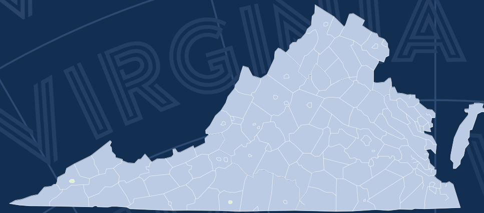


Virginia STEM Education Commission Final Report

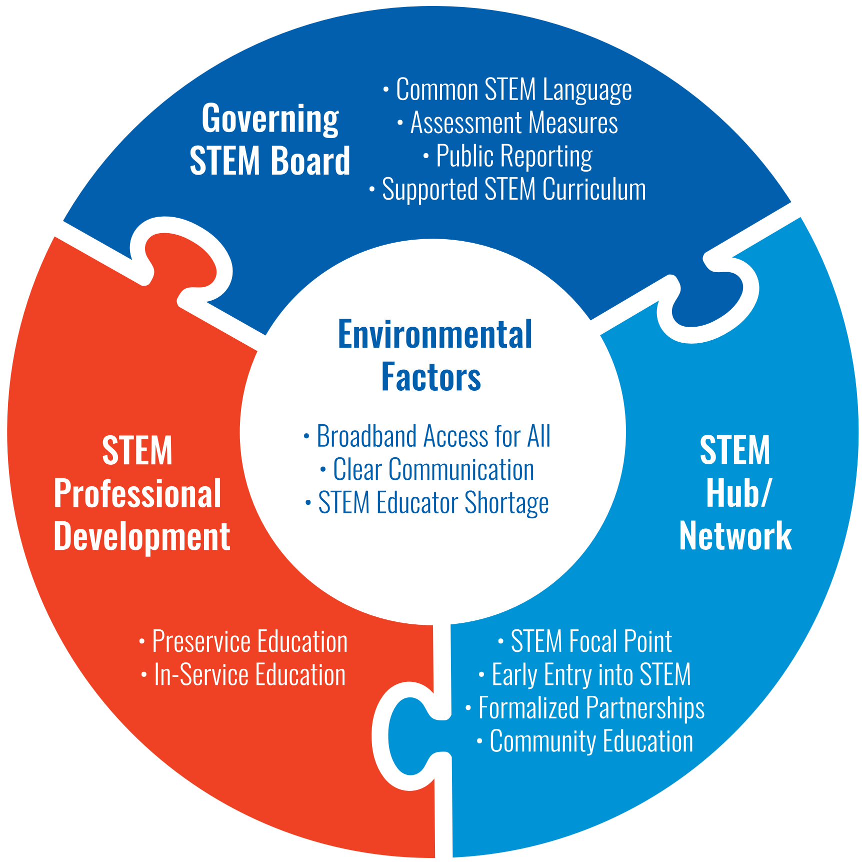
August 2020

Science, Technology, Engineering, and Mathematics (STEM)

EXECUTIVE SUMMARY

The Governor's STEM Education Commission was established by Governor Ralph Northam on July 17, 2019, to create a unified vision for STEM Education in the Commonwealth and adopt a set of shared goals to strategically inform how Virginia prepares students for STEM jobs of the future. Since its establishment last year, the Commission has conducted a cursory landscape analysis of Virginia's STEM programs, opportunities, and growth.

During this time, the Commission has worked across sectors and regions to develop a robust set of recommendations to make STEM education in the Commonwealth more inclusive, accessible, and collaborative. Virginia has numerous initiatives designed to engage and encourage youth to seek opportunities in STEM fields once they depart the PK-12 setting; however, the number of students that demonstrate interest are lower than the number of students that enroll into and graduate from these rich and plentiful STEM opportunities. This disparity is partially explained by inequities of opportunities and experiences accessible to all Virginia youth. Some providers can work more collaboratively to impact youths' comfort and confidence in STEM as well as help them recognize the relevance of STEM within their very own communities. With a streamlined effort, Virginia's STEM stakeholders can create programming to help students, their supporters, and their broader communities collectively foster the development of STEM literacy for all.



This document highlights key data collected, identifies challenges, and outlines a pathway forward to align the state's various efforts and create a unified STEM Plan for the Commonwealth. This proposal features three key elements: a Governing STEM Board, regional STEM hubs, and a robust, cooperative STEM educational model.

- **The Governing STEM Board** would be responsible for continued efforts in creating a common language; rubric for expectations; facilitated efforts statewide; and reporting on our next challenges, goals, and successes. It would also work to support some common exemplars in STEM curricular resources for both formal education as well as resources for settings outside of the classroom, whether they are after school programs or for parents.

- **Regional STEM hubs** would help create a local vision for STEM. The Hub Network would coordinate information sharing efforts within communities to deconstruct misconceptions about STEM. Additionally, the Hub would identify STEM champions within communities across the Commonwealth. These efforts would improve educational STEM literacy, with the goal of enabling youth to see themselves as STEM capable from preschool onward.

- **The STEM professional development** model would include opportunities not just for educators, but for informal educators as well. A useful model helps scaffold the opportunities for youth to see STEM as something more than just a classroom concept, but something woven through their everyday lives. The importance is to ensure that this model helps bridge the variety of STEM programming, language, and experiences in Virginia to help create a unified vision and expectation.

In the time of COVID-19, we have seen the immense relevance of STEM in our daily lives. The ability to gather with friends, go to work, attend school, and even participate in worship is now predicated on a basic understanding of technology. This unique period in history has shown us that STEM literacy is vital for survival, growth, and success in an increasingly technology reliant, virtual world. As we seek to improve the STEM literacy of all communities in the Commonwealth, the unified vision and thorough recommendations of the STEM Education Commission should serve as a roadmap for policymakers, educators, and community leaders alike as they determine next steps and identify opportunities to align efforts.

Virginia STEM Plan

In the past 10-15 years, “STEM” has emerged as a universally recognized acronym in the education community to represent the subjects of science, technology, engineering, and mathematics. The use of “STEM” has evolved into a strong, nationwide, motivating initiative to strengthen those critical fields of education that have a strategic impact on our future. STEM has been adopted, not just as an acronym, but as a concept of integrating instruction effectively in the four key fields. These critical fields form a foundation for many disciplines and career paths, but more importantly, the foundation of a strong economy.

Virginia is a leader in education (Liebowitz, 2018), business (Cohn, 2019), innovation (Swanner, 2018), as well as STEM jobs (Carnevale, 2014). This recognition is a direct result of our drive towards educational excellence, manufacturing, and logistical prowess, and, most of all, the capable and willing workforce that propels our Commonwealth. These accolades help spotlight our success, drawing more attention, and creating more growth in fields that encompass STEM.

Virginia has succeeded in setting STEM pathways without having developed a direct STEM Plan, common STEM goals, or shared vocabulary. While STEM in Virginia has grown (Liverman, 2020), many STEM efforts have lacked connection and alignment with other similar initiatives around the Commonwealth. Many of Virginia’s STEM initiatives have been effective, but some efforts have been redundant or competitive. Many states are working diligently to create STEM plans, goals, and actions to help drive their state forward. All states compete for growing businesses (such as Amazon and HQ2) and seek to educate citizens to promote a STEM literate culture.

For Virginia’s economy to continue growing, there must be greater coordination and collaboration between various STEM efforts. Given the current economic, employment, and health climate, a purposeful creation of a State STEM Plan may help align the various efforts of our universities, communities, schools, and investors. Outlining specific next steps toward educationally focused goals will ensure that Virginians are working collectively and collaboratively to ensure that the entire Commonwealth moves forward. It is time to not only look at STEM as content in the classroom or a workforce development idea, but also something that can impact and inspire us in our everyday lives.

Virginia STEM Today

On July 17, 2019, Governor Northam signed Executive Order 36 to establish the Virginia STEM Education Commission (Commission). This Executive Order was the state's first formalized effort to pull together STEM stakeholders from across the Commonwealth with a focus on improving and aligning STEM education efforts throughout Virginia.

Governor Northam appointed a wide range of state and local stakeholders to serve on the Commission, including early childhood, K-12, post-secondary, out-of-school programs, informal education, workforce development, environmental education, and business and industry partners from every region of the state.

The Virginia STEM Education Commission was charged with working collaboratively across fields to develop a State STEM Plan to include a set of definitions, goals, strategies, and measurable impacts and outcomes related to the following key areas:

1. Inspire and empower our students to develop the knowledge, skills, and mindsets necessary to thrive in a rapidly changing, technologically advanced, global society.
2. Ensure equitable opportunities and access for every Virginian to become a vital part of a robust STEM ecosystem.
3. Continuously improve the awareness, effectiveness, support, and quality of partnerships among educational entities, employers, and nonprofits.
4. Create sustainable and supportive conditions to align Virginia's educational, economic, and community goals.

First Lady of Virginia Pamela Northam served as the Chair of the STEM Education Commission and was supported by Secretary of Education Atif Qarni, as well as staff from the Science Museum of Virginia and Virginia Department of Education.

The Commission held its first meeting in August 2019, followed by several in-person conferences that focused on establishing common language, goals, vision, and mission for the work ahead. One Commission gathering occurred at the site of Virginia's first STEM Summit at Virginia Commonwealth University, which included speakers such as Dr. Jeff Weld and Astronaut Leland Melvin. This Summit culminated in a 4-VA STEM Network Whitepaper that outlined a set of recommendations to the STEM Commission.

