A cross-university collaboration

DEVELOPING A VIRGINIA STEM NETWORK

funded by

4-VA

Advancing The Commonwealth

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KEY TAKEAWAYS

STEM literacy is critical to workforce development and to an educated citizenry. Virginia has many points of pride in STEM education and is poised to accelerate STEM opportunities for all of its citizens.

We propose the Commonwealth of Virginia launch a statewide STEM Network that strengthens our existing collaborations, cultivates new strategic partnerships, and ensures that all Virginians can access the activities, relationships, and tools that will equip them with the knowledge, skills, and dispositions for the future.

THREE KEY CONDITIONS FOR SUCCESS

ACTIVE PROMOTION OF EQUITY, ACCESS, AND INCLUSION

COLLABORATION ACROSS REGIONS AND SECTORS

SUSTAINABLE INFRASTRUCTURE

SEVEN STRATEGIC RECOMMENDATIONS

01 **Seek consensus on “quality STEM” in terms relevant to this network.**

02 **Build culture of STEM awareness with a focus on equity, accessibility, and inclusion.**

03 **Develop an accessible and thorough inventory of Virginia STEM activities.**

04 **Support sustainable network infrastructure.**

05 **Advance a communication plan.**

06 **Embed an evaluation plan that ensures annual assessment of network activities and operations.**

07 **Commit to long-term support and sustainability.**

EXECUTIVE SUMMARY

Literacy and workforce competency in science, technology, engineering, and mathematics (STEM) are vital to our nation's global leadership and advancement of our citizens' quality of life. In 2019, Governor Northam launched the STEM Education Commission to develop a state STEM education strategic plan. The goal of this plan is to guide future learning opportunities to advance STEM literacy and workforce development. In support of the Commission, five public universities (George Mason University, James Madison University, University of Virginia, Virginia Commonwealth University, and Virginia Tech) joined in a collaborative effort to launch a needs assessment that would inform the development of a statewide STEM Network, providing an infrastructure to advance the Commonwealth's STEM plan for the future. In February 2019, the collaborative was awarded a 4-VA[1] grant to create a foundational data-based document to inform the development of a network. This paper describes this collaborative led by Virginia Tech, the outcomes of the needs assessment, and evidence-based recommendations for developing and sustaining a strategic multi-sector STEM Network in Virginia.

Our goal is to summarize the data into the major themes and key considerations that can serve as a foundation for the blueprint of a successful and thriving STEM Network in Virginia.

A needs assessment approach to our research was chosen in order to give voice to all of the major sectors involved in STEM education in Virginia. Two major needs assessment activities yielded information to frame this document: 1) a pilot inventory of the current STEM education programs and collaborations that have been successful at our institutions and that might be scaled up or replicated across Virginia, and 2) a day-long *STEM Summit* that convened nearly 150 STEM leaders representing multiple sectors from across Virginia and the nation.

Essential to building a STEM culture of success in Virginia, three major themes pervaded the data in terms of values and design elements. First, we must promote equity, access, and inclusion in the availability and delivery of high-quality STEM activities across the Commonwealth. Second, the principle of collaboration is fundamental for this culture of sharing and opportunity for all. Third, the infrastructure must be supported by all sectors that commit to investment and advocacy for at least 10 years. The governance of the network must have a strong financial base and leadership that is recognized, sustained, and rewarded.

Seven strategic recommendations emanated from the data analysis and are articulated in order that is both linear and recursive. First, we must build consensus of the features of a quality STEM program. Second, we must ensure that the culture of equity, accessibility, and inclusion are fundamental to the network design and activities. Third, the Commonwealth must maintain an inventory of STEM education activities available across the state so that quality programs are identified and shared in regions of need. Fourth, we must commit to the creation and support of a network that is sustainable and embedded in our formal and informal educational programming. Fifth, information and news about our programming across regions must be communicated on a regular basis. Sixth, network activities need to be evaluated for continuous improvement and to ensure a return on investment for all sectors. And, seventh, we must commit to long-term support and investment. This support must transcend leadership changes, economic downturns, and loss of focus.

[1] The mission of 4-VA is to promote collaborations that leverage the strengths of partner universities across the Commonwealth of Virginia.

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BACKGROUND

Literacy and workforce competency in science, technology, engineering, and mathematics (STEM) are vital to our nation's global leadership and advancement of our citizens' quality of life. Yet STEM is more than the letters in the acronym. It is an integrated understanding, a habit of mind, a way of approaching the world—asking and answering questions, thinking critically, and using evidence to make informed decisions in everyday situations and circumstances. Major issues, such as reductions in biodiversity, energy sustainability, emergence and re-emergence of infectious diseases, vulnerabilities of the Internet, clean oceans, and food demand are just a few of the grand challenges that affect our citizenry on local, regional, state, and global proportions. There are benefits and trade-offs embedded within these STEM-infused issues. As such, it is paramount we help students successfully analyze, evaluate, and enact their collective response beyond their formative years and create innovative solutions to these challenges. Thus, STEM education is of critical importance now and into the foreseeable future.

