Establishing a Research Experience for Teachers Site to Enhance Data Analytics Curriculum in Secondary STEM Education

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Abstract

This paper introduces the background and establishment of the first Research Experience for Teachers (RET) Site in Arkansas, supported by the National Science Foundation. The Arkansas Data Analytics Teacher Alliance (AR-DATA) program partners with school districts in the Northwest Arkansas region to promote research-driven high school analytics curriculum and education to reach underserved students, such as those from rural areas. At least thirty 9^{th}-12^{th} grade mathematics, computer science, and pre-engineering teachers will participate in AR-DATA and work with faculty mentors, graduate students, curriculum coaches, and industry experts in a six-week RET Summer Program and academic-year follow up to develop and disseminate learning modules to enhance current curriculum, attain new knowledge of data analytics and engineering applications, and benefit professionally through the RET program activities. The learning modules developed will reflect current cutting-edge analytics research, as well as the development needs of next-generation analytics workforce.

Keywords

Data Analytics, Secondary STEM Education, K-12 Outreach, Research Experience for Teachers

Background

There have been recent and rapid advancements in engineering research on data analytics theories and methodologies, enabled and driven by smart and connected technologies, to maintain and improve our health, infrastructure, and communities [1]. Compared to the growth in analytics research, curriculum development in the K-12 and higher education environments are often much slower and do not reflect this growth [2]. Current curricular data analytics lesson plans for secondary schools mainly focus on the ready-to-use applications and resources such as Microsoft Access and Excel, while leaving out the deep understanding of the ideas and theories [3]. Others use infographics to teach data analytics to high school students [4]. There are also some efforts on developing data science courses for secondary schools [5, 6]. These courses are designed based on interdisciplinary approaches integrating mathematics, statistics, and computer science education.

Although there is a recent increase in studies focused on developing data analytics and machine learning curriculum for secondary schools, previous systematic review studies on related course development in K-12 education show that there are not enough resources to support data analytics education in the secondary school environment. Examples of such limitations include lack of teacher training and lack of systematic development to reuse in other systems [7, 8]. In addition, a disconnect exists between K-12 education and next-generation workforce needs in analytics [9]. In 2017, the Governor of Arkansas formed a Blue Ribbon Commission to Report on the Economic

Competitiveness of Computing and Data Analytics in Arkansas. Governor Hutchinson noted, "This is the next step in growing the computer coding initiative as it will allow our higher education ßinstitutions and workforce development agencies to address the specific needs of Arkansas companies in the computer science and data analytics sector [10]."

To address the urgent needs of incorporating modern analytics materials in secondary education, the investigative team at the University of Arkansas established the first Research Experience for Teachers (RET) Site in Arkansas in Fall 2020, supported by the National Science Foundation (Award # 1953733). The Arkansas Data Analytics Teacher Alliance (AR-DATA) Program will provide at least thirty 9^{th}-12^{th} grade mathematics, computer science, and pre-engineering teachers with transformative research experience thematically centered on data analytics, especially engineering applications towards smart and connected health, infrastructure, and community. Northwest Arkansas is strengthening the data analytics sector with support from various local organizations. The AR-DATA program aims to utilize analytics research at the University of Arkansas as well as analytics workforce in Arkansas. The teachers participating in the AR-DATA program will develop, implement, and disseminate analytics learning modules suitable for high school curriculum, reaching high school students in Northwest Arkansas.

AR-DATA Overview

The principal investigators of the AR-DATA program established the following mission and vision statements to strategically plan and operate the RET site with long-term sustainability.

Mission: The AR-DATA RET program is determined to promote research-driven high school analytics education, reaching underrepresented students and those in rural areas in Arkansas. AR-DATA will provide professional development opportunities for teachers to attain new knowledge in engineering, analytics, and pedagogies. AR-DATA is striving to establish partnership between 9^{th}-12^{th} grade public schools, the University of Arkansas, and industries to strengthen analytics research and develop next-generation analytics workforce in Arkansas.

Vision: The AR-DATA RET program is to become a nationally recognized RET program in training and facilitating 9^{th}-12^{th} grade STEM teachers in research and curriculum design, reflecting continuous engineering and technology advancements in analytics.

The design, implementation, and management of the RET site will be undertaken according to the following three objectives.