The STEM Education Commission began to gather virtually in the Spring 2020 as a result of COVID-19 closures and travel restrictions. Executive Order 36 required the development, drafting, and submission of a State STEM Plan to Governor Ralph Northam by July 1, 2020. This deadline was extended to September 15, 2020, due to delays related to COVID-19.

To ensure alignment with the Virginia Department of Education, the Commission adopted the following key definitions and principles:

- **What is STEM Education?**
  Science, Technology, Engineering, and Mathematics (STEM) education entails authentic learning experiences for all students with an interdisciplinary and applied approach where all fields connect in complex relationships. In today's economy, problems are not solved in isolation of a specific discipline but are solved through multiple approaches ad perspectives. A strong STEM educational foundation helps to prepare our students for tomorrow's world by emphasizing collaborative, innovative, quantitative and logical analysis rooted in a solid understanding of the interdisciplinary nature of science, technology, engineering, and mathematics.

- **How is STEM education being refocused?**
  Recently there has been a shift in beliefs about the purpose of STEM education. Traditionally a STEM education focused on creating a pipeline of students whose educational backgrounds prepared them for a STEM-specific workforce. Today, the focus is on developing STEM-literate citizens necessary for success in any 21st-century profession. STEM literacy is the ability to identify and acknowledge science, technology, engineering, and mathematics concepts and processes in everyday life.

- **STEM literacy comes from an understanding that it takes:**
  - a scientific approach to observe and interpret the world;
  - technology to serve as a tool to solve problems or reach a goal;
  - engineering to design, test and solve a problem through the creation of products or processes; and,
  - mathematics to help quantify, comprehend, and evaluate the problem and solution's success.
    As students become STEM literate citizens, they have the foundational content and the discipline processes to allow them to make informed decisions and to participate in public/civil discourse concerning future STEM issues and technologies.

Resources other than the Virginia Department of Education have also helped refine our understanding of STEM, STEM Education, and STEM Literacy.

Rodger Bybee, in his book, "The Case for STEM Education: Challenges and Opportunities," (2013) clearly articulates that the overall purpose of STEM education is to develop a STEM literate society further. His definition of "STEM literacy" refers to "an individual's:

- knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen." (p. 101).

A report assembled by the Committee on STEM Education of the National Science & Technology Council called Charting a Course for Success: America's Strategy for STEM Education, created a 5-year national plan. Their national strategy focuses on a "Vision for a future where all Americans will have lifelong access to high-quality STEM education, and the United States will be the global leader in STEM literacy, innovation, and employment" (Executive Summary).

STEM Education's goal is to create a STEM literate citizenship as well as prepare youth for the potential of entering a STEM career, introducing them to a range of jobs that tend to pay more and is growing faster than non-STEM jobs. What counts as a STEM career provides a unique conundrum. There are a variety of ways to identify and categorize STEM jobs. Many agencies, both at the federal and state level, use different criteria on what should count as a STEM career. It would be vital that Virginia comes up with a common rubric for interpreting STEM careers and jobs as we move forward. Using common STEM careers from a few different regions of Virginia helps us more clearly see the breadth of opportunity we are considering.

- Northern Virginia has a strong focus on computer science and cybersecurity. The region also includes a lot of military security and intelligence, as well as a plethora of big data specialists.
- The Tidewater region has many careers tied to shipbuilding and repair, many of which include technical jobs requiring a robust set of STEM skills and the ability to apply them, from drafting and engineering, to programming and electronics. It is also the home of world-renowned research facilities from Jefferson Labs to NASA Langley.
- Southwestern and Southcentral Virginia are growing in terms of technology use in agriculture, construction, and modernizing jobs that are quickly evolving, such as in the energy industry. The manufacturing industry is also growing quickly, taking a new set of computerized, robotic skills into a modern manufacturing setting.

Numerous documents can supply STEM definitions, goals and careers. The examples, as mentioned earlier, represent the progression of the STEM Commission. The Commission's work started with the definitions implemented by the Department of Education. Continued work led the Commission to recognize growth broadening our viewpoint to speak more towards STEM Literacy, as Bybee presented. Finally, we decided that our vision needed to mirror national efforts, and we needed to ensure that our work and that our STEM ecosystem meets the needs of ***all Virginians***.

The Commission's STEM Vision and Mission are designed to be memorable and simple to provide direction and focus to our future work[1].

Virginia STEM Vision:

Create and advance a STEM-literate, capable, and collaborative community to ensure Virginia's continued economic success and growth in a global society.

Virginia STEM Mission:

Re-imagining, transferring, and sharing integrated and equitable STEM-learning experiences.

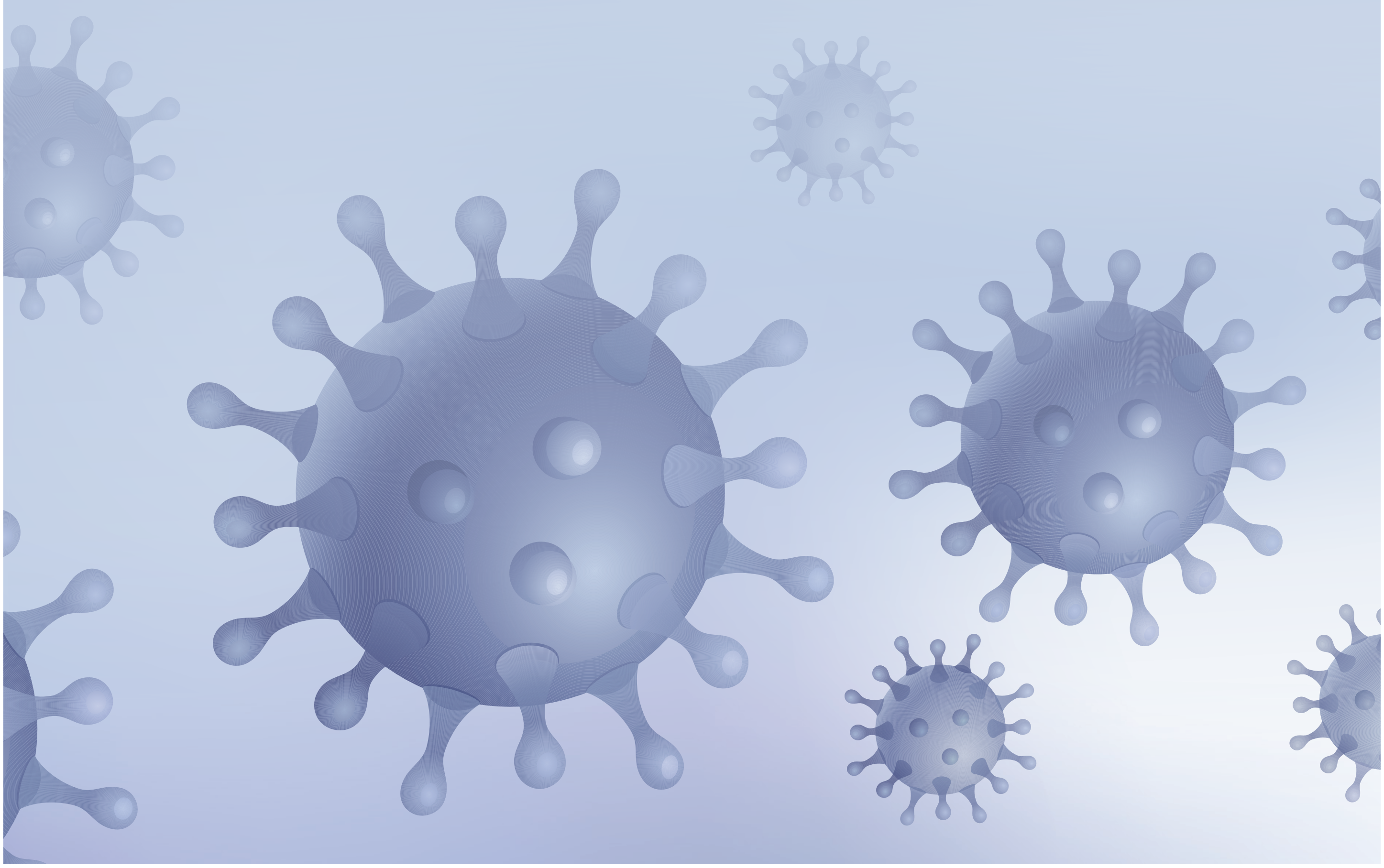
[1] The Secretary of Education's website includes work and notes from the State STEM Education Commission meetings.

STEM in an Era of a Pandemic

COVID-19 has helped change our outlook in regards to STEM. STEM is more than education and workforce development; it is about STEM literacy for everyone. Right now, we are experiencing a serious need to have a citizenry and culture that understands the integrated concepts of STEM. It is this understanding and education that will best support our ability to best survive and thrive in our evolving post-COVID.

STEM provides the platform where we can pull together the separate elements of the content we have learned while we were in schools and helps us better understand how we can best apply it, collectively, to any given scenario. In this case, that scenario is our daily lives during COVID-19 closures and restrictions. STEM literacy is for everyone and is as vital now as it ever has been. STEM literacy needs to be an educational attainment goal so that everyone can better understand the current COVID-19 environment. STEM is vital, not only to survive, but to also thrive through the changes that will come from this experience. Many of the problems we are experiencing within the initial COVID-19 spread within the United States are the result of people not knowing or understanding the STEM implications of the virus's impact and how it will affect our medical resources.

