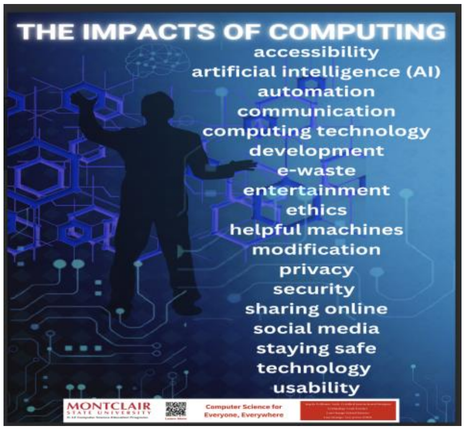
4.4 Word Wall Posters

A common teacher and student classroom resource is a word wall. This tool serves as a visual cue and reminder of relevant content and terms. The CS word wall concept was developed first, during initial reviews by PLC and workshop participants for each grade band. The completeness of these lists were checked using Artificial Intelligence (AI). For example, a prompt "Examine the NJ Student Learning Standards CSDC for computing systems and provide a list of keywords and terms that students should know by the end of second grade" provided an expanded view of the terms to include for a final draft of a word wall poster.

The fourth and most demanding step entailed scrutiny of the resulting list to determine what additions and modifications were needed to accommodate knowledge gaps that might impede student learning. One source of terms would be implied knowledge, such as components of other terms, either in their general ("system" from "computing systems") or specialized ("architecture" from "computer architecture") meanings. Another would be knowledge extension, terms needed from other disciplines or domains: for example, if a data table is to be generated and statistical analysis applied, then mathematical terms such as sum, difference, average, mean, and mode would be added to the vocabulary list. This step generated a third draft vocabulary list.

The final step involved user review. A final draft of the word wall was shared with program participants (school administrators and teachers) during meetings and workshops. Comments and suggestions were discussed and the resulting modifications incorporated, yielding a final list for each disciplinary concept and grade band. These were then used to generate word wall posters, direct the focus of teacher instructional videos and development of both the Slide Deck and accompanying assessment. Figure 3 depicts a word wall post for the 3-5 grade band.

Figure 3. Impacts of Computing



5. Evaluation of Survey Data

A survey evaluating the curated resources was distributed to participants of the PLCs and professional development sessions. This section reviews the format, questions, responses and major takeaways from the information gathered.

5.1 Survey Format

Google Forms were used to construct, disseminate, and collect data from survey participants. Thirty-seven (37) responded (12 for grades K-2), 15 for grades 3-5, 6 for grades 6-8, and 4 for grades 9-12). Personal data related to ethnicity, gender, name, school district, and years of experience were not collected.

5.2 Survey Construction And Questions

Twelve (12) questions were designed to elicit feedback on curated resources based on the format, effectiveness, relevance of content, recommendations for changes, and suggestions for additional resources. Questions 1 through 5, and 7 through 9 implemented a five-point ordinal scale (strongly agree, agree, neutral, disagree, strongly disagree). Question 6 implemented categorical yes/no responses, and Question 10 contained a three-point ordinal scale (Likely, Neutral, Unlikely). Question 11 included a 3-point ordinal scale. Participants were asked to watch two videos, one from Grade K-2 and the 3-5 Computing Systems video. See Table 1 below for a list of questions and survey data for strongly agree and agree.

Video resources and other materials examined by survey participants were well received. Seven out of ten questions had a 90% favorability rating or higher. All questions were rated 75% favorable or higher.

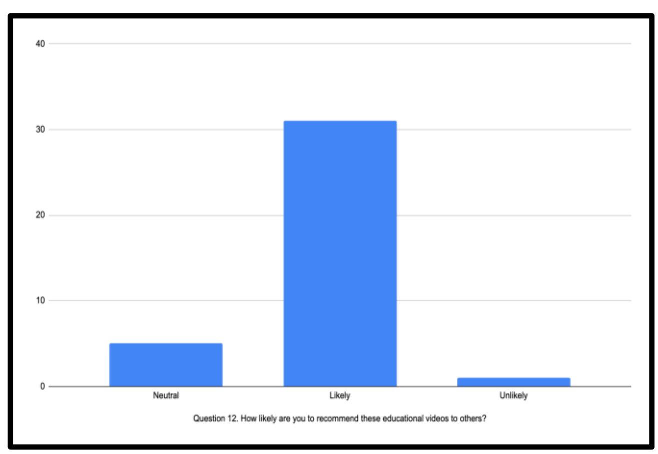
As evidenced by responses to Question 11, Participants indicated Pre/Post Test assessment as the most important resource at 38%, followed by Word Wall Posters at 35%, and Slide Decks at 27%.

Table 1. Survey Question Data

Question	Strongly Agree	Agree	Favorability Rating
1. The video effectively explained the main concepts or topics.	57%	41%	**97%**
2. The visuals and graphics used in the video were helpful in understanding the content.	54%	38%	**92%**
3. The video maintained my interest throughout its duration.	32%	51%	**84%**
4. The examples and illustrations used in the video are clear and relevant.	57%	34%	**91%**
5. The 3-5 Computing Systems presentation contained useful and relevant information.	63%	28%	**91%**
7. The 3-5 Computing Systems word wall contained useful and relevant information.	44%	44%	**89%**
8. The 3-5 Computing Systems resources are useful and relevant.	58%	32%	**90%**
9. These types of resources should be developed for all grade bands.	68%	27%	**95%**
Question	**Just Right**	**Too Long**	
6. The 3-5 Computing Systems, Lesson Plan contained useful and relevant information?	78%	22%	
Question	**Likely**	**Neutral**	**Unlikely**
10. How likely are you to recommend these educational videos to others?	84%	14%	2%
Question	**Word Wall Posters**	**Slideshow Presentations**	**Pre/Post Test**
11. Aside from the video content, which is near completion, what resource is most important to you?	35%	27%	38%

Question 12 asked participants how likely they are to recommend the educational videos to other teachers. The results are displayed below in Figure 4. Recommendation of Videos.