Program Objective 1: Curriculum Development: RET participants will develop and promote modules to enhance current curriculum, guided by curriculum coaches and research mentors, to train the next-generation STEM workforce, reflecting state-of-the-art research on data analytics with applications in various engineering disciplines. Specifically, 10 RET participants each year over three years will (1) create curricula and learning modules on data analytics with engineering applications in health, infrastructure, and community, which will meet the Arkansas K-12 Computer Science and Math Standards, serving as a model for other states; (2) deliver and pilot developed modules in one of the following: mathematics, computer science, or pre-engineering; such modules can be for any high school 9^{th}-12^{th} grade students in Northwest Arkansas, including schools in rural areas and with significant minority populations; and (3) improve and disseminate

curriculum through the TeachEngineering digital library, the University of Arkansas Center for Math and Science Education, and various STEM-related conferences.

Program Objective 2: *Teacher Development*: RET participants will attain new knowledge of data analytics and engineering applications, gain a better understanding of the next-generation STEM workforce needs in data analytics, and learn innovative pedagogies and effective strategies from peers, mentors, and curriculum coaches. Specifically, RET participants will (1) involve and participate in cutting-edge research in data analytics mentored by engineering faculty and graduate student researchers, especially focusing on the concept of smart and connected health, infrastructure, and community; (2) observe and learn about the integration of research, industry applications, and teaching from research and industry mentors, and discuss ideas for potential real world applications for students in the classroom; (3) increase their understanding of data analytics applications in the public and private sector as well as the current and future needs for the analytics workforce, especially in Northwest Arkansas; and (4) share ideas, knowledge, and experiences in adopting effective strategies along with modules and teaching materials among peers, mentors, and curriculum coaches.

Program Objective 3: *Partnership Development*: All AR-DATA participants will benefit professionally through the RET program activities and achieve a long-term collaborative partnership between the University and public school districts in Northwest Arkansas. Specifically, RET participants will increase collaboration and networking opportunities through interaction with university faculty and graduate students, industry mentors, and RET peers. RET mentors and program team members will (1) establish a long-term partnership with 9^{th}-12^{th} grade educators and leaders and will visit the high school classrooms to observe module implementation and provide feedback; (2) visit with various teachers in the region to recruit additional participants and to disseminate existing modules; and (3) explore collaboration opportunities among mentors themselves and be motivated to develop and implement new pedagogies in their own classrooms.

Team Management

This RET site consists of six teams (i.e., program management, recruitment, curriculum, research mentor, industry, and evaluation teams) to ensure success.

The program management team consists of the principal and co-principal investigators. They oversee the RET site administration and management, activities planning and implementation, reporting and dissemination. Additionally, this team serves as the program point-of-contact for NSF. The program management team in conjunction with a curriculum specialist makes up the recruitment team. This team is responsible for program promotion and participant recruitment. They have decades of experience in recruitment and teacher development. The curriculum team consists of a curriculum specialist and a mentor-teacher liaison. This team has extensive experiences in K-12 education and integration of research into K-12 curriculum. The research mentor team consist of the principal investigator and the mentor-teacher liaison, who will facilitate communication between research mentors and teacher participants. From our previous experiences, such role is critical to the success of idea exchanges between teachers and professors. It ensures that consistent information is provided to all parties.

The industry mentor team consists of the principal investigator, the co-principal investigator, and an industry liaison. This team is responsible for industry mentor recruitment and management. Additionally, they facilitate all communication between the industry advisory board and participating teachers. The industry advisory board ensures that the teachers are learning and developing materials consistent with the needs of data analytics in industry. The industry advisory board meets each spring with the following topics: (1) The PIs will report the progress and findings of AR-DATA; (2) Representative AR-DATA participants will share their experiences and present their research and education components; (3) Representative faculty, graduate student, and industry mentors will share their experiences and provide views, concerns, and suggestions for AR-DATA; (4) The Board will discuss and prepare a brief recommendation report to the investigator team; (5) The investigators will respond and implement the recommended improvements in the following year. The results from the updated implementation will be reported in the following year.

The last team is the evaluation team. It consists of a program evaluator and the program management team. The program evaluator designed the AR-DATA evaluation methodology and instruments and will execute data collection instrument, analyze survey data, and provide annual reports on program outputs and implementation. The program management team will review the reports and timely act upon the evaluation outcomes, finding areas for improvement in the following year(s) of program.

Program Participants

AR-DATA targets at least thirty 9th-12th grade mathematics, computer science, and pre-engineering teachers from Northwest Arkansas, specifically teachers from schools in Benton, Madison, and Washington Counties. These three counties contain 23 districts in approximately 2,673 square miles. Table 1 summarizes the rural status (Yes/No) and race/ethnicity of the targeted school districts. The AR-DATA team determined rural status by using the Rural and Low-Income School (RLIS) Program classification [11]. Particularly, as highlighted in Table 1, Lincoln and West Fork are rural districts, while Springdale and Rogers districts have very high percentage of Hispanic population. Springdale also has a large Pacific Islander (Marshallese) population. The AR-DATA RET program strives to reach these underrepresented student population.