Now is the time to recognize the value of STEM for everyone. We just needed a moment like this to help us more clearly define how STEM impacts our daily lives. This unique period may very well change educational and community institutions. Nobody can deny the impact STEM literacy will have in all careers as well as our daily lives. Together we can make sure that everyone has opportunities to continue their growth, to improve, learn, and support the next generation of learners as they will need to seek a path forward. This impact is doubly true for those in school now since they had shortened opportunities to effectively and efficiently learn through institutions unprepared for a shift of this magnitude when they lost Spring 2020. Now is a time we can embrace STEM literacy as an opportunity to prepare better Virginians to move forward in STEM literacy and the preparedness to re-open Virginia with a refreshed viewpoint on what we all need to succeed.



Virginia STEM Tomorrow

Virginia has created a wealth of opportunities for youth to be engaged in STEM; however, these opportunities are not accessible to all Virginians. Many school divisions or Governor's Schools/Academies have created programs that have exceeded national standards academically or in creating unique learning opportunities for their students. Regional partners have created after school programs for select youth, including some of Virginia's nationally recognized research facilities. The problem is that these experiences have helped a privileged few. The small population that takes advantage of these experiences tend to be well-off; meaning they are informed about the programs, know how to apply, are supported by parents, are encouraged by their schools, and can easily afford the experience.

Virginia's excellent STEM offerings are not available for all youth. Many schools have limited the experiences to gifted youth, students that choose to take select electives, or have transportation to bring them home after their out-of-school time clubs meet. Virginia needs to take this time to ensure that all students have quality exposure to STEM programs and opportunities and have a chance to see how STEM impacts their daily lives. All youth need exposure to the wide variety of STEM skill jobs and careers. These opportunities not only provide an understanding of how the skills learned in the class setting can be applied to the future workforce, but it also creates opportunities to see how you can stay within your community/region and find valued gainful STEM employment.

STEM Commission members looked at national and international models that include a variety of strategies that have succeeded as well as a few that have failed. Members have participated in the Battelle STEMx partnerships as well as STEM Ecosystems. They have worked with the STEM Alliance and other professional education organizations. The main outcome is that there is not a consistent message between larger entities. Some states have adopted a form of a State STEM Network to ensure that access exists for all youth; however, the implementation of the models may look different between the STEM 'Hubs.' This report lists out a start of what Virginia can do to ensure that we provide STEM experiences, opportunities, and growth potential for all Virginians.

Four Focus Areas

The STEM Education Commission created four subcommittees to help research and write sections for the full STEM Plan. The subcommittees included STEM Literacy; Equity, Inclusion & Access; Workforce Pipeline; and Creating Sustainable Partnerships. The subcommittees and their guiding questions were:

STEM Literacy
What can we do to build support for STEM education and community literacy? STEM Literacy should tie into the Virginia Department of Education's STEM goals.

Equity, Inclusion, and Access
How are we going to ensure that STEM is for all? How will we work with schools and communities to make sure resources, programming, and support is provided for everyone and that everyone is encouraged to identify with STEM in their everyday lives?

Workforce Pipeline
How do we create effective models/methods to help bridge the workforce with PK-12 schools? How do we support better communication networks that help youth and educators to connect STEM programming to real careers and college opportunities?

Sustainable Partnerships
In what ways could we build better bridges between schools and communities, including non-profits, afterschool, informal education, etc., so that the STEM opportunities are supportive of one another and help sustain future efforts?

The four separate groups worked over many weeks and, through a multitude of smaller meetings, created four informative reports that will help identify some of the biggest obstacles, some potential solutions, action steps, and even measures for success. These reports include recent research helping us develop a plan with a foundation in best practices as well as a clear pathway helping us avoid pitfalls other states and organizations have come across. They also compiled a database of research looking for best practices and issues to avoid regarding their topics and problem statements/solutions. Summaries of these four Subcommittee reports can be found in the appendix.

STEM Literacy

STEM literate individuals can use concepts from science, technology, engineering, and mathematics to understand complex problems and innovate with others to solve them. A STEM literate person considers how STEM can improve the social, cultural, economic, and environmental conditions of their local and global communities. The committee identified problem statements in four significant areas: K-12 Education, Higher Education, Informal Education, and Network systems. Network systems are the lead challenge since it is vital to the success of STEM in Virginia, as together, we can do more than when we stand alone.

Equity, Inclusion, and Access

A variety of factors lead to inequities in student exposure and interest in STEM, the development of STEM skills, and the pursuit and attainment of STEM degrees and careers. Inequities occur over many demographic measures, including zip code, economic, race, gender, English-learner, and disability status, and have led to a lack of diversity in many STEM professions.

The current COVID-19 situation has shone a bright light on, and exacerbated some of these inequities, especially regarding broadband access, teacher and district readiness for distance learning, and family capacity for supporting distance learning from home (Goldstein, 2020).

Building equity in STEM will require an expansion of STEM opportunities across schools, school districts, community colleges, and universities across every region of the Commonwealth to reach all students. It will also require intentional outreach to students from disadvantaged backgrounds and those who are under-represented in STEM, who might not be aware of, or feel they belong on, STEM pathways. We can reach these students by pursuing a variety of strategies at the local, regional, and state levels.

Workforce Pipeline

Workforce pipeline identified several disconnects that may help exacerbate some of the problems that create potential 'bottlenecks' in the pipeline preventing people from identifying themselves as potential STEM candidates. Being a STEM Candidate includes STEM options in school as well as career. Workforce Pipeline broke their work down into three general categories.

- Educators and skill development impact the effectiveness of any STEM initiative, curriculum, or program that is anchored in quality training and expertise of teachers in the classroom.
- Coordination among partnerships that includes crucial workforce development contributors, education sectors, nonprofit and public agencies, and industry partners is lacking. The result is missed opportunities to leverage shared creativity, expertise, and resources in pursuit of common priorities.
- Disconnectedness between STEM pathways and pipelines exist. We should stay abreast of current and future pipeline needs, and challenges with pathway implementation results in a general difficulty/inability for education systems to respond to market needs with a timely and scalable strategy.

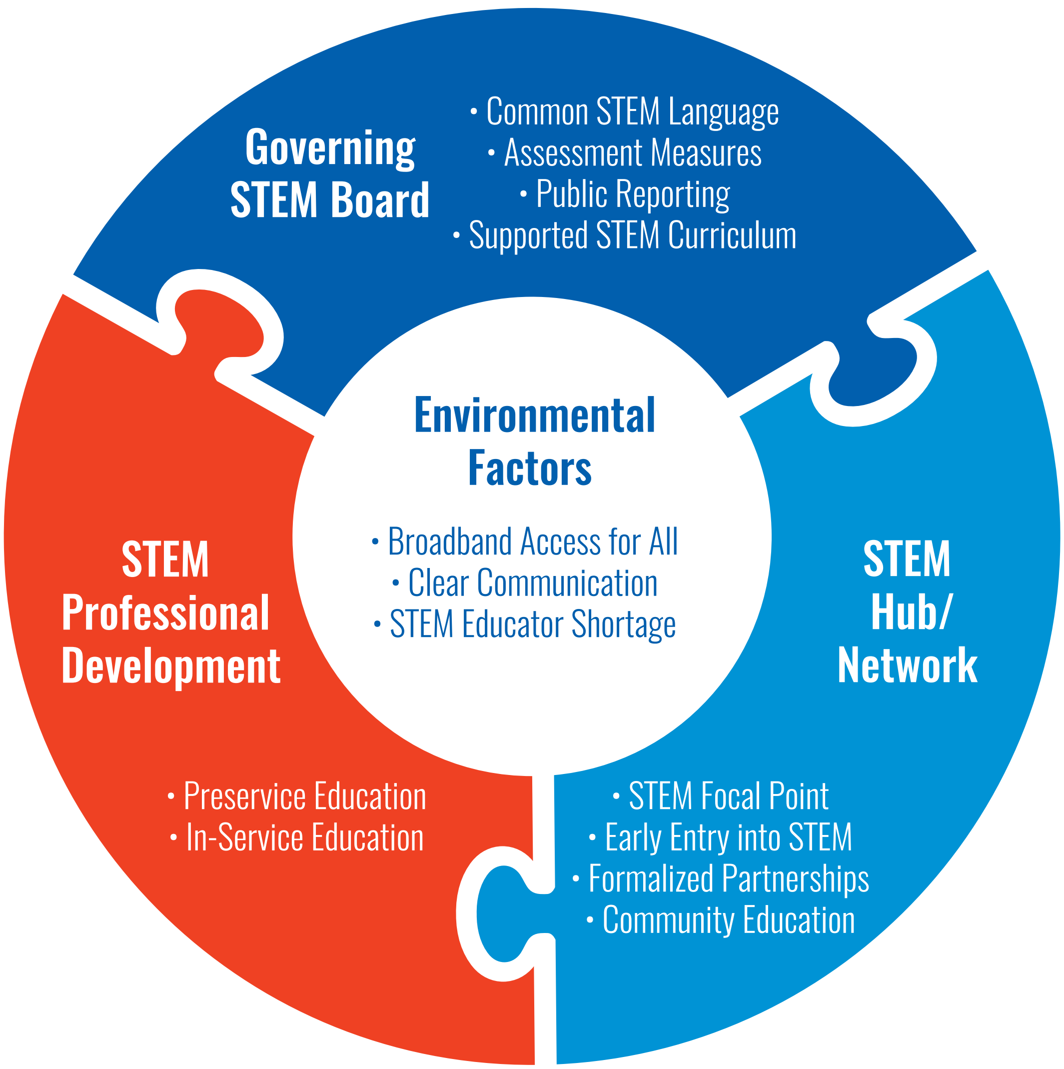
Sustainable Partnerships

High-quality STEM education opportunities for all are essential to ensure that all Americans can participate in our technological world, advance our nation's innovation economy and build a collaborative, equitable, and inclusive community (Handelsman & Smith, 2016). Further, Virginia's New Economy is predicated on the development of a STEM workforce to fill current jobs, as well as the jobs of the future. However, regional differences in terms of culture, educational and economic opportunities, resource availability, and infrastructure underscore the need for a concerted effort to address this challenge by intentionally advancing STEM learning across the entire state (Virginia Economic Development Partnership, 2017).