STEM literacy is foundational to everyday life, and expertise across the STEM disciplines is essential to our economic growth, competitiveness, and national security (Council on Foreign Relations, 2012). For almost 40 years, accessible and high-quality STEM career pathways leading to a qualified workforce have been called for at the federal, state, and local levels (National Academy of Education, 2009).

One of the most successful mechanisms for achieving both STEM literacy and a STEM workforce has been the development of strategic multi-sector partnerships at the community, regional, state, and federal levels (Committee on STEM Education, 2018). This "pathway to success" has been identified in the most recent federal STEM education plan. This white paper represents a collective, multi-university effort summoning Virginia to heed this call to build a formal network of strategic, multi-sector partnerships for STEM education.

In 2019, Governor Northam launched the STEM Education Commission to develop a state STEM education strategic plan. The goal of this plan is to guide future learning opportunities that advance STEM literacy and workforce development. In support of the Commission, five public universities joined in a collaborative effort to launch a needs assessment that would inform the development of a statewide STEM Network. This paper describes the collaborative, the outcomes of the needs assessment, and evidence-based recommendations for a multi-sector STEM Network in Virginia.

We propose the Commonwealth of Virginia launch a statewide STEM Network that strengthens our existing collaborations, cultivates new strategic partnerships, and ensures that all Virginians can access the activities, relationships, and tools that will equip them with the knowledge, skills, and dispositions for the future.

A Collaborative Effort

In February 2019, our collaborative was awarded a 4-VA[2] grant to complete two tasks related to developing a Virginia STEM Network: 1) inventory the current STEM education programs and collaborations that have been successful at our institutions and that might be scaled up or replicated across Virginia, and 2) convene STEM leaders representing multiple sectors from across Virginia and the nation at a day-long *STEM Summit*. Led by Virginia Tech, the collaborative partners include George Mason University, James Madison University, University of Virginia, and Virginia Commonwealth University.

We, the authors of this white paper and members of the collaborative, have been involved in a range of STEM education pathways initiatives over the past 20 years. Within our collective, we have a diversity of experience with STEM education, but also understand the limitations of our perspectives. We strongly believe in the importance of collaboration and partnerships in the design, development, implementation, evaluation, and sustainability of a STEM Network using a multi-sector approach. We are professionally and personally committed to collaborating with all sectors to advance this effort.

We also value the use of multiple forms of data and evidence to inform the decision-making process, which include both local and national voices. Preceding the grant, we studied other states' STEM networks to understand what is available, as well as their missions, infrastructures, operations, and funding. As part of our work, we also gathered data from various stakeholders across the state. Those perspectives are included throughout this white paper. Finally, we use the research on STEM education to understand these voices within the national context. This paper outlines key considerations that have emerged from our research, providing a set of ideas that, based on the data, can serve as a foundation for the blueprint of a successful and thriving STEM Network in Virginia.

Coming from the sphere of higher education, our collaborative is uniquely situated to be able to respond to large-scale challenges such as:

- *Developing a STEM-informed citizenry.*
- *Supporting the needed STEM workforce for Virginia's New Economy in cooperation with strategic business partners.*
- *Working toward equity and access in the STEM pipeline.*

One way we aim to do this is by supporting efforts to the create a public, searchable database of available resources. We also hope to engage the STEM, education, literacy, and career development communities. Finally, the use of a data-based approach to inform our recommendations represents one of the major contributions that higher education can make to all phases of this work.

[2] The mission of 4-VA is to promote collaborations that leverage the strengths of partner universities across the Commonwealth of Virginia: https://4-va.org

EXPLORING STEM IN VIRGINIA

As mentioned above, our collaborative had two main goals: 1) Identify *STEM initiatives* across our collective institutions that can inform the development of a STEM Network and 2) Hold a statewide STEM summit to bring key stakeholders together to understand what is needed to create a statewide STEM Network.

STEM Education Inventory

To make progress toward a publicly searchable database of current STEM initiatives within Virginia, we sent a survey in April and May of 2019 to faculty and administrators at our five institutions to inventory the outreach opportunities they were providing in K-12 education, whom they were providing it for, and the target region of the state. The goal of this survey was to understand what was already happening across the state in terms of STEM programming from universities.

