BOSTON UNIVERSITY

DataNetSciK20: Data & Network Science K-20+ STEAM Collaborative

1. Broadening Participation: Challenge and Opportunity for Transforming Education

In recent years, there has been a radical shift in much of science, technology, engineering and mathematics (STEM) towards an emphasis on the application of computational, network, and data-intensive approaches to solving complex 21st century challenges associated with the changing environment, medical advances, shifts in agricultural patterns and urbanization, societal issues, and evolving notions of human wellbeing [1] [2] [3] [4] [5]. This movement coincides with a new interdisciplinary – and inclusive – STEM practice, establishing diverse communities and breaking down silos across scientific and technical domains [6].

This new approach to doing science has been called "The 4th Paradigm" and changes problem solving using computers from one that is analytic – one that "breaks apart" – to one that is synthetic, that identifies the patterns, dynamic activities, influences, and behavior exhibited by entire systems [7]. The skills needed by the 21st century STEM workforce will include the ability to: (i) interact with large quantities of data; facility with visual metaphors and granularity for both static and dynamic data streams in order to see patterns in complex data and (ii) understand the changing role of models; higher-order thinking associated with model development which allows both exploratory and inductive skills to be used to identify general patterns and characterize their behavior across a wide range of differing environments.

We believe that computational, network, and data-intensive approaches are key to building "4th Paradigm" or 21st century skills. Unfortunately, these advances are often inaccessible to disadvantaged young learners. Such lack of access sends students down a path devoid of opportunities to fully participate as innovators in our digital economy, thereby failing to close gender and racial gaps in STEM and leaving behind wide swathes of our population [8] [9]. Yet the opportunity for positive impact is enormous [10] [11] [12]. It is projected that by 2020, the United States will have 1.4 million computer science jobs with only 400,000 trained workers to fill those jobs [13]. Perhaps even more important is that computer science skills are sought by both employers in both STEM and non-STEM fields [14].

DataNetSciK20 aims to initiate a grassroots movement to transform the next generation of the STEM workforce to conduct a mode of thinking that differs markedly from that currently mandated by curricula and educational practice and effectively addresses systems and computational thinking, cross-cutting ideas, and complex problem-solving, as articulated in Common Core and Next Generation Science Standards, thereby driving US economic competitiveness, and bringing STEM education in closer alignment with STEM practice [15] [16] [17].

2. Strategic Plan: Collaboratory for K-20+ Smart and Connected Pipeline

We will catalyze, extend, unify and support collaborative alliances between public and private sector researchers, educators, and practitioners to help students move from navigators in a complex world to become empowered to make meaning and discover patterns in big data, find connections across networks, and gain understanding and propose solutions to real-world complex problems.

We envision evolving the imagery of an "education pipeline" towards a "common education playground" by cultivating a *K-20+ Smart and Connected Network* where *people* are connected through a data-driven collaborator – interrelated community partnerships and community impact approaches (*e.g.*, suite of training activities, research opportunities, mentorships, informal education, grade-specific curriculum, online collaboration portal). Such a network can have implications for career growth, advancement and development, building social capital and progress, personal growth and development, and empowering underrepresented communities. Such a network can synthesize K-12 STEM education outreach, STEM research, and undergraduate education. Such a network can lead to the realization of "high impact education," creating a "whole student" with core knowledge and skills, and adding real-world enablers and

the arts to truly open students' minds, unleash students' innate creativity, and move towards systems-level "big picture" learning [18] [19] [20] [21] [22] [23] [24] [25] [26] [27].

Boston University (BU), Education Development Center (EDC), and many partners* are ready for a smart-and-connected approach. BU is a microcosm of the larger societal challenge: It is big and as a result has myriads of initiatives and efforts that are individually quite successful, yet siloed. BU is fashioning its own vision for General Education around the idea of a capstone *Cross-College Challenge*, a collaborative experience that connects students from different colleges around problems motivated by contemporary issues by producing a tangible project [28]. With the vision in place, different BU constituents, including for STEM, have an incentive to work on positioning their individual pieces to cater to that vision. Our pilot can complement and enhance this existing initiative by creating a convening platform that supports smart-and-connected K-20 STEM education.

Building on the "NetSci High" NSF ITEST program - www.bu.edu/networks/ - we plan to launch an *Innovation Hub* or "common education playground" that joins underrepresented Boston-area high school students, undergraduate students, high school teachers, STEM and education graduate students, undergraduate faculty, and project staff. Members of this hub will embark on a 6-week summer immersion experience that: (1) motivates and teaches computational, network, and data-intensive skills, (2) inspires through high-profile speakers, workshops, career and education guidance, technology field trips, (3) mentors by team-based approaches to problem solving, (4) builds confidence by cultivating "soft skills" such as developing impactful presentations and public speaking, and (5) fosters creativity by integrating the arts and design. High school teachers and undergraduate faculty will mentor teams while also developing their own action research projects such as curriculum enhancements and after-school programs [29] [30].