Potential Solutions

The STEM Commission came up with a variety of next steps. Many of the solutions addressed problems identified across the Subcommittees and echo the whitepaper strategies, revealing a streamlined set of solutions that potentially solve numerous identified problems and optimize many of the affordances already in our Commonwealth.

The Subcommittees' solutions are organized in a way that fits a potential model that will address the potential solutions. The three main categories are possible solutions and include the Governing STEM Board, STEM Hub/Network, and STEM Professional Development. Under each of those main categories are other potential solutions. This graphic provides a means to organize the solutions in a manner that can be most easily executed. There is a fourth category that is not one of the solutions but recognized conditions for success: environmental factors. These conditions include things that have a significant influence on the effectiveness of the solutions outlined in the graphic. The Commission believes that we can help influence these conditions, but they are most likely outside of our control (Broadband access for all and STEM educators which refer to a teacher shortage problem) or an area we need to support, but does not provide a direct solution (clear communication). If possible, these would be opportunities for the continuation of the STEM Governing Board to partner with other groups looking to address these issues.



Governing STEM Board

The STEM Commission should dissolve after the submission of the State STEM Plan, and a smaller Executive committee should be created as a Board for a State STEM Coordinator.

- **Common STEM Language**
  The variety of ways in which the term STEM has been used diffused the potential power it has within the communities across Virginia. If we have a common set of terms that everyone should recognize, it will strengthen the intent and purpose for proposing a State STEM Plan and improve equity, inclusion, and access for all students.
- **Assessment Measures**
  The STEM Committee needs to create comprehensive structures to collect and share longitudinal data across PK-12, higher education, and the workforce in a consistent and clear manner that will help understand and support student transition and retention.
- **Public Reporting**
  An annual STEM report should be made so the entire State can see the growth and progress of STEM efforts.
- **Supported STEM Curriculum**
  There are a plethora of STEM resources online, but they do not necessarily adhere to Virginia's expectations of quality STEM programming.

STEM Hub/Network

Multi-sector partnerships at the local, regional, and state levels are foundational for success for basic STEM literacy as well as workforce development.

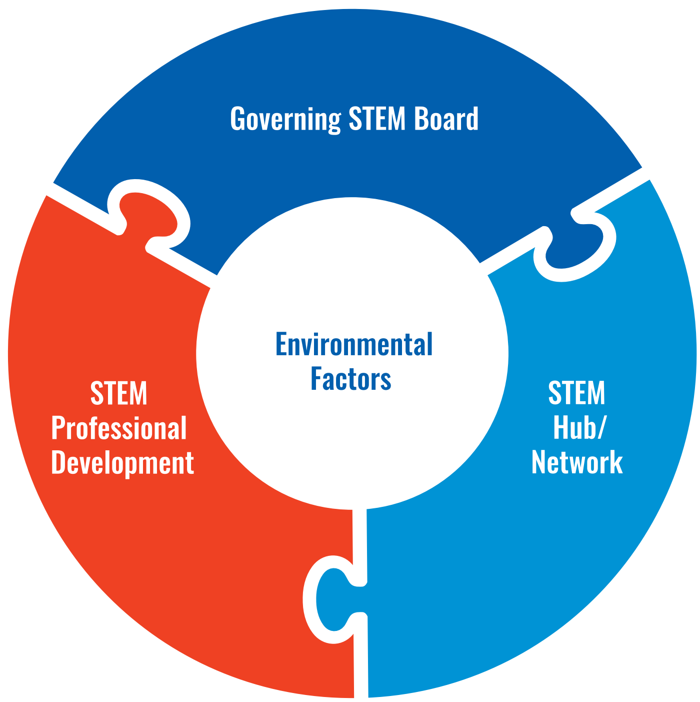
- **STEM Focal Point**
  A publicly accessible website/database sharing STEM resources and opportunities should be available.
- **Early Entry into STEM**
  STEM Education should start at a young age so youth can start with identifying themselves within STEM roles. Early Childhood Education needs to be included in State STEM efforts.
- **Formalized Partnerships**
  Formalizing partnerships helps alleviate some of the misunderstandings, false expectations, or for the partnerships to feel one-sided or dependent on one or two leaders.
- **Community Education**
  Community based offerings to learn more about available STEM advances, learning activities, and careers provide channels of communication to support STEM literacy and support.

STEM Professional Development

- **Preservice Education**
- **In-Service Education**

Environmental Factors

- **Broadband Access for All**
  Broadband may not be a direct solution tied to STEM; however, it is a hindrance to equity, inclusion, and access when most of the STEM resources are available online.
- **STEM Educator Shortage**
  Virginia, as well as all surrounding states, suffer from educator shortages. There is no unified licensing mechanism to ensure STEM educators are adequately prepared and qualified.
- **Clear Communication**
  Clear, efficient, and effective education is a major obstacle in many communities. While the State is looking to implement a common language and rubric for STEM, communication is a vital tool for all stakeholders.

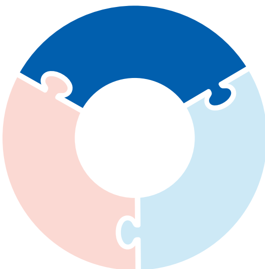


Appendix B provides additional summaries of these potential solutions. The Subcommittee Research Summaries (appendices D-G) provide more detail, research, and in some cases, implementation proposals.

Next Steps

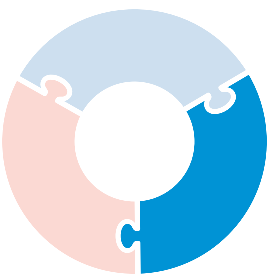
The following steps create the most significant impact toward a unified STEM Plan for Virginia, with the least investment. It was the pathway that appeared most logical given the variety of priorities that have emerged due to COVID-19.

Governing STEM Board



This group needs to continue to be a bridge between the State levels of education, connecting the Secretary of Education, Department of Education, Governor's Office, and potential funders looking at creating a Statewide Impact. This Governing STEM Board, or Executive Committee, can be assembled in three different formats: a State agency, a contracted agency, or an independent non-profit. We recommend that in the short term that the work continues as an endorsed STEM Board with the support of the Secretary of Education's Office and under the leadership of existing STEM Coordination supported and hosted by the Science Museum of Virginia. This group would work with various stakeholders to create, endorse and communicate a consistent common language and assessment measures for STEM Education, STEM Literacy, and what constitutes quality STEM programming in partnership with the Virginia Department of Education. This Board would also work with the Virginia Department of Education to make sure that there is an endorsed, supported STEM set of lessons, programming, and sample curriculum. Lastly, the Committee would be responsible for communicating the impacts of the STEM efforts through data collection and analysis. The culminating product would be a report for the Governor's Offices as well as a public-facing report to help everyone understand the impacts throughout the Commonwealth.

STEM Network/Hubs



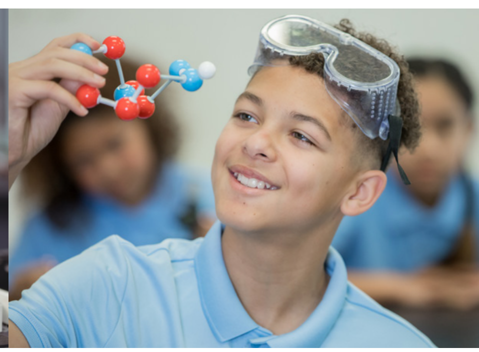
Numerous states have developed a 'hub' network or ecosystem to help develop and disseminate STEM language, communication, and programming. It helps create a more relevant localized voice since the State has a breadth of STEM understanding and connections. It helps the Tidewater region understand STEM in their everyday lives and what separates that from the coal and agricultural focus in the west or the technology focus in the north. It is also a means to develop best practices and identify pitfalls to share with other 'hubs' across the State. Many of the prosperous state models created a 'call for proposals,' so the 'hubs' are smaller partnership networks that apply to be the central point for the STEM work within a region. The call for proposals would be the ideal direction to move Virginia towards; however, in the shorter term, it would make sense to kick off some of the programming with organizations that have started some of these efforts already. There are small versions of these 'hubs' identified through the work done at some of our state universities including, Virginia Tech, Virginia Commonwealth University, James Madison University, Old Dominion University, George Mason University/Northern Virginia Community College (student-focused). We should work on developing what we want out of a STEM hub with these existing partners and looking at the proposal process used by states such as Oregon, Iowa, Tennessee, and others.

These 'hubs' would also be a focal point for STEM in the communities, sharing with the public STEM opportunities for afterschool/out-of-school-time programming, professional development, community programming, or even newsletters. The hubs would be a means to highlight STEM experiences, internships, jobs that are local, so people can identify STEM as something that impacts them, not just people in other places. The hubs can also determine the best way to engage families and youth, knowing that different approaches, sites, and models may work better for different audiences. It is also a way to take advantage of resources locally to help create engaging experiences for younger children. These local networks are also the best pathway for building more robust, sustainable partnerships. It is a way to ensure that people know each other and can more easily identify what all involved parties should expect out of formalized relationships. The Governing STEM Board could help facilitate the conversations, but unless the partnership is designed to impact the entire Commonwealth, the formalized partnerships should be local. Fundraising should also follow the same format. Statewide investments should flow through the STEM Board for distribution, but local networks should work with their regions, or even develop cross partnerships between multiple network regions. All of this should be communicated through the network to prevent overlaps, but this will easily tighten the structure of current programming and fundraising overlap.