STEM Summit

We then turned our attention to organizing the *STEM Summit*. The goal was to convene STEM education leaders from across the Commonwealth to inform the development of a Virginia STEM Network blueprint. An important step in the planning process was identifying and inviting individuals from key sectors (e.g., higher education, K-12, informal education, government, and corporate) to attend. Quotas ensured a relatively balanced distribution of attendees and that the *STEM Summit* would represent diverse participants and perspectives. Members of the Governor's STEM Commission were also invited and most attended.[3]

The *STEM Summit* convened on October 11, 2019, in Richmond, Virginia, with Virginia Commonwealth University serving as the host institution.[4] The design of the summit incorporated experiences and activities that mirror skills from STEM disciplines and professions.[5]

Virginia STEM Summit
OCTOBER 11, 2019
VIRGINIA COMMONWEALTH UNIVERSITY
RICHMOND, VIRGINIA

Nearly 150 STEM education stakeholders from across Virginia and the nation came together with the goal of creating a blueprint for a statewide STEM Network.

[3] The full membership of the STEM Commission may be viewed here: https://www.governor.virginia.gov/newsroom/all-releases/2019/august/headline-844015-en.html

[4] Summit sponsors were Discovery Education, Lego Education, The Steward School, Virginia Commonwealth University, and Virginia Tech. Our activities are supported by advisors from the Office of the Governor and the Virginia Department of Education.

[5] The full summit program and list of attendees is available here: https://ceni.icat.vt.edu/va-stem-summit.html

The *STEM Summit* opened with a video from Senator Mark Warner, who stated the importance of young people gaining the specific skills to meet the demands of STEM-savvy employers and the long- and short-term impacts this has on Virginia's economy and our national security.[6]

The *STEM Summit* featured a keynote address by Virginia native Leland Melvin, a retired NASA astronaut. He shared his inspirational story of grace, grit, and second chances, describing the people and mechanisms that enabled him to succeed in his amazing career. Then, a panel of experts in STEM education

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DR. ROBERT CORBIN
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DR. ANDREW DAIRE
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Executive Director, Iowa Governor's STEM Advisory Council

fielded a range of questions about developing and sustaining a statewide STEM Network. With a focus on access and inclusion, the panel offered specific ideas, concerns, strategies, and potential solutions.[4]

The clear messages from the panelists were:

- *Virginia already has many points of pride in STEM education,*
- *we need to build on our existing resources, and*
- *we need to create an infrastructure to ensure that all Virginians have access.*

Participants then organized into "by sector" groups, then "cross-sector" groups to identify the key issues and priorities for STEM education in Virginia. The groups identified exemplary initiatives, and associated success metrics, implementation steps, and sectors to be involved. These ideas were articulated on chart paper and posted around the room for a gallery walk. Participants reviewed and voted for their top initiatives. The *STEM Summit* concluded with a summative statement from Dr. Jeff Weld, Executive Director, Iowa Governor's STEM Advisory Council.

Following the *STEM Summit*, participants completed an evaluation that provided feedback to our collective on the day's events. It also provided a mechanism for individuals to articulate their thoughts and share perspectives on creating and sustaining a STEM Network.

[6] Senator Warner's address may be viewed here: https://www.governor.virginia.gov/newsroom/all-releases/2019/august/headline-844015-en.html

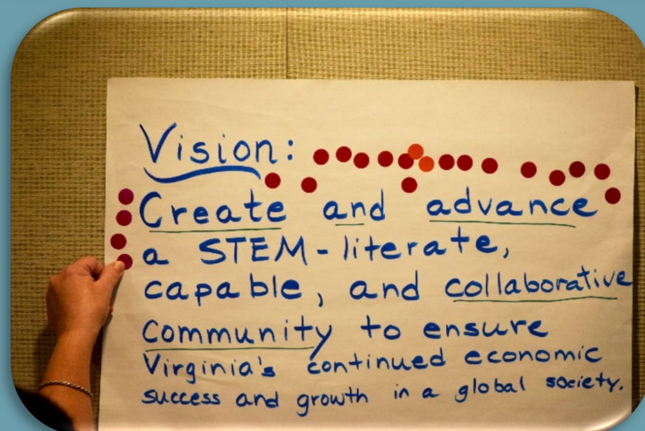
Collection and Analysis of Data

The collaborative used two major data collection and analysis processes aligned with the project goals. For the first goal, inventorying STEM education initiatives across the state, the collaborative deployed a survey to build an initial STEM inventory with the intent of assessing the survey's effectiveness. We analyzed responses to identify the number, type, and nature of STEM education initiatives across Virginia that institutions of higher education coordinated or partnered to implement.

For the second goal, the *STEM Summit*, we analyzed the responses to the open-ended evaluation questions and documents produced by attendees during the 'by sector' and 'cross-sector' activities. The process identified 15 initial themes with some overlapping features. The members of the collaborative discussed these initial/emerging ideas to create the broader overarching themes and principles, described below, that comprehensively captured attendees' perceptions.

