Paper ID #26217

What Can We Learn from a Research Experiences for Teachers (RET) Site? Three Perspectives on Big Data and Data Science

Dr. Stephanie Boggess Philipp, University of Louisville

Dr. Philipp is an assistant clinical professor in the Department of Middle and Secondary Education at the University of Louisville. She spent eight years as a project manager for various environmental and geophysical exploration firms and then as many years as a middle and secondary science teacher in chemistry and physics. She is a liaison between the Center for Research in Mathematics and Science Teacher Development and the Center for Teaching and Learning in Engineering at the University of Louisville. Her research includes studying changes in science and engineering teacher practice, best practices in teacher professional learning experiences, teacher and student learning in mathematical and computational thinking, and the use of undergraduate learning assistants in introductory STEM coursework. Address: Department of Middle and Secondary Education, Porter Building, University of Louisville, Louisville, Kentucky 40292 Phone: 502.852.3948 Email: sbphil02@louisville.edu

Dr. Jason Immekus, University of Louisville

What can we learn from a Research Experiences for Teachers (RET) site? Three perspectives on Big Data and Data Science

Stephanie B. Philipp, Olfa Nasraoui, and Jason Immekus
University of Louisville
College of Education and Human Development & J.B. Speed School of Engineering
Louisville, KY 40292
stephanie.philipp@louisville.edu
olfa.nasraoui@gmail.edu
jason.immekus@louisville.edu

Abstract

This paper will share initial findings from the first year of a Research Experience for Teachers site, supporting nine secondary STEM teachers from diverse schools in six-week university research projects in socially impactful Big Data and Data Science. We have examined the perspectives on learning of three key site groups: the computer scientist principal investigator, the secondary STEM teachers participating in the RET, and the graduate research assistants who mentored the teachers in original research projects. Teachers also translated their research experience into curriculum incorporating the engineering practice of mathematical and computational thinking and described the lessons they learned from the research process through focus group interviews, seminar presentations, and lesson plans. Preliminary findings suggest each of the site groups saw their own work and their role in that work, from a different perspective. Members of each group found themselves in the role of a novice in another field and enjoyed the challenge that being a novice represented.

Introduction

The breakneck pace of technological innovation and data-centered operations have led to an explosion of data, along with related applications, amenities, and human-machine interaction. This abundance of data has given rise to a booming ecosystem of "Big Data" algorithms and applications that can discover patterns and relations between different phenomena to make predictions and forecast the future. The analysis of large amounts of data from diverse sources promises new insights into relationships and interactions between humans, the environment, and the myriad of physical entities or Internet of Things (IoT) [1]. Analysis of Big Data can reveal new knowledge for decision making in healthcare, education, scientific discovery, finance, policy, journalism, and environmental science, etc. [2]. Furthermore, as more humans become consumers of -and are affected by- Big Data algorithms, bias, transparency, and flexibility are important considerations in Big Data research.

Moreover, as Big Data penetrates through all the parts of society, Big Data problems often arise in diverse disciplines, not just the computing field. In particular, the data-enabled approach is revolutionizing the way that scientists and engineers practice, understand, and make discoveries in diverse disciplines. This means that Big Data can have a significant impact on all STEM subjects. Therefore, Big Data, with its myriad socially relevant applications and interdisciplinary reach, is a good way to interest students and teachers in computer science as a discipline and in Computational Thinking (CT) as a powerful problem-solving approach.

Across all scientific and engineering disciplines, Computational Thinking (CT) is a core practice essential for understanding and explaining scientific concepts and designing solutions to engineering problems. CT is a key component of K-12 mathematics standards [3], and K-12 Science standards [4], as well as a recognized competency for both the International Society for Technology in Education (ISTE) and the Computer Science Teacher Association (CSTA) standards [5]. Unfortunately, the development of CT in K-12 students is not well understood and is infrequently assessed [6] [7].