STEM Professional Development

This category includes a variety of educational opportunities: preservice education, in-service education as well as opportunities for lifelong learning for the public or youth outside of the formal educational setting. Creating a strong and capable STEM learning model and professional development will provide opportunities to help streamline efforts between higher education, professional development, community programming (from Museums to Boys & Girls Clubs), and state agencies such as the Virginia Department of Education. The first task would be an explicit adoption of what is expected in STEM Education to not only help universities but public education and public programs. This adoption would impact the training for future educators, whom we should recruit, and how we prepare them. It would help mold the development of professional development in-service programming for existing educators as well as administrators and counselors.

The most substantial ties are in preparing future STEM educators or continuing educational enrichment opportunities for current educators, which is often ties to colleges and universities. Competition exists at all levels, but in researching existing programs around Virginia, significant communication gaps were discovered between colleges at the same university, creating significant overlaps in programming, efforts, time, and money. STEM changes in PK-12 may also impact colleges and universities admissions, changing what is accepted as high school STEM classes, but do not currently fit within the current class code structure for high school credit on transcripts. This model will also help align the efforts for all of the State's higher education partners, especially if they plan to be a STEM Hub, which places the higher education center as a focal point for professional development and community programming.


Summary

Virginia is a leader in education, both PK-12 and in teacher preparation. We are consistently recognized as a leader in business. We are in position to maintain these leadership roles as we continue to evolve, creating new and innovative ways to engage our youth in preparing them for the workforce of tomorrow. We need to prepare for a future yet to be defined. We need to prepare a vision that includes the partnerships, the communications the supports needed to help us swiftly move into position as our understanding of what is needed in education, what is needed for future employability continues to move. This is a step in the right direction to help mobilize a Commonwealth-wide initiative so we are creating the much-needed collaborative impact for these changes, rather than competing for the dollars. This is a chance to allow each region, each lead institution to maintain their voice, yet work towards a unified vision that starts here, and continues to advance as the Governing STEM Board continues its work with people across the State.

Special Acknowledgements and Thanks

Virginia Science, Technology, Engineering, and Math (STEM) Education Commission

Blair Blanchette of Richmond, Outdoor Field Educator, Chesapeake Bay Foundation

Dr. Al Byers of Chesterfield, Visiting Scholar for STEM Education, Virginia Commonwealth University

Dr. Jared A. Cotton of Chesapeake, Superintendent, Chesapeake Public Schools

Marie T. Culver of Virginia Beach, Gifted Resource Teacher, Virginia Beach City Public Schools

Rebecca Dovi of Henrico County, Director of Education, CodeVA

Charles English of Midlothian, Virginia STEM Coordinator, Science Museum of Virginia

Dr. David Eshelman of Midlothian, Director, Workforce Development and Initiatives, Virginia Department of Education

Todd Estes of Williamsburg, Director, Career Education Programs and Workforce Partnerships, Virginia Community College System

Jocelyn Forest of Halifax County, Educator, Halifax County High School

Megan Graybill of Salem, Computer Science Teacher, Salem City Schools

The Honorable Megan Healy of Richmond, Chief Workforce Development Advisor to the Governor, Commonwealth of Virginia

Dr. David C. Jeck of Marshall, Superintendent, Fauquier County Public Schools

Dr. Barbara Kanninen of Arlington, School Board Member, Arlington Public Schools

Matt Kellam of Henrico, Military and Recruitment Program Coordinator, Dominion Energy

Bobbie Greene Kilberg of McLean, President, and CEO, Northern Virginia Technology Council (NVTC)

Helen W. Kuhns of Virginia Beach, Assistant Director and Pearl Programs Coordinator, Lynnhaven River Now, and Executive Board Member, Virginia Association for Environmental Education

Dr. Pamela Leigh-Mack of Chester, Professor and Chair, Department of Engineering and Computer Science, Virginia State University

Louie R. Lopez of Bel Air, Maryland, Director, STEM Education and Outreach, United States Department of Defense

Dr. Emily Loving of Chesterfield, Lead STEM, and Secondary Science Specialist, Chesterfield County Public Schools

Dr. Susan Magliaro of Christiansburg, Professor Emerita, Virginia Tech

Dr. Tina Manglicmot of Newport News, Chief Academic Officer, Newport News Public Schools

Kate Matthew of Charlottesville, Senior Research Specialist, University of Virginia

Margaret Mayer of Glen Allen, Managing Vice President – Technology, Capital One

Dr. James A. Meyer of Spotsylvania, Representative, Virginia School Boards Association

Pamela Northam of Richmond, Former Science Educator, First Lady of Virginia

Dr. Keisha Pexton of Hampton, Director of Learning and Workforce Development, Newport News Shipbuilding and Member, Virginia Board of Education

Angela Patton of Chesterfield, Founder, Camp Diva and CEO, Girls For A Change

James Pohl of Virginia Beach, Chief Academic Officer, Norfolk Public Schools

Dr. Tinell L. Priddy of Leesburg, Principal, The Academies of Loudoun, Loudoun County Public Schools

The Honorable Atif Qarni of Prince William, Secretary of Education, Commonwealth of Virginia

Casey M. Roberts of Chesapeake, Executive Director, New Horizons Regional Education Centers

Eric Robertson of Minneapolis, Minnesota, Global Education, Amazon Web Services (AWS)

Paula Fisher Robinson of Newport News, Assistant Director of College Access and PK12 Outreach, State Council of Higher Education for Virginia (SCHEV)

Krystal Rubio of Colonial Heights, Student, CodeRVA Regional High School

Amy Sabarre of Rockingham County, Director of STEM Education, Harrisonburg City Public Schools

Kamaljeet Sanghera of Fairfax, Executive Director of STEM Outreach, Volgenau School of Engineering at George Mason University

Dr. Matthew W. Shields of Charlottesville, Teacher, Charlottesville City Schools

Troy Simpson of Chatham, Director of Advanced Manufacturing, Institute for Advanced Learning and Research

Zuzana Steen of Manassas, Academic and Community Relations Manager, Micron Technology, Inc.

Lily Toombs of Charlotte County, Student, Virginia Council on Women's 2019 STEM Essay Contest award recipient

Clayton Turner of Hampton, Director, NASA Langley Research Center

Jorge Valenzuela of North Chesterfield, Educational Coach, and Teacher, Lifelong Learning Defined and Old Dominion University

Amy Stinnett White, MS of Buchanan, Dean, School of STEM, Virginia Western Community College

Elizabeth (Beth) Wright of Abingdon, Associate Professor of Nursing, Virginia Highlands Community College

Support for the Virginia STEM Commission and its work to develop a State STEM Plan includes partnerships and funding from, and state partners such as the Science Museum of Virginia, 4-VA STEM program, Virginia's Secretary of Education, and the First Lady's Office. Host locations for meetings include James Madison University, Virginia Commonwealth University, the Chesapeake Bay Foundation's Brock Environmental Center.

The STEMx Rural Tour meetings to collect voices from rural Virginians were supported by the STEMx/Battelle Challenge Grant and the rural STEM gatherings were hosted by the Southwestern Virginia Center for Higher Education, the Danville Science Center, the University of Mary Washington Dahlgren Campus and Rappahannock Community College Warsaw Campus. The writing for the STEM Plan was supported by the STEM Commission members listed above.

References

Bybee, Rodger W. The Case for STEM Education: Challenges and Opportunities. Arlington, Virginia: National Science Teachers Association, 2013.

Byers, A., Cresawn, K., Edmondson, E., Jones, R., Maeng, J., Magliaro, S., Newbill, P., Seshaiyer, P., Webb, A., Wheeler, L. (2020) Developing a Virginia STEM Network.
https://soe.vcu.edu/media/school-of-education/pdfs/4-VASTEMNetworkWhitePaper3-6-2020.pdf
Retrieved June 4, 2020

Carnevale, A., Smith, N., & Melton, M. (2014). STEM State-Level Analysis. Georgetown University Center on Education and the Workforce.
https://cew.georgetown.edu/wp-content/uploads/2014/11/stem-states-complete-update2.pdf.
Retrieved November 5, 2019

Cohn, S. (2019). These are America's Top States for Business in 2019. CNBC.
https://www.cnbc.com/2019/07/10/these-are-americas-top-states-for-business-in-2019.html
Retrieved June 22, 2020

Committee on STEM Education, National Science & Technology Council, the White House (2018). Charting a course for success: America's strategy for STEM education. Washington, DC. **https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf**
Retrieved December 3, 2018.

Goldstein, Dana, "Research Shows Students Falling Months Behind During Virus Disruptions: The abrupt switch to remote learning wiped out academic gains for many students in America and widened racial and economic gaps. Catching up in the fall won't be easy." New York Times, June 5, 2020.

Graf, N., Fry, R., & Funk, C. (2018). "7 Facts about the STEM Workforce." Pew Research.
https://www.pewresearch.org/fact-tank/2018/01/09/7-facts-about-the-stem-workforce/
Retrieved August 5, 2020

Handelsman, J., & Smith, M. (2016). STEM for All: Ensuring high-quality STEM education opportunities for all students. Washington, DC: Office of Science, Technology and Mathematics. Retrieved from: **https://obamawhitehouse.archives.gov/blog/2016/02/11/stem-all**.