SURVEY TO BUILD AN INITIAL STEM INVENTORY

OPEN-ENDED EVALUATION QUESTIONS AND DOCUMENTS PRODUCED BY ATTENDEES DURING THE STEM SUMMIT



Photos by Kevin Morley,
VCU University Relations

OUTCOMES AND DISCOVERIES

In this section we describe the results from our pilot survey of STEM initiatives and the *STEM Summit*. Survey results revealed important information about current activities reported by the participating universities, as well as about the survey itself. The *STEM Summit* results represent the voices[7] across multiple sectors, and specific principles and themes emerged that provide considerations for STEM Network design. Example comments from the data illustrate these themes. Integrated in each section are relevant connections to prior published work.

The Landscape of STEM Programs by Virginia's Universities

In brief, the pilot survey of STEM initiatives yielded 82 responses (i.e., different STEM activities) detailing a myriad of different types of programs in regions served by the 4-VA universities. Each university serves its surrounding region with a range of programs. Most of the programs served 21 to 50 people and focused on a regional or metro area audience.

While the survey responses provided useful information from the participating institutions, scaling the instrument for use across the state to develop a more complete analysis of initiatives will require several modifications. First, a revised survey will reduce the time required to input program information. Second, a measure of program quality or specific program features needs to be included. Finally, including items that assess the potential for replicability and scalability while maintaining implementation quality are paramount. These improvements should be made to the survey before further use.

Prevailing Themes

One of the main ideas that came from the *STEM Summit* was that "STEM is a culture, not a class" (Corbin, 2019). The Virginia STEM Network should focus on building a strong foundation for STEM literacy for all Virginia learners by ensuring opportunities for learners to master basic STEM concepts (Weld, 2018). According to the Virginia Department of Education (2020), "STEM literacy is the ability to identify and acknowledge science, technology, engineering and mathematics concepts and processes in everyday life**."** Furthermore, STEM literacy should be viewed as a "dynamic process" that transcends educational content objectives to align with learners' emotional needs, physical skills, and cognitive skills. Beyond individual growth, STEM literacy reaches to the economic, societal, and personal needs of humanity (Zollman, 2012, p. 18). Such a perspective enables us to focus on "STEM literacy for continued learning" (Zollman, 2012, p. 18) and promote STEM as a culture (Corbin, 2019).

Over 80% of the fastest-growing occupations require significant mathematics and science preparation (US Department of Labor and Statistics, 2019). Priorities and activities of the STEM Network should be informed by workforce trends to ensure alignment between "what is taught and learned with what is needed at work and in the

[7] These voices represent the Summit participants' words and are quoted with no reference or name to preserve anonymity.

communities" (Committee on STEM Education, 2018). *STEM Summit* participants saw value in a STEM Network informed by workforce trends with regard to "creation of talent to supply a skilled workforce to companies working in Virginia" and "improving the number of children who are interested in pursuing a career in a STEM field."

> ***"Making STEM a statewide network will even up the playing/learning/ experience field for* all students *across the Commonwealth."***

Necessary Conditions for Success

ACTIVE PROMOTION OF EQUITY, ACCESS, AND INCLUSION

When *STEM Summit* participants were asked what was most important to them about creating a STEM Network in Virginia, attention to issues of equity, access, and inclusion quickly surfaced, acknowledging the need for "a focus on equity and access to extend the reach into as many communities as possible." As one participant commented, creating a STEM Network in Virginia is important for "the future of its children to remain and grow and thrive." To realize this hope, the STEM Network must work for *all* children across Virginia. Participants discussed the need to support *all* Virginia students through equitable access to resources, high academic standards, and opportunities to learn STEM. Learners within the STEM Network should be provided equitable access to and opportunity for formal and informal STEM learning that is intentionally inclusive of learners of diverse backgrounds and abilities.

Attention to students' opportunity to learn STEM is necessary to promote equity, access, and inclusion across the STEM Network (Tate, 2001). Focused on quality STEM education for all, opportunity to learn encompasses three related constructs: time on task (i.e., engaged time, time allocated to science instruction), quality of instruction (relative to concepts assessed), and technology (including science equipment; Tate, 2001). Yet, across Virginia we see disparities in opportunity to learn consisting of, for example,

- » **limited time engaged in STEM due to inadequate resources or limited course offerings,**
- » **curricular or ability tracking that limits exposure to quality STEM instruction, and**
- » **little opportunity for students to interact with the tools and technologies of STEM via authentic investigations and inquiries.**

Further, educational approaches need to be culturally relevant to ensure all students are motivated and challenged to learn. For example, locally focused STEM experiences germane to students' everyday lives support intrinsic inspiration to learn. One participant put it this way: "Making STEM a statewide network will even up the playing/learning/ experience field for *all students* across the Commonwealth. Just a little touch of what some call 'STEM' is zero compared to what other regions are accomplishing and what other students are experiencing and learning that should be available and required for *all students*" (emphasis in original). [8]

[8] Additional background information on equity, access, and inclusion can be found in Appendix B.