CT has been characterized as a problem-solving process by ISTE with the following attributes: finding patterns in data, breaking a problem down into smaller parts, using technology to automate the problem-solving process, strategies for organizing and searching data, creating algorithms, and using and developing new simulations of a wide variety of natural and designed systems to make predictions, solve problems, test solutions, support claims, or craft scientific explanations**.** To be a successful computational thinker, ISTE members have agreed on the development the following dispositions: confidence in dealing with complexity; persistence in working with difficult problems; tolerance for ambiguity; ability to deal with open ended problems; skills in communication and working with others to achieve a common goal or solution [8].

The Next Generation Science Standards (NGSS) vision for science education is that students cannot deeply learn scientific and engineering concepts without engaging in the practices of inquiry and discourse that helped to develop those concepts. The NGSS performance expectations require that all students engage in the eight science and engineering practices, such as mathematical and computational thinking, over each grade band and recommend that the practices become more complex and sophisticated across the grades. By aligning teacher pedagogical activities to the NGSS, National Council for Teachers of Mathematics (NCTM), and ISTE standards, we are working with teachers to shift their instructional practices towards deeper science and mathematics learning for all students and also making university faculty and graduate students more aware of current performance expectations in high school science, technology, engineering, and mathematics.

Current research on computational thinking in grades K-12 includes studies on ideal computational thinking learning environments. For example, Repenning, Webb, & Ioannidou [9] found that effective computational thinking environments and tools for school children should be easy enough to start using right away, yet powerful enough to satisfy the needs of more advanced learners. The tools should scaffold to build skills and knowledge, support equitable use, enable transfer of skills, and be sustainable. Sengupta, Kinnebrew, Basu, Biswas, and Clark [10] developed a theoretical framework for integrating computational thinking and programming into K-12 science curricula. This framework lays the groundwork for the development of a long-term curricular progression in which students can engage in learning science using computational modeling and thinking over a span of multiple years. Grover and Pea [11] have summarized recent research in computational thinking with school-aged children and have identified several gaps in the field. They recommend bringing the cognitive science of how people learn into discussion, as well as the idea of computing as a teaching medium for other subjects. Moreover, there are many questions about the dispositions for, attitudes toward, and stereotypes concerning computational thinking and how they connect to stronger learner identity. Investigating differences between how males and females develop computational thinking is also needed, as well as the trajectory between novice and expert computational thinking. Very little research has been published on how teachers learn to incorporate computational thinking into their content.

Project Activities

We envisioned a professional learning experience for secondary STEM teachers that would provide an authentic research experience in data science. We also wanted to help translate that experience into high quality curriculum that incorporates the practice of Computational Thinking. We were awarded a Research Experience for Teachers (RET) grant from the NSF Computer and Information Science and Engineering (CISE) directorate to fund this learning experience and have just completed summer activities and fall curriculum implementation with our first cohort. This paper will describe our initial findings from our first year. We examined the perspectives on learning of three key RET Site groups: the computer scientist principal investigator (PI), the secondary STEM teachers participating in the RET, and the graduate research assistants who mentored the teachers in original research projects.

A month before the summer research experience, RET teachers were introduced to the five possible research projects and given a lab tour by the mentoring faculty. After the introduction to the projects, teachers submitted their top three project choices and reasons for their choice via Google Form. All ten participating teachers were able to join their first or second choice project. During the first week of the summer research experience, the PI planned two weeks of training to step through the most common and crucial foundational concepts (e.g. classifiers) and hands-on skills and tools (e.g. Python's scikit learn Machine Learning library) for the projects, as needed by the cohort. The training also touched on coding, data acquisition, data management, classifiers, recommender systems, model evaluation through cross-validation, text mining tools. We adopted a blended online and offline learning program, previously used by the PI with novice data scientists. The training also included a final unit on ethical issues such as privacy, bias and fairness issues in Big Data, as well as issues of implicit bias, all of which are important in computing. Post-orientation, teachers continued to polish and learn new specialized foundational concepts progressively within their hosting research groups as needed. They also participated in optional additional training on more advanced topics that were decided upon by the teachers, on demand. This included Deep Learning.