Table 1. Rural Status and Student Race/Ethnicity Distribution of the Targeted School Districts [12]

District	RLIS Rural	Race and Ethnicity							Total
		2+ Races	Asian	Black	Hispanic	Native American/ Native Alaskan	Native Hawaiian / Pacific Islander	White	
Bentonville	NO	712 (4%)	1092 (6%)	523 (3%)	1988 (12%)	232 (1%)	88 (1%)	12590 (73%)	17225

Farmington	NO	116 (5%)	16 (1%)	61 (2%)	216 (9%)	14 (1%)	2 (0%)	2086 (83%)	2511
Fayetteville	NO	643 (6%)	324 (3%)	1015 (10%)	1232 (12%)	56 (1%)	83 (1%)	6981 (68%)	10334
Huntsville	YES	54 (2%)	13 (1%)	10 (0%)	206 (9%)	19 (1%)	66 (3%)	1849 (83%)	2217
Lincoln	**YES**	37 (3%)	37 (3%)	14 (1%)	109 (10%)	40 (4%)	2 (0%)	890 (79%)	1129
Prairie Grove	NO	7 (0%)	21 (1%)	45 (2%)	99 (5%)	69 (3%)	5 (0%)	1750 (88%)	1996
Rogers	NO	370 (2%)	291 (2%)	262 (2%)	**7215 (46%)**	127 (1%)	253 (2%)	7086 (45%)	15604
Springdale	NO	301 (1%)	369 (2%)	523 (2%)	**10433 (48%)**	110 (1%)	**2846 (13%)**	7380 (34%)	21962
West Fork	YES	49 (5%)	10 (1%)	6 (1%)	56 (6%)	13 (1%)	0 (0%)	827 (86%)	961

Due to the unavailability of demographics distribution by grade, Table 2 presents the number of students and percentage by grade (targeted grade levels). The table also shows the homeless status and free-reduced lunch status in each school district. Particularly, Lincoln and Springdale districts have a high percent of students with free or reduced lunch and more families with low income.

Table 2. Student Population by Grade and Free/Reduced Lunch Status [12]

District	Total	Number (%) Students by Grade				Homeless	Free Lunch	Reduced Lunch	% Free-Reduced
		9	10	11	12				
Bentonville	17225	1300 (8%)	1328 (8%)	1265 (7%)	1144 (7%)	87 (0.51%)	2959	1022	23%
Farmington	2511	189 (8%)	200 (8%)	200 (8%)	183 (7%)	1 (0.04%)	598	187	31%
Fayetteville	10334	716 (7%)	782 (8%)	747 (7%)	712 (7%)	47 (0.45%)	3145	711	37%
Huntsville	2217	163 (7%)	179 (8%)	157 (7%)	161 (7%)	15 (0.68%)	1112	310	64%

Lincoln	1129	102 (9%)	94 (8%)	89 (8%)	99 (9%)	28 (2.48%)	585	205	**70%**
Prairie Grove	1996	148 (7%)	160 (8%)	142 (7%)	151 (8%)	14 (0.70%)	634	203	42%
Rogers	15604	1183 (8%)	1216 (8%)	1219 (8%)	1126 (7%)	53 (0.34%)	6897	1698	55%
Springdale	21962	1704 (8%)	1768 (8%)	1696 (8%)	1400 (6%)	87 (0.40%)	13166	2316	**70%**
West Fork	961	86 (9%)	80 (8%)	85 (9%)	60 (6%)	7 (0.73%)	347	166	53%

This data demonstrates that AR-DATA is targeting rural and underserved communities. The AR-DATA leadership team partnered with superintendents to recruit teachers. Additionally, they used teacher professional development listservs through the University of Arkansas Center for Math and Science Education.

Each interested teacher completed an online application to the program. Applicants described their initial needs for creating a module to help strength curriculum in computer science, math, and/or pre-engineering. Returning RET participants will also be selected based on their past participation and their goals to achieve in their second RET experience.

Program Design

AR-DATA program leaders designed it to engage participants in a year-long transformative experience, thematically centered on data analytics, which refers to the discovery, interpretation, and communication of patterns and connections in data that helps describe, predict, and improve system performance [13]. There are five main components of the program for the RET participants: (1) pre-program learning from and matching with research and industry mentors in the area of data analytics; (2) involving in appropriate research activities with a faculty and graduate student, and participating in the summer RET workshops on analytics; (3) extensively working on curriculum development during summer under the guidance of the curriculum coach team; (4) piloting, implementing, revising the developed curricular modules with support and guidance from a curriculum specialist; and (5) sharing and disseminating final curriculum via TeachEngineering.com, STEM-related conferences, and the AR-DATA Symposium.