Liebowitz, S. & Kelly, M. (2018). Fixing the Bias in Current State K-12 Educational Rankings. Policy Analysis, Cato Institute.
https://www.cato.org/sites/cato.org/files/pubs/pdf/pa-854-updated.pdf
Retrieved June 22, 2020

Liverman, E. (2020). 2018-2019 Marks Continued Growth of Bachelor's Degrees and STEM-H Credentials in Virginia. SCHEV Press Release
https://www.schev.edu/index/agency-info/media-center/news-releases/press-release-list/schev-news/2020/01/03/2018-19-marks-continued-growth-of-bachelor's-degrees-and-stem-h-credentials-in-virginia
Retrieved June 24, 2020

National Association of Colleges and Employers. STEM Majors Projected to be Class of 2019's Top Paid. January 9,2019.
https://www.naceweb.org/job-market/compensation/stem-majors-projected-to-be-class-of-2019s-top-paid/
Retrieved August 5, 2020

Sondergeld, T. A., Johnson, C. C., & Walten, J. B. (2016). Assessing the impact of a statewide STEM investment on K-12, higher education, and business/community STEM awareness over time. School Science and Mathematics, 116(2), 104-110.

STEM Ecosystems
https://stemecosystems.org/
Retrieved June 24, 2020

STEMx Partnerships
https://stemx.us/
Retrieved June 24, 2020

Swanner, N. (2018). Best States for STEM Job Opportunities, Ranked.
https://insights.dice.com/2018/03/26/best-states-stem-jobs-opportunities/
Retrieved June 22, 2020

U.S. News and World Report. Best STEM High Schools.
https://www.usnews.com/education/best-high-schools/national-rankings/stem
Retrieved June 24, 2020

Virginia Department of Education
http://www.doe.virginia.gov/instruction/stem/index.shtml
Retrieved January 24, 2020

Virginia Economic Development Partnership (2017). 2017 Virginia Economic Development Partnership strategic plan. Retrieved from **https://www.vedp.org/strategicplan**.

Virginia Governor's Executive Order #36.
https://www.governor.virginia.gov/media/governorvirginiagov/executive-actions/EO-36-Establishment-of-the-Virginia-Stem-Education-Commission.pdf
Retrieved July 17, 2019

Virginia Secretary of Education STEM Website with Commission Dropbox information
https://www.education.virginia.gov/initiatives/stem/
Retrieved June 22, 2020

Virginia STEM Summit Website
https://ceni.icat.vt.edu/va-stem-summit.html
Retrieved March 3, 2020.

STEM Plan Appendices Table of Contents

STEM Plan Appendix A: Subcommittee Report Summaries

STEM Literacy

STEM literate individuals can use concepts from science, technology, engineering, and mathematics to understand complex problems and innovate with others to solve them. A STEM literate person considers how STEM can improve the social, cultural, economic, and environmental conditions of their local and global communities. Building on the recommendations in the white paper *Developing a Virginia STEM Network* (2020), and ongoing collaboration through the STEM commission meetings, the subcommittee for STEM literacy for all has addressed and expanded on five of the seven strategic recommendations (page 1 of the whitepaper and listed in potential solutions of this document). The committee identified problem statements in four significant areas: K-12 Education, Higher Education, Informal Education, and Network systems. For each problem statement, there is a rationale and broad solutions. Network systems are the lead since it is vital to the success of STEM in Virginia, as together, we can do more than when we stand alone.

- **Network Systems**
  - While regional STEM collaboration is happening in pockets, there is a need to systemize and provide support and structure to regional STEM efforts.
- **PK-12**
  - Across the Commonwealth, there needs to be a better, more formal system to provide policy, teacher preparation, and accountability guidelines related to assessing, implementing, and revising STEM teaching and learning to produce STEM literate students.
  - Engineering is a critical component of STEM education and was recently added to the 2018 VA Standards of Learning (SOLs) for Science; however, the habits of mind, practices, and engineering knowledge which can be clearer in its vertical alignment or more fully professionally developed for pre and in-service teachers.
- **Computer Science:**
  - There is an unprecedented need for immediate professional development for teachers, administration, instructional coaches, and school counselors on the topic of computer science education so they can more effectively guide the development of student’s skills and learning in this emerging and ubiquitous field of study.

- **Higher Education:**
    - All higher education institutions must collaborate both within their respective institutions between colleges/schools as well as across institutions in the Commonwealth. This collaboration would increase their STEM literacy offerings in teachers' preparation that will help to both enhance teacher content knowledge and their pedagogical practices for teaching STEM using an integrated approach.
    - Additional efforts are needed to align programs between PK-12 and post-secondary education that can help support successful student transitions. These efforts would provide opportunities for students at risk and underserved populations, to enhance content knowledge and competencies required for life-long learning through integrated STEM education.
    - Instruction in higher education needs to mirror practices outlined and recommended for PK-12 Education. There is a great need for understanding and pervasive implementation of STEM habits of mind, practices, competencies, and knowledge that can help students at institutions of higher education to make meaningful and interdisciplinary connections to relevant STEM education and learning. There is no cohesive formal system to provide preparation, accountability, and policy related to assessing, implementing, and revising STEM instruction to create STEM literate students in higher education.
- **Informal/Nonformal Education**
    - The connection between informal educational opportunities, experiences, and resources are not clearly aligned with formal education or with community partners and families regarding the efforts of STEM.

Equity, Inclusion, and Access

A variety of factors lead to inequities in student exposure and interest in STEM, the development of STEM skills, and the pursuit and attainment of STEM degrees and careers. Inequities occur over many demographic measures, including zip code, economic, race, gender, English-learner, and disability status, and have led to a lack of diversity in many STEM professions. The factors leading to inequities include:

- Varied STEM awareness, understanding, and/or emphasis across families, demographic groups, and regions;
- Opportunity gaps, including lack of access to quality early learning experiences, gaps in developing foundational STEM skills in PK-12, and access to rigorous STEM courses and experiences;
- Disparities in opportunities to keep the "spark" alive, build on the spark, and/or strengthen STEM skills, including access to camps, programs, clubs, competitions, and internships;
- Variation in educator capacity across schools and school districts, including potential teacher shortages in some STEM areas, gaps in STEM content knowledge, best-practice pedagogy, and/or cultural competencies; and

- Disparities in school and academic institutions' funding and resources available to students, including tools, technologies, and broadband.

The current COVID-19 situation has shone a bright light on, and exacerbated, some of these inequities, especially regarding broadband access, teacher and district readiness for distance learning, and family capacity for supporting distance learning from home (Goldstein, 2020).

Building equity in STEM will require an expansion of STEM opportunities across schools, school districts, community colleges, and universities across every region of the Commonwealth to reach all students. It will also require *intentional outreach* to students from disadvantaged backgrounds and those who are under-represented in STEM, who might not be aware of, or feel they belong on, STEM pathways. We can reach these students by pursuing a variety of strategies at the local, regional, and state levels.

- **Curriculum, Resources, and Educator Capacity**
  The curriculum, resources, and practices that teachers and faculty use every day in the classroom have profound impacts on students. They can invite, and they can disinvite, interest, and engagement. When students of color, for example, do not see STEM professionals of color in their learning materials, they feel disinvited. Similarly, when girls do not see STEM professionals in fields that are traditionally male-dominated, their interest, and even confidence, wains (White, 2018). We need to be *intentional* about providing curriculum materials and experiences that are inclusive, inviting, as well as engaging to all students. Students need to see STEM as being part of their daily lives and accessible to them. They need to see STEM professionals who look like them. To complete the invitation, school counselors, together with administrators and educators, must be available to encourage students to explore STEM pathways and support them along those pathways, including academic support and advising. Students' families must also have the opportunity to be engaged and informed about STEM and STEM pathways so that they can support and encourage their children.

  Fundamentally, all students must be given the opportunity to learn from high-quality teachers who have relevant STEM content knowledge. Teacher shortages in STEM fields must be addressed. Furthermore, all teachers, across subjects, need access to ongoing professional development and coaching in STEM-related content and pedagogy. In addition to content knowledge, educators need ongoing training and support in understanding and overcoming their implicit biases, as well as in cultural competence. Because the actions educators take can, unintentionally, derail a student's confidence, performance, and decision-making, it is important that they are supported in developing their understanding and awareness of their own biases and well trained and prepared with action steps. Furthermore, cultural competence training should impart an understanding of the factors that motivate under-represented populations toward STEM and provide tools for encouraging and supporting those students.

  It is important that <u>all</u> students develop the foundational STEM skills they will need to succeed. If gaps emerge in student learning, opportunities in STEM diminish. It is essential that the development of foundational STEM skills begins *for all students* in early childhood (Virginia Kindergarten Readiness Project, 2020) and continues into the elementary grades with developmentally appropriate math, science, and inquiry skill-building.

- **Disparities in Funding**
  Disparities in school funding and resources hinder STEM growth in communities where STEM opportunities and aspirations are most needed. In Virginia, there are school districts that spend approximately $20,000 per pupil, while there are others that spend less than $10,000 per pupil. While one might expect schools in low-income communities to receive extra resources, the reverse is often true. A U.S. Department of Education study found that 45 percent of high-poverty schools received less state and local funding than was typical for other schools in their district. (U.S. DOE Equity of Opportunity, 2020) This means that many of our most vulnerable school communities are being asked to do more with less. These gaps in funding and school resources require a commitment to equity and intentional human and monetary investments at the local, regional, and state levels supported by strategic partnerships.