The faculty member heading up each research project served as the teacher’s formal supervisor, and along with designated graduate student mentors, they interacted with the teacher on a periodic basis. The designated student mentors additionally interacted with the teacher on a continuous basis every day in their lab. Just as important, the teacher also interacted on a daily basis with the faculty members’ research group, consisting of undergraduates, graduate students, post-doctoral fellows, and research engineers who were present in the lab. All RET teachers participated in their own faculty member’s weekly group meetings and lab seminars to be truly integrated and paired with the students engaged in research in the labs. In addition, weekly social activities, such as snack and game times as well as weekly seminars, including all participants in the RET were organized. These social activities gave the teachers a chance to get to know each other and to experience fun activities together outside the work requirements. Planned social activities also gave teachers an opportunity to process and make meaning of their work with others outside of their lab groups.

The teacher research projects selected for our program are listed in Table 1 below. The list of interesting projects reflects the interdisciplinary nature of the topic of computational thinking, while leveraging the diverse pool of faculty expertise at the university. After completing the 6-week (approximately 180 hours) summer research program, each teacher's goal was to have a solid appreciation for the relevance of computational thinking practices as well as engineering design principles connected to this theme. Most projects accommodated two teachers, with each teacher having an individual research objective or question related to the bigger project.

TABLE 1. RET SITE: SUMMER 2018 PROJECTS

Research Project Name	Research Question/Design Problem
Project 1: Big Data for Adaptive Conversational Robotic Assistants	What are the foundational concepts of chatbot design, text mining, and algorithm design to process data sources that form the basis for the dialogue content?
Project 2: Humanizing Big Data Predictions: Explainable Recommendation Algorithms	What are the foundational concepts that form the building blocks of designing and evaluating an accurate yet explainable recommendation system?
Project 3: Big Data for Visualization	How can we research, test or modify the design of technologies to visualize, analyze and predict statistically reliable "events" and "event spans" within and across multiple time series data?
Project 4: Big Data for Humanitarian Aid: Landmine Detection	Develop and test algorithms to represent, analyze, visualize, and mine large multimedia databases to detect buried explosive devices, such as landmines and improvised explosive devices (IED).
Project 5: Big Data Energy Efficient High-Performance Computing	Can replication and storage device heterogeneity be exploited to reduce the energy consumption of data centers without significantly affecting performance?

Teachers developed lesson plans (teacher guides and student lessons) and curricular materials to create an entire unit based on their research experience. After piloting these units with students and receiving student and observer feedback, teachers will update materials with necessary edits and will post materials in the TeachEngineering library. We plan to directly share the teacher developed curricular materials with other teachers in each of the school districts from which we will recruit. In addition, teachers will attend and present their work in the form of workshops, posters or talks at state/regional conferences. We are also supporting teachers to submit practitioner journal articles in refereed science and engineering teacher journals, such as National Science Teachers Association's *The Science Teacher* or *The Mathematics Teacher* from NCTM.

One of the most interesting lessons learned from the first year of this RET site was the changes in thinking about teaching and learning experienced by three key groups: the computer scientist faculty PI (2nd author), the secondary teacher participants, and the graduate students who worked with the teachers on their research projects. We collected multiple sources of data from each group to tell this story. The PI kept a journal of her thinking throughout preparation and implementation of the RET site this past summer. The first author (an education faculty researcher) also interviewed the PI about her thinking with a semi-structured interview. The PI also kept artifacts such as emails between the teacher, graduate students and herself to demonstrate her thinking over time. The teachers participated in focus group interviews with the project evaluator to talk about their experiences before, during and after the summer RET experience. They shared their weekly research seminar presentations which illustrated their thinking about big data, their curriculum ideas concerning computational thinking, and their experiences with their own learning during the research project. The teachers also shared pre and post RET lesson plans which provide evidence for their changes in teaching strategies. The graduate students were interviewed individually by the first author to find out about their perceptions of teaching and learning after the RET. The graduate assistants also contributed plans for working with the teachers before the RET began and those were discussed during the interview. This set of qualitative data was analyzed as a case study, with the RET Site as the unit of study and the PI, Teacher and graduate students as subunits of study.