Student teams will come out of the summer experience ready to begin working on yearlong data-driven projects that address real-world problems (*e.g.,* commerce, pollution, global health, *etc.*). Each team will consist of members from every stage of the pipeline (*i.e.,* high school students, undergraduate students, high school teachers, graduate students). They will work collaboratively at the *Innovation Hub*, as needed, but also through online collaborations, with high school teachers and graduate students providing core mentorships. Additionally, teams will have mentor support from the Boston University Global App Initiative (training students as mobile-app developers for non-profits), BUILDS (collaborative student technology projects), and other programs [31] [32]. At the end of the yearlong experience, we will assist in helping students in applying for and obtaining summer internships by involving industry and academic partners as volunteers.

At the undergraduate education level, our *Innovation Hub* will create a marketplace such that undergraduate courses can become more relevant and incentivize faculty to develop programs that can make them innovators in their field [33]. By using the lens of "4th Paradigm" science as a glue, we believe we can take an important step towards strengthening undergraduate and graduate education, contributing to undergraduate "general education" goals, and continuing to break down barriers between the sciences, mathematics, engineering and the arts at BU and elsewhere. Our *Innovation Hub* will serve as a platform for

* Partners include Boston Museum of Science, Center for Data Science at UMass Amherst, Cyberinfrastructure for Network Science Center at Indiana University, Network Science Institute at Northeastern University, and The New York Hall of Science; all with long-standing collaborations on many projects and initiatives. Our K-16 school partners include Boston Public Schools, Framingham State University, Holyoke Public Schools, Hudson Public Schools, Marlborough Public Schools, Massachusetts Bay Community College, Match Charter Public School, Minuteman Career and Technical High School, and Pathways Academy at McLean Hospital. Our community-based partners include Assabet Valley Collaborative, CodeEd, Destination Imagination, Girls Who Code, Massachusetts Academy of Sciences, Massachusetts Partners for Public Schools, Massachusetts Technology Collaborative (MassTech), Sprout & Co, Youth Design Boston.

allowing undergraduate faculty from the hard and soft sciences to begin to include computational, network, and data-intensive approaches in their courses and provide pathways for students to engage in high impact education.

Our *Innovation Hub* will evolve to serve as a high impact education vehicle, tying growing numbers of students into a broader ecosystem that includes experiential learning, thereby creating reinforcing touch-points. By building links between formal and informal learning activities, we can educate and engage the pipeline in real-world data-intensive problem-based learning opportunities that adopt the mantra of thinking globally, but acting locally. Students, for example, could learn from a curriculum module in their high school or undergraduate mathematics course to plot pollution data in their city or town, creating a hook for future learning opportunities. A student may then be motivated to join a real-world community-driven research project as part of the *Innovation Hub* that uses "big data" to develop a better understanding of how local pollution relates to regional or even global climate change, and thus informing locally-relevant action plans, which in turn can be managed through effective community planning processes. Pathways between formal and informal opportunities will be guided by the "smart and connected" pipeline such that students and teachers can move from formal education opportunities (*e.g.*, curriculum modules, online teacher guides, software tools repurposed for education, teacher training, *etc.*) to informal education opportunities (*e.g.*, museum exhibits, community action projects, deep engagement in student research, *etc.*).

3. Collective Impact: Achieving Sustainable and Scalable Outcomes

We believe impactful STEM education and outreach must *begin* by uncovering the synergies between ongoing efforts at the lead institution level. At Boston University, there are a number of programs involved in K-20 STEM education and outreach, many of which share in the mission of this proposal, but for the most part they operate independently. For our *Innovation Hub* to realize its potential, we will vertically integrate and align with other K-12 STEM programs and with other university centers and initiatives, such as General Education Requirements, Digital Learning Initiative, Arts Initiative, Advance, Recruit, Retain & Organize Women in STEM (ARROWS), Office of STEM Initiatives' Learning Assistant Program, College of Engineering's Inspiration Ambassadors Program, and Center for Psychiatric Rehabilitation [28] [34] [35] [36] [37] [38] [39]. We appreciate the potential impact of this pilot is integrative to the mission of Boston University with a model that can be adopted at other institutions – *i.e.,* creation of new *Innovation Hubs* synthesizing content, skills, research, community, and societal impact.

For over 25 years, members of our team have been at the forefront of developing programs to bridge cutting-edge interdisciplinary research and education. A recent example is the NSF CDI and ITEST-funded NetSci High program that immerses teams of underrepresented high school students in New York and Boston in yearlong research projects in network science [40] [41]. Our education outreach includes sustainable programs, such as PROMYS in mathematics [42], CityLab on biotechnology [43], LERNet's Artemis Project and Summer Pathways for young women [44], Upward Bound Math & Science for underserved students [45]. Our smart-city, cybersecurity and cloud computing initiatives are leading interdisciplinary computational and data-driven research and are actively leveraging many of BU's own education outreach programs. Our NSF Big Data Spoke proposal – PETALS – engages wide-ranging research and public-private partnerships for emissions tracking and analytics and paves the way for K-20 data science education, public outreach, and community engagement [46].

Our collective impact approach is about empowering individuals, teams, institutions and organizations to unite around a shared vision and discover where the alignments are so that the whole can be greater than the sum of our parts. In doing so, we will empower underrepresented communities, synthesize K-12 STEM education outreach, STEM research, and undergraduate education, and realize a "high impact" next generation education.

For more information, visit www.bu.edu/networks or contact Paul Trunfio at 617-353-9041 or networks@physics.bu.edu

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