Workforce Pipeline

Workforce pipeline identified several disconnects that may help exacerbate some of the problems that create potential 'bottlenecks' in the pipeline preventing people from identifying themselves as potential STEM candidates. Being a STEM Candidate includes STEM options in school as well as career. Workforce Pipeline broke their work down into three general categories.

- Educators and Skill Development
  The effectiveness of any STEM initiative, curriculum, or program is anchored in quality training and expertise of teachers in the classroom. Unfortunately, the talent pipelines for teachers with the knowledge, experience, and training are shallow and disjointed with the needs of industry and the 21st-century workforce needs. Here are two key barriers that have stymied the efforts of developing a robust STEM education experience for all students across Virginia:
  - A lack of opportunity, resources, and interested talent among several stakeholder groups has contributed to an incoherent strategy to recruit, retain, and develop a highly qualified STEM teacher corps.
  - Lack of state policy and legislation that modifies/removes barriers between the PreK-20 system and industry to create innovative consortiums (to scale) to drive curriculum development, teacher preparation programs, and bridges access to STEM-related employment opportunities.

- Partnerships and Community Resources
  A lack of coordination among crucial workforce development contributors, including education sectors, non-profit and public agencies, and industry partners, results in missed opportunities to leverage shared creativity, expertise, and resources in pursuit of common priorities. Developing the infrastructure needed to improve communication and collaboration among these actors will increase the likelihood of producing innovative, scalable workforce solutions.

- Pathways and Pipelines
  Disconnectedness between STEM pathways and pipelines exist. Not staying abreast of current and future pipeline needs and challenges with pathway implementation results in a general difficulty/inability for education systems to respond to market needs with a timely and scalable strategy.

Sustainable Partnerships

High-quality STEM education opportunities for all are essential to ensure that all Americans can participate in our technological world, advance our nation's innovation economy and build a collaborative, equitable, and inclusive community (Handelsman & Smith, 2016). Further, Virginia's New Economy is predicated on the development of a STEM workforce to fill current jobs, as well as the jobs of the future. However, regional differences in terms of culture, educational and economic opportunities, resource availability, and infrastructure underscore the need for a concerted effort to address this challenge by intentionally advancing STEM learning across the entire state (Virginia Economic Development Partnership, 2017).

At the regional and local levels, partnerships based on needs, having common vision and language, and have created specific plans for their work together have yielded great success in meeting the partnership goals and extending the longevity of the collaborations (e.g., STEM Ecosystems, 2019; Zinth & Goetz, 2016). That said, while partnerships are relatively easy to suggest as a solution, developing and sustaining partnerships are equally as challenging as the range of needs that we see across our Commonwealth. A myriad of problems beset even the most promising of partnerships. However, given the research on partnership development and sustainability, as well as the numerous program and partnership models available across the nation and our own state to replicate, the case is clear that to advance Virginia's STEM literacy and workforce goals for all citizens we must invest in the creation of an organized, coordinated, and financed partnership network system with accessible resources to launch, develop, and sustain productive collaborations.

1. How to launch a sustainable partnership?
2. How to develop a sustainable partnership?
3. How to sustain an effective partnership?

References

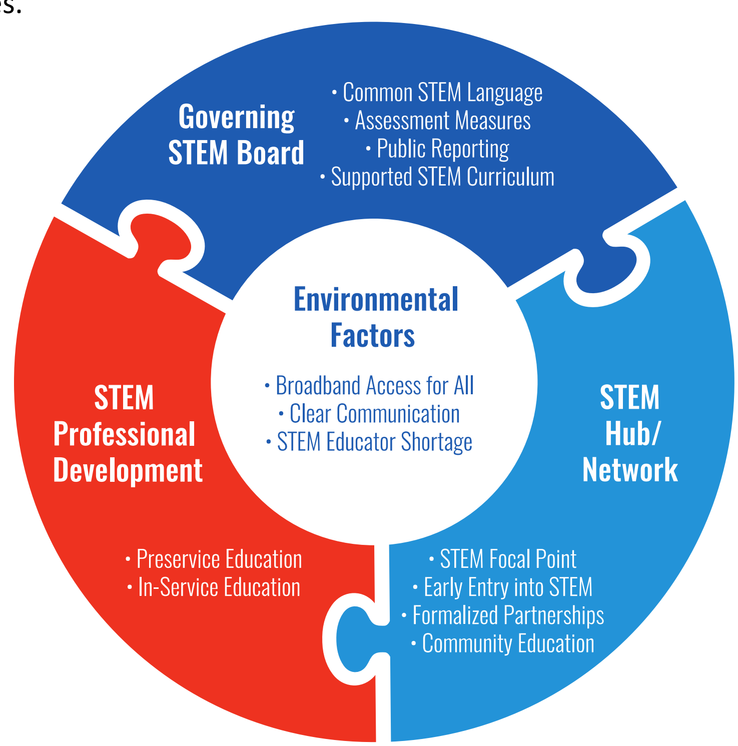
(in order of appearance except for the data and references in "Why STEM, why now? are listed in a separate section)

- Byers, A., Cresawn, K., Edmondson, E., Jones, R., Maeng, J., Magliaro, S., Newbill, P., Seshaiyer, P., Webb, A., Wheeler, L. (2020) Developing a Virginia STEM Network. https://soe.vcu.edu/media/school-of-education/pdfs/4-VASTEMNetworkWhitePaper3-6-2020.pdf
  Retrieved June 4, 2020
- Goldstein, Dana, "Research Shows Students Falling Months Behind During Virus Disruptions: The abrupt switch to remote learning wiped out academic gains for many students in America and widened racial and economic gaps. Catching up in the fall won't be easy." New York Times, June 5, 2020.
- Handelsman, J., & Smith, M. (2016). STEM for All: Ensuring high-quality STEM education opportunities for all students. Washington, DC: Office of Science, Technology and Mathematics. Retrieved from: https://obamawhitehouse.archives.gov/blog/2016/02/11/stem-all.
- STEM Ecosystems (2019). Building and strengthening STEM learning ecosystems: A growing guide to success. Retrieved from https://1va22l4dun7a16k87y2j3tfx-wpengine.netdna-ssl.com/wp-content/uploads/2019/09/ecoguide2019bookletR2.pdf.
- U.S. Department of Education Equity of Opportunity website
  https://www.ed.gov/equity
  Retrieved June 22, 2020
- Virginia Economic Development Partnership (2017). 2017 Virginia Economic Development Partnership strategic plan. Retrieved from https://www.vedp.org/strategicplan.
- Virginia Kindergarten Readiness Program.
  https://vkrponline.org/
  Retrieved June 24, 2020
- White, Gary, "Sex, gender, and physics, and the introductory physics classroom," Phys. Teach. 56, 580 (Dec. 2018).
- Zinth, J., & Goetz, T. (2016). A state policymaker's STEM playbook. Denver, CO: The Education Commission of the States. Retrieved from https://www.ecs.org/a-state-policymakers-stem-playbook/.

STEM Plan Appendix B: Potential Solutions Details

The STEM Commission came up with a variety of next steps. Many of the solutions addressed problems identified across the Subcommittees and echo the whitepaper strategies, revealing a streamlined set of solutions that potentially solve numerous identified problems and optimize many of the affordances already in our Commonwealth.

The Subcommittees' solutions are organized in a way that fits a potential model that will address the potential solutions. The three main categories are possible solutions and include the Governing STEM Board, STEM Hub/Network, and STEM Professional Development. Under each of those main categories are other potential solutions. This graphic provides a means to organize the solutions in a manner that can be most easily executed. There is a fourth category that is not one of the solutions but recognized conditions for success: environmental factors. These conditions include things that have a significant influence on the effectiveness of the solutions outlined in the graphic. The Commission believes that we can help influence these conditions, but they are most likely outside of our control (Broadband access for all and STEM educators which refer to a teacher shortage problem) or an area we need to support, but does not provide a direct solution (clear communication). If possible, these would be opportunities for the continuation of the STEM Governing Board to partner with other groups looking to address these issues.



- **Governing STEM Board**
  The STEM Commission should dissolve after the submission of the State STEM Plan, and a smaller Executive committee should be created as a Board for a State STEM Coordinator. The Governing Board can be established three different ways as seen in other state models:
    - as a state entity answering to a Governor's Office,
    - as a contracted agency to the Governor's Office, or
    - as an independent non-profit organization.

  The method of continuing a formalized STEM Committee has pros and cons tied to potential bias, whether political or geographical, fundraising capacity, and the potential to bridge different partners, from Virginia Department of Education to Universities and Governor's Office as a separate third party. All options enable this group to help communicate State goals, common language, and rubrics for quality and success as well as a means to communicate and share resources and talent.

    - **Common STEM Language**
      The variety of ways in which the term STEM has been used diffused the potential power it has within the communities across Virginia. If we have a common set of terms that everyone should recognize, it will strengthen the intent and purpose for proposing a State STEM Plan and improve equity, inclusion, and access for all students. The goal would be to align everyone's language so it cannot be identified as an extra-curricular option for gifted youth or specialized groups. STEM needs to be clearly defined and supported by the Governor's Office, Department of Education, and school districts. The support needs to help schools identify how they currently employ STEM programming and give them a short time to adjust their programming to meet the integrated expectations of STEM to help all of their youth. Universal terminology will also help create more alignment with after school/out-of-school-time programming, so it better supports what is happening within the school setting. Creating a common language also makes it easier to implement a common rubric for quality STEM and STEM programming, making it easier for educational leaders to understand the intent and outcomes of STEM. The aforementioned STEM Network and STEM Committee would be able to help communicate these shifts to ensure that Virginia has common goals, language, and expected outcomes.