Computer Scientist Perspective

The PI thought it was vitally important to know the RET participants as complex human beings with interests, passions, strengths and weaknesses. She began the first week of the RET experience with a set of 10 questions she shared in an open discussion with the teachers. The questions, crafted with help from the first author, elicited from the teachers their thoughts on their strengths and struggles as a teacher, the content that excited them, what new content they wanted to learn, and how they preferred to learn new knowledge and skills. The PI's emphasis on getting to know the teachers aligned strongly with the teaching philosophy of many of the teachers in the RET. The two middle school teachers in particular stressed that their students "did not care how much you know until they know how much you care." With knowledge of teachers' interests and personal connection to each teacher, this caring happened naturally for the PI. From the answers to these discussion questions, teachers shared important teaching concepts described below.

The PI found that working with experienced teachers was totally different from working with college level undergraduate or graduate students in that preferred ways of learning were different. According to the PI, undergraduate students have depended on being told what to do, reading about concepts, and then asking questions of the professor. In contrast, the teachers preferred to be oriented to the topic or problem, then jump right in and try things. The teachers were comfortable finding their own learning resources that fit what and how they wanted to learn. The PI discovered three formal educational concepts, that although she may have occasionally used in the past, were not part of a formal vocabulary or instruction method repertoire. Yet the teachers used and referred to these concepts frequently, and they ended up becoming essential to use in the training sessions. The first was "chunking" -- breaking down complex information into smaller, more manageable pieces for learning. The second concept that teachers thought about in relation to this project was the explicit teaching model of "I do, we do, you do." This gradual release of responsibility model [12] was found to be an effective way to support student learning through teacher modeling a skill (I do), guiding student work with similar problems until students show understanding (we do), then turning over responsibility for the skill for the students to do themselves (you do). The third concept that teachers thought about was differentiation or consideration of learner variance in instructional planning and implementation. The PI was able to incorporate these three new skills into her own work with the teachers and saw for herself how effective they were for learning. The teachers were pleasantly surprised that they had taught the PI new skills that she, in turn, incorporated immediately and transparently into her introductory orientation work with them.

Teacher Perspective

The teachers started the RET experience self-admitting very little knowledge of Big Data and data science. One teacher described data science as a process where you "mine, refine, and interpret". Another saw Big Data as "big, a lot of it, coming at you fast, complex, and not necessarily being associated with each other or having patterns in it." When asked about their understanding of computational thinking at the beginning of the experience, teachers gave a wide spectrum of answers. Two teachers shared that they really had no idea what computational thinking was but knew that their academic standards required that it be taught. Other teachers related computational thinking to being able to use computers and program them. Still other teachers defined computational thinking as a problem-solving skill that could be used in their courses or across the curriculum. At the start, teachers in this project admitted to feeling like their own students must feel at the beginning of many lessons: unsure of the knowledge and skills being introduced, uncertain of the importance of what they are about to learn, and struggling to fit the new information into their existing knowledge framework.

The 6-week RET experience encouraged the teachers to learn computer science content that related to their chosen research and design project. All teachers reported learning basic programming skills in a variety of languages depending on their assigned projects and labs (Python, R, Matlab) and gaining a more authentic idea of how the engineering design process works. All teachers could connect content and processes that they learned in their research project to the subjects that the teachers taught in their own classrooms. The math teachers in the cohort reported that they have a more profound understanding of the content that they teach and are now able to better answer the timeless student question: Why do we need to learn *this* in math class? The science teachers had a greater understanding of engineering as a whole, which filled a gap for these teachers who are also expected to teach engineering concepts in order to meet the NGSS. Not surprisingly, the computer science teachers made the most direct connections between their RET experience and their curriculum in AP Computer Science courses.