COLLABORATION

As a second theme from the *STEM Summit*, participants overwhelmingly cited collaboration as a valuable component of creating and sustaining a STEM Network. To be effective, collaboration heavily relies on inter-sector and inter-stakeholder group communication. For example, stakeholders from different regions and sectors (e.g., K-12 educators, K-12 administrators, postsecondary, out-of-school time, businesses, state offices) need opportunities to communicate, and where appropriate, share ideas or partner with one another. Parents, community members, and students should also be included in these conversations. Importantly, communication should involve cross-sector data sharing. As one participant stated, a STEM Network needs "increased opportunities for collaborations and a clearer path for direct communication among stakeholders."

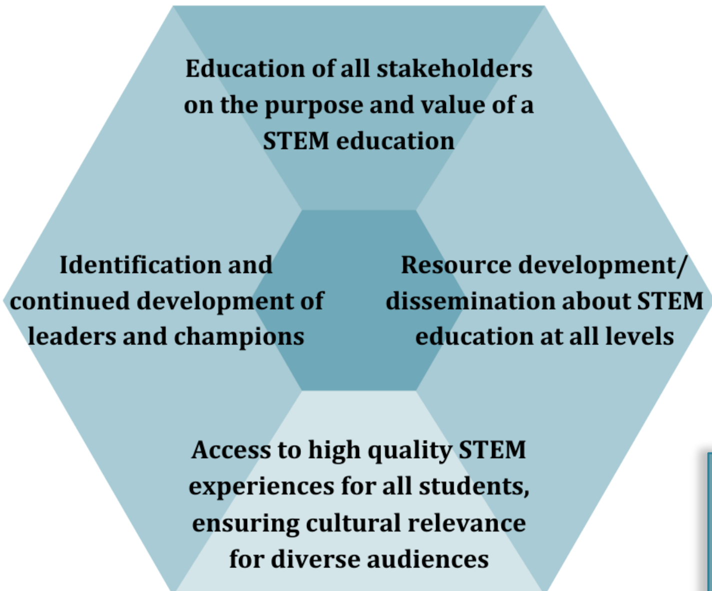
"True collaboration involves equity and mutual participation" (Burbank & Kaushack, 2003, p. 500), which aligns with the two additional characteristics that emerged as themes related to successful collaborations: (1) what it means to collaborate, and (2) the distinction between collaboration and competition. First, participants across stakeholder sectors hold differing perceptions of what it means to collaborate and, acknowledging and respecting these differences as collaborations are forged, is important. For example, one participant stated, "Each stakeholder is looking at STEM through their lens" and suggested the need to make sure that all stakeholders who collaborate also benefit. Second, we should recognize key distinctions across sectors and encourage collaboration rather than competition. For a STEM Network to be successful and sustained, resources need to be equitably distributed and collaboration between stakeholders take the driver's seat over competition. As another participant noted, "The infrastructure needs to change to allow for true STEM education. We also need to become more collaborative and less competitive." One approach to this goal may be creating state-based funding and corporate/foundation incentive structures to encourage collaborative partnerships. Or, more established STEM entities could support budding and smaller STEM organizations, while simultaneously recognizing all contributors' expertise.

> ***"The infrastructure needs to change to allow for true STEM education. We also need to become more collaborative and less competitive."***

When these aspects are achieved and aligned with shared principles of a STEM Network, "a statewide plan for STEM will join the many voices of STEM in one pathway moving forward. From education to careers and literacy throughout the populace, a coordinated STEM initiative will help optimize STEM efforts so that entities 'work smart' providing equity in access and supporting stakeholder needs." This sentiment of "working smart" was echoed by stakeholders from several different sectors, and our team reiterates its importance.

INFRASTRUCTURE

Another overarching theme perceived to be a prerequisite for a successful STEM Network was having the infrastructure to support it. Participant responses indicate that these infrastructure components include:



Several participants noted that key stakeholders (e.g., school administrators, faculty, parents) need to be supported in better understanding STEM. This is vital to having a successful STEM Network with a shared vision and set of principles. For example, participants stated, "Building a culture of awareness and support for STEM within the state" and "supporting families trying to navigate the changing work environment in STEM fields" were essential. Another participant suggested, "The state department *must* require superintendents to participate in STEM education workshops and require that *all* central office supervisors receive formal training and require that all faculty participate in required hours of training on STEM education and integration into the classroom at every level and in all subjects."