The AR-DATA leadership team designed the pre-program program to allow RET participants to (1) have a better understanding of current analytics research from participating mentors and (2) better connect teachers' needs in standards-based modules with potential research projects and approaches. The team held several virtual presentations for the teachers to engage with mentors and the curriculum coach team. In fact, the participants went through three rounds of mentor matching. The helped ensure both parties would be able to contribute to the module development. Participants brainstormed during these meetings potential connections to standards to start thinking about how the research projects would connect to the required classroom content.

The summer program started with a week-long orientation to teach participants data analytics content, expose them to best practices in curriculum design, and demonstrate data analytics in industry through tours and discussion with industry partners. The AR-DATA RET participants chose from three research tracks: (1) smart and connected health for improved diagnosis and treatment, (2) smart and connected infrastructure for enhanced resilience and maintenance, and (3) smart and connected communities for healthier environment and daily life. Smart technologies, while enabling our surroundings to be more connected and informed, often generate big data that requires the use of analytics to be translated into meaningful information. Participants experienced how descriptive, predictive, and prescriptive analytics were applied and advanced to effectively use data for improved decisions. Participants started to meet with the curriculum coaching team around week 3 of the summer program. The participants used these meetings to review their current lesson plans and content with the curriculum coaching team to receive timely feedback. The summer program ended with the AR-DATA Showcase and additional industry tours with discussions. The AR-DATA Show was a time for all teachers to present their lesson plan ideas. All participants and the AR-DATA team including the industry advisory board were invited to provide feedback to help the teachers improve their modules before they implement them during the following school year. This is also a time for potential future participants to join to learn more about the program.

RET participants are expected to pilot and implement the developed modules during the immediate academic year. The AR-DATA team will observe the content delivery and provide feedback to the teachers. The participants will then work with a curriculum specialist to refine their modules before disseminating and archiving. AR-DATA leadership will encourage participants seeking to enhance and expand their modules to re-apply to the AR-DATA program in the following year(s).

Program Evaluation

The AR-DATA program evaluator designed the evaluation plan to assess the implementation of the RET Site AR-DATA program activities and evaluate the success of program outcomes. This related to curriculum development, teacher development, and partnership development. The planned evaluation required project team decisions throughout the implementation and evaluation of the project activities.

To evaluate the developed curriculum, the evaluation team will use the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for science. The EQuIP Rubric, “provides criteria by which to measure the alignment and overall quality of lessons and units with respect to the Next Generation Science Standards (NGSS).” The rubric has four purposes: (1) review existing lessons and units to determine required revisions; (2) provide constructive criterion-based feedback and suggestions for improvement AR-DATA RET; (3) identify exemplars/models for teachers’ use within and across states; and (4) inform the development of new lessons and units. Program mentors will fill out the rubric for each AR-DATA RET.

The evaluation team planned to use pre-post surveys to evaluate teacher development. The surveys include questions to determine if participants experienced an increase in knowledge of data analytics and engineering applications, understanding of the next-generation STEM workforce needs in data analytics, and the innovative pedagogies and effective strategies from peers, mentors, and curriculum coaches. The surveys are administered electronically prior to the summer RET program (late May) and after the last week of the summer program (August).

An additional survey was designed to evaluate partnership development. In this survey, participants provided feedback on their partnerships with mentors and the data analytics global communities (i.e., industry advisory board).

Conclusion

The AR-DATA RET program seeks to address the lack of integration of data analytics research with associated engineering applications into 9^{th}-12^{th} grade mathematics, computer science, and pre-engineering curriculum. The learning modules developed because of this effort will reflect current cutting-edge research in analytics as well as the next-generation analytics workforce development needs. This program will provide a timely opportunity for high school teachers to experience innovative research in the era of transformational change with smart technologies connecting the world and our daily life. Moreover, this RET program will emphasize a teaming approach to provide a culture of communication and facilitate the success of idea exchange between teachers and professors. Particularly, instead of finding an area for module development based on the mentor's project, the program seeks to understand the teacher's needs for modules that will strengthen curriculum and investigate the applicability of research projects to standards-based modules. The appropriate matching between teachers and faculty researchers will ensure the success of module development. In addition, this program aims to effectively integrate research, real world applications, and classroom teaching through strong partnership and active engagement among university professors, industry mentors and external board members, and public school administrators and teachers.

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