From analysis of the teachers' final seminar presentations, we saw that the teachers came to understand that computational thinking does not necessarily involve computers but does use a knowledge of methodical human thinking. Teachers shared examples of computational thinking that they were going to add to their curriculum, based on what they had learned during the RET experience. Examples of new lessons included unplugged algorithmic thinking in the form of directions to make a sandwich; bin packing exercises; relating the engineering process and its iterative nature; using Google Collaboratory to collaboratively write computer code that will help create a machine learning-based recommender system for a student-designed project; have students discover for themselves the relationships between a function and its first and second derivatives using new graphing software; using tablets to generate and collect light data, then graphing the data to create a mathematical model; using a recommender system as context for teaching matrices and matrix algebra; and training inexpensive chatbots from Amazon and

Google. Based on their RET experience, the teachers also concluded that lessons using computational thinking are best developed as experiences that solicit student input and interest.

All but one of the teachers had five or more years of experience in STEM teaching and all had communicated an interest in science or engineering and a passion for teaching. Few of the teachers had any research experience and none had engineering design experience. The teachers learned that the research and design process is not linear, but is iterative, involving open-ended problem-solving and learning from failure. These are learning experiences that teachers rarely create for their students, especially with the common use of procedural "cookbook" laboratory activities or worksheet-based mathematics practice. The teachers came to value their intense learning experience during this RET and, with the first author, crafted a six-stage instructional plan to replicate this type of learning with their students. Briefly, the instructional plan started with an **orientation** to a problem or phenomenon, then allows students time and space to **explore** the problem. After a period of student-led exploration, students **debrief** with each other about their initial findings and then craft questions to investigate or identify small problems to work on. The students **plan and carry out** an experiment or design solution, knowing that results from these activities may involve a reiteration of past steps. Finally, the students **analyze** their results and **communicate** their findings to others. Teachers submitted lesson plan ideas at the beginning of the RET that took on a variety of forms. Many of these initial lesson plans, aligned with academic standards, were little more than sequences of activity. Post RET, the teachers' lesson plans followed the above structure, which aligns with best practice STEM teaching [13].

Graduate Student Perspective

The graduate students were pleasantly surprised that the teachers they mentored could be "pushed"—that is, the teachers welcomed the challenge of learning new content and skills and they diligently searched for and found resources to meet their own learning needs. The teachers were willing to try new things: resources, tools, and ways of communicating. They were good at switching into "student mode", which meant seeing things from a student perspective. The teachers considered the following questions as they were thinking through their own research project: How would students learn this concept? What would they struggle with? In what ways and when could this concept be presented?

The graduate students and faculty mentors carefully developed a week by week research plan for the teachers. This planning indicates that the graduate students highly valued the research and design process and this importance was communicated to the teachers. In the graduate students' opinion, the teachers gained "programmer thinking" -- that is, they were able to break a problem into smaller, manageable problems (decomposition) in order to analyze and solve the problems using a design, test, and debug method. The teachers initially thought this was how novice computer scientists worked, but after observing the work habits of the more expert graduate students, the teachers realized that expert computer scientists also design, test, and debug. The teachers came to understand that computer science work starts with how people think and that using computers for this initial planning and thinking is not necessary.

The graduate students learned how demanding it is for teachers to take their new learning and fit it into the state academic standards that they are required to teach children. They can't just teach anything they want—it has to fit into the prescribed standards for the courses and grade levels they are responsible for teaching. This was a realization by the graduate students about the U.S.

education system that they had not considered before working with teachers, because many of the graduate students completed their pre-college education outside the U.S. The graduate students also learned to be better mentors during the summer RET experience. They were reminded of what it is like to be a novice and need a clear explanation of fundamental concepts. They developed their explanation skills to be more coherent and flexible, meeting the learning needs of each teacher. They also experienced the reward most teachers appreciate: seeing their student progress in their learning and lose their fear of "doing" computer science.