A STEM Network also requires broad development and dissemination of resources. Resources can be developed by stakeholders in any section (teachers, students, community, business). Suggestions in this area included: "Availability of resources to use in the classroom. This could be sharing of ideas between teachers, state supplied resources or curriculum or suggestions of things to look," "STEM career opportunities for our students to learn about," and "a one-stop warehouse where information, contacts, resources, and grant opportunities are maintained." Not only are the types of resources important, but the access to and maintenance of resources are key to effectively sustaining a STEM Network.

Not only are the types of resources important, but the access to and maintenance of resources are key to effectively sustaining a STEM Network.

Access is imperative to building the STEM pipeline in Virginia. All students should be able to envision themselves as having the potential to be scientists and engineers, and they should be given opportunities to develop interests in STEM (Malcolm & Feder, 2016). They should also have role models that "look" like them in the teachers that teach them STEM, in the internship opportunities they have, in access to higher education, and, ultimately, in knowledge of available STEM careers. Diversity increases creativity in the STEM pipeline that will ultimately benefit all sectors with interests in STEM within the state, nationally, and internationally. One participant's response comprehensively captured the need for changes to infrastructure to support equitable access:

> ***There are systemic barriers to strong STEM education that are inherent within the education system. Often, we try to arm students and teachers to navigate a system that has been shown to be unfriendly to women and people of color, rather than trying to change the system (fix the student vs. fix the system). There is a need to not only assess what programs and gaps exist, but also to look at issues that arise due to state and district policies, implicit bias, access to quality education opportunities, recruitment/hiring/ retention/ promotion of STEM teachers and faculty, and more.***

Another response deftly captured the need for state-level commitment to any STEM Network: “Unless there is legislation, policy, and funding, it will be meaningless to call for STEM action. Unless teachers and professors view STEM as part of an effort to reprioritize basic skills and a general education, little will change overall. STEM is now and will continue to be a series of events in some schools, some programs, and some departments throughout the Commonwealth.”

We strongly believe in the importance of collaboration and partnerships in the design, development, implementation, evaluation, and sustainability of a STEM Network using a multi-sector approach. We are professionally and personally committed to collaborating with all sectors to advance this effort.

STRATEGIC RECOMMENDATIONS

In order to develop a strategic STEM Network or multi-sector partnership to support STEM in Virginia, we offer the following recommendations and considerations:

01

SEEK CONSENSUS ON "QUALITY STEM" IN TERMS RELEVANT TO THIS NETWORK.
To help maintain focus on developing a plan, we advocate seeking a consensus on what it means to provide a quality STEM experience for students. We recommend using the published work on STEM education, other well-established statewide STEM networks, and voices within our state to frame the conversation and identify a shared language.

02

BUILD A CULTURE OF STEM AWARENESS WITH A FOCUS ON EQUITY, ACCESSIBILITY, AND INCLUSION.
Families, parents, communities, school administrators, faculty, businesses, and the workforce need to hear and value the perspectives and needs of all stakeholders regarding STEM. All voices need to be respectively heard and all sectors, racial and ethnic groups, and geographic regions be equitably represented.

03

DEVELOP AN ACCESSIBLE AND THOROUGH INVENTORY OF VIRGINIA STEM ACTIVITIES.
While the pilot STEM inventory survey provided a starting point, we need to include additional voices, i.e., other regions of the state, additional colleges and universities (including community colleges, historically Black colleges and universities, and Hispanic serving institutions), and private and government sectors. Continued data collection, perhaps by survey or landscape analysis, should use the findings from the pilot survey as a guide. Ideally, this inventory would capture programs and initiatives open to all Virginians, including children, young adults, and beyond. As part of this inventory, we also need to identify the economic strengths and geographic characteristics that affect the Virginia STEM Network. A more complete understanding of the network will also enable all partners to share experiences, leverage expertise, and collaborate with each other.

04

SUPPORT SUSTAINABLE NETWORK INFRASTRUCTURE.
To achieve a sustainable infrastructure, questions that will need to be answered include:

- ***What do we need to sustain the STEM initiatives in Virginia?***
- ***Where are there deficits in programming? and***
- ***How can we support sustainable growth of successful programs?***

We have identified three approaches that build on existing projects and resources in Virginia. First, data from the STEM inventory can help identify what already works in each region, which can be used to develop regional hubs with long-term capacity. Second, teacher professional development may also be a way to build the network and support the development and broad dissemination of curriculum materials. We suggest coordinating with the VA Department of Education (VDOE) on STEM initiatives that include populating, promoting, and disseminating resources via such mechanisms as Go Open, an Open Educational Resources (OER) portal. Third, leveraging existing Virginia resources (i.e., dual-enrollment, internships, outreach programs, student conferences, Virtual Network, grant mechanisms such as 4-VA, VDOE) and network partners (e.g., shipbuilding, big data, healthcare, agribusiness, government, military, cybersecurity, entrepreneurship, veterinary science, mineral resources, etc.) to support the development and sustaining of the network.