Figure 4. Recommendation of Videos



Of the participant pool of 37 people, 31 or 84% selected “Likely” to recommend the video resources to others. Five (5) or 14% remained “Neutral” and 1 person or 3% selected “Unlikely”.

Finally, responses to Question 13 provided additional qualitative information documenting the extent of participants' satisfaction with the professional development presentation and materials. Comments included, but were not limited to the following: “Impressive”, “easy-to-use/user friendly”, relevant information is “short and concise”,” very explicit and engaging”, etc. Perhaps most telling was the participant who commented, “Your resources are amazing, and your wealth of knowledge will help create meaningful lessons for the students.”

Question 13 also provided important constructive feedback that the authors addressed or intends to address as they complete the next round of revisions. Some feedback concerned the presentation itself:

- “The need for the speaker to better modulate their voice, speak slower, and to allow more time for viewers to process information.”
- “Break down the materials into grade bands and have teachers start with an examination of their own band to keep them focused and prevent cognitive overload.”
- “Some videos should be broken into smaller chunks to assist with learning the content. “
- “...create and share resources for [each grade band] in order from Pre and Post test then Vocabulary word wall, then Presentations.”
- “Provide options beyond Google Translate or relying too much on other students to support those who are emergent and developing English language learners.”

The above data and feedback have assisted the authors in developing a better understanding of the complexities of creating Universally Designed computer science-related learning experiences for teachers and students. As indicated above, some of these issues have already been partially addressed and more work remains to be done.

6. Conclusions and Future Work

This paper discusses one ongoing effort by the MSU Hub/PLC to provide a comprehensive, online library of resources aligned to the NJCS disciplinary concepts. The library was designed to build confidence in CS content and CSPCK for teachers in Grades K-8. These resources represent a first step toward expanding the ways teachers access and acquire content for self-learning and classroom instruction.

Key takeaways from this experience are consistent with takeaways from referenced materials; specifically (1) The need for continued professional development, mentoring, and coaching. (2) Unpacking State standards to explain the organizational structure and how they flow from the beginning to the end, to tell the story of computer science for elementary teachers is essential to developing a complete picture of what is to be taught and why. (3) Teachers as adult learners must be given a variety of learning tools aimed at increasing their CS content and CSPC in order to understand and retain educational mandates in forms that are easily comprehensible.

The following results were also revealed as key takeaways from this exercise; specifically (4) Resources that are easily accessible and with modifiable content are more likely to be used. (5) Providing educational videos, Slide Decks, Pre/Post Tests, and Word Wall Posters, are extremely helpful, especially for K-8 teachers. (6) These resources will also be important to the SIGCSE community because they can be used or modified by teachers and school districts anywhere.

This report presents a snapshot of the possibilities of resources that can be developed and seamlessly incorporated for teacher professional development and in-class use. There are three areas that require additional work in order to expand the depth and breadth of this work. Each area is discussed in more detail below.
Demographic information of the teacher group used to create resources must become part of any future work. Future surveys must take into account a teachers’ gender, ethnicity, school district, student population, and experience. This type of data will ensure equitable representation across our society and a better description of the computer science teaching workforce.

Post-use surveys and follow-up feedback must become part of any future work. Accessing the viability and usefulness of resources after they have been used would go far in evaluating long term professional development needs including the type of ongoing support and coaching teachers will require. It can also aid in future attempts to direct monetary resources in the direction which are most beneficial. Finally, future work should address updates in all disciplinary concepts plus artificial intelligence for all grade bands.

Recommendations to consider include the following.

1. Tailor CS teaching with Universal Design for Learning (UDL) to meet the needs of increasingly diverse learners and learning communities.
2. Community outreach includes staff development at state, regional, and district levels to increase awareness, use of, and comfort with, these open access resources. This will also provide additional, continuous feedback for refinement and extension of these materials.
3. States need to emphasize attention to and funding for sustained coaching and mentoring of novice and in-service teachers.
4. Build upon and grow new partnerships with institutions of higher education and industry to provide multiple opportunities for interdisciplinary activities that involve the expertise of educators, scientists, administrators, and families. F
5. Focus on preservice teachers by integrating CS content and CSPCK into teacher education courses and programs, or the development of tracks and additional service courses.

Expand preparation of how to teach students about the real-world implications of CS by extending this work into other applications. With NSF RET grant support through MSU, the principal author and others are studying the intersection of solar weather, computer science, and data science and its pedagogy for grades 6-12 and community college instruction. Extreme solar weather events have increased impact due to society's and the economy's increasing reliance on computing, technology, and electronics, affecting communication, transportation, and computing. But these events can be anticipated and mitigated, or their consequences addressed (impacts of computing), via satellite observation (computing systems, networks) and sophisticated analysis of those observations combined with historical data (algorithms, data and analysis, artificial intelligence).

All materials developed for this project, as well as further discussion of the survey results, can be found at the Montclair State University K-12 Computer Science Education website [13].

7. Acknowledgements

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

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