Conclusions

The RET experience allowed each key group, PI, teachers, and graduate students, to see their own work and their role in that work, from a different perspective. The PI discovered new ideas from her "students" (the teachers), the teachers found themselves in the role of student and discovered how computer scientists and engineers actually work, and the graduate students discovered how teachers think about learning and the nature of the job of a U.S. teacher. All of these groups experienced the feeling of being a novice: the PI was a novice teacher professional development leader, the teachers were novice computer scientists, and the graduate students were novice mentors. Notably, these groups, who are expert in at least one field, reported enjoyment in being a novice in another field. All three of these groups were strong examples of self-directed learners who were supported by the open and collaborative environment of the RET. By the end of the 6-week RET experience, all groups felt they had gained new knowledge and skills, that made them, if not expert, then competent practitioners.

Future work may include investigation of any connections between the self-directed learner characteristics of these groups and the use of educational technology or increased competency in the data science technologies that are the focus of the research experience. Future work will also include quantitative evaluation of lesson plans and classroom implementation for evidence of increased practice in computational thinking and more student-centered, inquiry-based lesson plans.

References

[1] S. Chen, H. Xu, D. Liu, B. Hu, & H. Wang, "A vision of IoT: Applications, challenges, and opportunities with China perspective," *IEEE Internet of Things journal*, vol. 1, no.4, 349-359, Aug. 2014.

[2] D.E. O'Leary, "Artificial intelligence and big data," *IEEE Intelligent Systems*, *28*(2), 96-99, Mar., 2013.

[3] National Council of Teachers of Mathematics, "Principles, Standards, and Expectations," *nctm.org*, 2000 [Online]. Available: https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Principles,-Standards,-and-Expectations/ .[Accessed Jan. 20, 2019].

[4] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2012. [Online]. Available: https://doi.org/10.17226/13165.

[5] International Society for Technology in Education (ISTE), “ISTE standards,” *ISTE.org*, 2019. [Online]. Available: https://www.iste.org/standards. [Accessed Jan. 20, 2019].

[6] S. Basu, G. Biswas, P. Sengupta, A. Dickes, J.S. Kinnebrew, & D. Clark, “Identifying middle school students’ challenges in computational thinking-based science learning,” *Research and Practice in Technology Enhanced Learning*, vol. 11, no. 1, pp. 13-25, Dec., 2016.

[7] K. Brennan, K., & M. Resnick, ”New frameworks for studying and assessing the development of computational thinking,” *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada*, vol. 1, p. 25, Apr. 2012.

[8] ISTE, “Operational definition of computational thinking for K-12 education,” *ISTE.org*, 2011. [Online]. Available: http://www.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf. [Accessed Jan. 20, 2019].

[9] A. Repenning, D. Webb, & A. Ioannidou, “Scalable game design and the development of a checklist for getting computational thinking into public schools,” *Proceedings of the 41st ACM technical symposium on Computer science education* (pp. 265-269). Mar. 2012.

[10] P. Sengupta, J.S. Kinnebrew, S. Basu, G. Biswas, & D. Clark, “Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework,” *Education and Information Technologies*, vol. 18, no. 2, 351-380, June 2013.

[11] S. Grover, & R. Pea, “Computational thinking in K–12: A review of the state of the field,” *Educational Researcher*, vol. 42, no. 1, 38-43, Jan/Feb. 2013.

[12] P.D. Pearson, & G. Gallagher, G. (1983). “The gradual release of responsibility model of instruction,” *Contemporary Educational Psychology*, vol. 8, no. 3, 112-123, Jul. 1983.

[13] M.R. Blanchard, & V.D. Sampson, “Fostering impactful research experiences for teachers (RETs),” *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 14, no. 1, 447-465, Jan. 2017 .