05

ADVANCE A COMMUNICATION PLAN.

A Virginia STEM Network needs to communicate and share resources as well as promising practices that may benefit other regions across the state. There is a myriad of possibilities for how this could be done, such as with a website, social media updates, or through regular conferences. Whatever plan is ultimately developed, it needs to be able to:

- ***educate all stakeholders on the purpose and value of STEM education;***
- ***provide resource development/dissemination about STEM education at all levels;***
- ***allow for access to high quality STEM experiences for all students, ensuring cultural relevancy for diverse audiences;***
- ***identify and support the leaders and champions who are doing this work; and,***
- ***share and celebrate the impact of the network across the state on a regular and consistent basis.***

06

EMBED AN EVALUATION PLAN THAT ENSURES ANNUAL ASSESSMENT OF NETWORK ACTIVITIES AND OPERATIONS.

We recommend following a process of evaluation, revision, and sustained iteration based upon data/evidence. Establishing a common baseline of mutually agreed upon metrics to track and document impact is critical. Agreed-upon metrics also help ensure consistency and coherence across the state-based STEM opportunities. For this process to be meaningful to the network and its stakeholders, we recommend the plan be developed in consultation with experts in assessment and evaluation, and the entity implementing the plan have dedicated time to do so.

07

COMMIT TO LONG-TERM SUPPORT AND SUSTAINABILITY.

Developing this network and shifting the culture of STEM education within it will take time. Research consistently shows that implementation of an innovation takes about five years, and at least five more years for stabilizing and full operation (e.g., Fullan, 2015, 2020). We must establish a long-term timeline and an operationalized phased implementation plan for these statewide efforts to come to fruition. Growing strong leaders is crucial. Similarly, financial support across the myriad of collective regional and federal avenues may be systematically and collectively pursued to help ensure sustainability for the delivery of services across the STEM Network.

These recommendations are presented in the order in which we recommend them to occur, as early activities are foundational to subsequent activities.

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APPENDICES

Appendix A: Author Biographies *(in alphabetical order)*

Al Byers, Ph.D. is a visiting scholar and assistant professor in STEM education at Virginia Commonwealth University (VCU) in the School of Education. He is the interim Executive Director of the Center for Innovation in STEM Education at VCU in collaboration with the Science Museum of Virginia. He leverages the resources and assets of VCU to bring high impact STEM experiences to the highest need students, and the teachers who serve them in Richmond, Virginia. Prior to this he served for nearly 16 years at the National Science Teachers Association as Associate Executive Director where he developed and implemented large scale sustainable solutions for teacher professional learning in cooperation with competitive funding from NSF, NASA, NOAA, FDA, and the US Department of Education.

Kerry Owens Cresawn, Ph.D. is the director of the Center for STEM Education and Outreach at James Madison University. Dr. Cresawn earned her Ph.D. in Molecular Biology from the University of Florida in 2004. Prior to her position as STEM Center director, she was a member of the Biology faculty at JMU for 11 years. Dr. Cresawn's areas of interest include building sustainable cross-campus collaborations between faculty and students in both the STEM and Teacher Education colleges for more impactful K-12 STEM outreach and developing programs that increase access to STEM enrichment in the Shenandoah Valley region.

Elizabeth W. Edmondson, Ph.D, is a science educator in the School of Education at VCU. She is the PI for the third round of funding for an NSF Noyce Track I proposal. She is also the Co-PI on an NSF Noyce Track 4, NIH NIDA funded grant, and two NOAA B-WET grants. She has worked for many years across the K-12 spectrum. Her research interests span across several domains from classroom discourse, implementation of best instructional practices, teacher retention, and teacher induction.

Rebecca M. Jones, Ph.D. is an associate professor in the Department of Chemistry at George Mason University. She regularly teaches general and inorganic chemistry and steadfastly works to improve outcomes for STEM students. Her research interests include photographic chemistry, improving STEM education, and faculty mentoring and student development related to undergraduate research experiences. She is an active member of the American Chemical Society, the president of Mason's chapter of Sigma Xi, and an elected chemistry councilor on the Council on Undergraduate Research.

Jennifer L Maeng, Ph.D. is a research assistant professor in the Department of Curriculum, Instruction and Special Education at the University of Virginia's Curry School of Education and Human Development. Her scholarship addresses three interconnected domains: (1) designing, implementing, and assessing the outcomes of professional development that facilitates K-12 teachers' implementation of research-based STEM instruction; (2) understanding the experiences of underrepresented undergraduate students in STEM; and (3) the role contextual factors of the K-12 educational setting, such as school climate and safety, play in supporting effective teaching and learning.

Susan G. Magliaro, Ed.D. is professor emerita in the School of Education at Virginia Tech. After earning an Ed.D. from Virginia Tech, she has served on the faculty for 28 years, including appointments as director of the School of Education for nine years. Her research interests focus on teacher learning, instructional design, and STEM education. Currently, she is working in the VT Center for Educational Networks and Impacts and serves on the Governor's STEM Education Commission.

Phyllis Newbill, Ph.D. is Outreach and Engagement Coordinator at the Center for Educational Networks and Impacts at Virginia Tech. She has served as faculty at Virginia Tech since 2016 and worked on informal science education research for over two decades. She directs the Virginia Tech Science Festival and serves as the liaison between Virginia Tech and the Science Museum of Western Virginia. She earned her Ph.D. in instructional design and technology from Virginia Tech, and also holds degrees in geology, English, and engineering geosciences. Her research interests include gender and education, improving attitudes toward science, and STEM education.

Padmanabhan Seshaiyer, Ph.D. is a full professor of Mathematical Sciences and the Associate Dean for Academic Affairs in the College of Science, George Mason University (GMU). At GMU, he has served as the Director of two Centers of Excellence including the STEM Accelerator Program and the Center for Outreach in Mathematics Professional Learning and Educational Technology. His research interests are in the broad areas of computational mathematics, scientific computing, bioengineering, teacher professional development, sustainable development goals, and STEM education. Over the last decade, he has helped to initiate and direct a variety of educational programs including graduate and undergraduate research, K-12 outreach, teacher professional development, and enrichment programs to foster the interest of students and teachers in STEM at all levels.

Angela W. Webb, Ph.D. is an assistant professor of Science Education in the College of Education at James Madison University. She teaches graduate and undergraduate science methods courses and internship seminar. Her scholarship centers on the preparation and early career development of secondary science teachers, with a specific focus on meaning making and identity during induction. She has provided professional development on inquiry, the nature of science, project-based learning, and co-teaching in science to middle and high school science teachers. Before earning her Ph.D., Dr. Webb taught high school biology, physical science, and AP Environmental Science.

Lindsay B. Wheeler**,** Ph.D. is an assistant professor and assistant director of STEM education initiatives in the Center for Teaching Excellence at the University of Virginia. Dr. Wheeler has a Ph.D. in Science Education from the University of Virginia. In her work, she supports instructors who teach undergraduate and graduate STEM courses. Dr. Wheeler's current research interests include how professional development for faculty impact instructional practices and student outcomes.

Appendix B: Additional Background Regarding Equity, Access, and Inclusion

The United States is experiencing a crisis in STEM fields due to a decrease in pursuit of STEM related careers (DeCoito & Myszkal, 2018). In particular, the number of students from underrepresented and underserved populations who choose careers related to STEM are significantly lower than their counterparts. And yet, "*all* students should be able to learn about the broad set of possibilities that modern life offers and to pursue their aspirations, including their occupations of interest" (National Research Council, 2012, p. 279, emphasis added). For African Americans and Hispanics who collectively constitute approximately 30% of the U.S. population (and growing), their pursuits of undergraduate degrees in physical science, mathematics, and engineering have remained flat since the 2000's hovering around 12%, and constitute only a very small percentage (3% or less) of the current U.S. STEM workforce in math, science and engineering (National Center for Science and Engineering Statistics, 2013). This leads to a troubling and significant gap among these underrepresented groups, which limits their participation in many well-paid, high-growth professions, and stifles our nation's benefits of their perspectives, talents and creativity (PCAST, 2010).

The National Research Council (2012) frames promoting equity in science in these ways: "Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of connecting to students' interests and experiences is particularly important for broadening participation in science" (p. 28). These same commitments to equity, access, and inclusion should apply to formal and informal STEM education and experiences across the Commonwealth's STEM Network.

We will increase the capacity to engage all students, especially those who are minoritized, marginalized, and othered, in an equitable manner (Hooper & Bernhardt, 2016). Many factors, e.g., color blindness, cultural conflicts, the myth of meritocracy, deficit mindsets, and low expectations (Milner, 2010), affect the teaching and learning process within in PreK-12 schools and classrooms. Moreover, the factors mentioned above often materialize into macro- and micro-aggressions and stereotypes (Castro, 2010; Sue, Lin, Torino, Capodilupo, & Rivera, 2009), which are informed by implicit/unconscious bias (Barnes, 2019). Thus, to ensure that educators are empowered to mitigate their potential implicit/unconscious biases together with their subsequent behaviors, our efforts will ensure programmatic and measurable strategies to increase their cultural awareness, equity-mindfulness, and inclusive teaching practices. Via our collective and collaborative effort, students (and the teachers who serve them) will develop skills for building an inclusive computing culture incorporating varied opinions that involve understanding of diverse perspectives, e.g., social, cultural, ethical, economic (Virginia Board of Education, 2017).

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