    - **Assessment Measures**
      The STEM Committee needs to create comprehensive structures to collect and share longitudinal data across K-12, higher education, and the workforce in a consistent and clear manner that will help understand and support student transition and retention. Assessment tools need to establish common performance measures between K-12 and post-secondary education for both

quantitative and qualitative success that helps to capture student growth mindset beyond just content knowledge but also competency development.

- **Public Reporting**
  An annual STEM report should be made so the entire State can see the growth and progress of STEM efforts and target needs. It should be a clear, simple, and short report ensuring that it is easily accessible and available so we can all celebrate in the successes and help create a strong vested base in our continued efforts in STEM education and STEM literacy.

- **Supported STEM Curriculum**
  There are a plethora of STEM resources online, but they do not necessarily adhere to Virginia's expectations of quality STEM programming. Virginia needs a bank of resources that show appropriate connections to educational standards, integrated across disciplines, and represents the State's push towards deeper learning. These resources need to include the integration of computer science and engineering as well as Career and Technology Education (CTE) offerings when appropriate. Resources can be developed in partnership with other organizations such as CodeVA or by educators, showing the rigor and quality of our new STEM expectations. Resources also need to be available for informal/nonformal educational entities so they can also recognize the level at which STEM programming should be implemented in their given setting. Additional banks of resourcing should be available to parents so they can also participate with youth. All resources also need to ensure that it reflects the diversity of Virginia, supporting and modeling our diverse culture so all youth can identify themselves within the work, making it relevant and applicable.

- **STEM Hub/Network**
  Multi-sector partnerships at the local, regional, and state levels are foundational for success for basic STEM literacy as well as workforce development (NSB, 2020; Weld, 2017), especially across our regions in rural Virginia (Rural Virginia Initiative, 2018). Throughout our nation, partnership models are yielding positive outcomes for stakeholders when collaborations are launched based on needs, commitment, and evidence of a return on investment (e.g., statewide STEM networks, regional and local STEM ecosystems). Statewide STEM networks comprised of regional hubs to coordinate and support STEM experiences are reporting increased STEM and STEM career awareness, industry engagement, preparation of students, and opportunities for workforce development (Magliaro & Ernst, 2018; Sondergeld, Johnson, & Walten, 2016). Led by a state coordinator, these regional hubs facilitate communication through information sharing, aid in the development and support for partnerships, coordinate across hubs, facilitate the sharing of resources, and assist in conducting the evaluation of activity for continuous improvement.

- **STEM Focal Point**
  A publicly accessible website/database sharing STEM resources programming, and opportunities should be available. This database can be used to help schools and families identify ways to engage youth in STEM experiences.

- **Early Entry into STEM**
  STEM education should start at a young age, so youth can start with identifying themselves within STEM roles (Zinth, 2020). There are many ways to engage youth in pre-school settings and at home before kindergarten. The earlier we help youth identify themselves as a STEM capable and confident person, the easier it will be to maintain that enthusiasm and curiosity throughout the rest of their educational experience.

- **Formalized Partnerships**
  Formalizing partnerships helps alleviate some of the misunderstandings, false expectations, or for the partnerships to feel one-sided or dependent on one or two leaders. The use of common language aids in any work being done in STEM, supporting a clear understanding of the context of a STEM partnership. Quality partnerships need to take into account what is needed and what can be provided by all vested partners. Work-based opportunities to help expose either youth or even educators is a common partnership. When possible, internships should be paid, helping erase any exclusion due to transportation costs or needs, creating opportunities for all students. Externships for educators help them create more real-life connections to the content they teach.

- **Community Education**

- **STEM Professional Development**
  Professional development will be a major factor in the successful implementation of integrated STEM. It will require several major factors.
  1. STEM-specific cultural competency training to help them overcome biases and be intentional about encouraging all students to consider STEM pathways;
  2. Long term training, implementation, coaching and follow-up;
  3. STEM training emphasizing an integrated STEM methods approach for both pre-service and in-service educators.
  4. Professional development for guidance counselors and administrators. Guidance counselors need to understand better the options for students, career pathways, Career and Technical Education (CTE) options, and changing models for post-secondary education. Administrators need to understand the changing model, so they provide the support, and time, needed for STEM integration and the teachers of various disciplines to meet but also support the model advances when more traditional educators or parents need a clear understanding of the transformation. Professional development may take the form of micro-credentialing, helping support the implementation of this model with the

Department of Education and several Universities looking to include this model in their continuing education efforts.

5. Informal/nonformal educators should be included in some of the professional development offerings. If we are looking to create common language and understanding of STEM, as well as better partnerships, we should ensure that some of the learning opportunities include all interested stakeholders.

- **Environmental Factors**
  - **Broadband Access for All**

    Broadband may not be a direct solution tied to STEM; however, it is a hindrance to equity, inclusion, and access when most of the STEM resources are available online. COVID-19 has shown us the importance of online access, from education and telecommuting to household medical care. Both educators and students need to have access to online programming and services. The workforce of tomorrow is dependent on the successful implementation of computer skills, including understanding how to use online resources effectively, and the lack of those resources creates a greater divide between the educators and students that have access from those who do not have broadband access. There are several models to make this happen, including a baseline broadband need identified as a utility and companies being able to offer services above and beyond the baseline to cover some of their interests. As long as students lack this service, we cannot say that they will have equitable access to STEM programming and opportunities.

  - **STEM Educators**

    Virginia, as well as all surrounding states, suffer from educator shortages. STEM has a compounding issue with how we license qualified educators. Many university programs require a student to get a degree in their area of expertise before they get a master's in education to teach. The problem is that many of those fields pay more for a bachelor's degree than what they would make encumbering themselves with a master's degree and debt to make less as an educator. Virginia is looking at 4-year degree/teacher licensing options; however, the Commission wanted to seek other incentives to recruit and maintain educators in STEM fields and as STEM leaders.

  - **Clear Communication**

    Clear, efficient, and effective education is a major obstacle in many communities. While the State is looking to implement a common language and rubric for STEM, communication is a vital tool for all stakeholders. The STEM Network and STEM Committee would help ensure communication across the major invested sectors; however, the communication chain needs to be woven more deeply into the various influential factors invested in STEM. Clear communication structures need to be built between partners, between private and public sector partners. Communication could include something as simple as Memorandums of Understanding to help define expectations and measures for success. In the University setting, there is a need to collaborate within institutions between different colleges/schools and between institutions to align course offerings, dual enrollment opportunities, and expand certification opportunities for pre-service and in-service teachers. One option would be to create conferences or summits for cross-sector collaboration between higher education and K-12 to identify clear connections to shared outcomes and overlapping interests in research, professional development, or joint STEM literacy and curriculum initiatives.

References

- Magliaro, S. G., & Ernst, J. V. (2018). Inventory of statewide STEM networks. Center for Educational Networks and Impacts, Virginia Tech.
- National Science Board (2020). Vision 2030. Alexandria, VA: National Science Board.
- Ryan, J. E., Sands, T. D., & Abdullah, M. M. (2018). Moving rural Virginia forward: Ideas for action and investment. Retrieved from https://rga.lis.virginia.gov/Published/2018/RD374.
- Weld, J. (2017). Creating a STEM culture for teaching and learning. Arlington, VA: National Science Teachers Association.
- Zinth, J., Weyer, M., Atchison, B. (2020). Enhancing STEM in P-3 Education. Education Commission of the States Policy Guide

STEM Plan Appendix C: Developing a VA STEM Network Whitepaper Brief

As the STEM Commission started their work, five Universities worked together through a 4-VA grant to investigate some common STEM language and some additional research and advice for the STEM Commission. This group consisted of two STEM Commission members and worked with the Virginia Department of Education and Virginia STEM Coordinator. Their work culminated in a document that provided a lot of background and research that has proven useful to the STEM Commission's efforts. Below are three key conditions for Virginia STEM Success and seven strategic recommendations that would aid in this process. Their work is closely aligned with the potential solutions and next steps recommended by the Commission.

Developing a Virginia STEM Network Whitepaper (2020)
https://soe.vcu.edu/media/school-of-education/pdfs/4-VASTEMNetworkWhitePaper3-6-2020.pdf

Three Key Conditions for Success

- Active promotion of equity, access, and inclusion
- Collaboration across regions and sectors
- Sustainable infrastructure

Seven Strategic Recommendations

1. Seek consensus on "quality STEM" in terms relevant to this network.
2. Build a culture of STEM awareness with a focus on equity, accessibility, and inclusion.
3. Develop an accessible and thorough inventory of Virginia STEM activities.
4. Support sustainable network infrastructure.
5. Advance a communication plan.
6. Embed an evaluation plan that ensures annual assessment of network activities and operations.
7. Commit to long-term support and sustainability.

STEM Literacy Subcommittee
Research Summary

Committee Members: Amy Sabarre (facilitator), Dr. Jared Cotton, Jocelyn Forest, Matt Kellam, Dr. Emily Loving, James Pohl, Krystal Rubio, Jorge Valenzuela,

Virginia is for *all* STEM learners
Created by the subcommittee for STEM literacy For All, as part of the Governor's STEM Commission

Overview

STEM literate individuals are able to use concepts from science, technology, engineering and mathematics to understand complex problems and to innovate with others to solve them. A STEM literate person considers how STEM can improve the social, cultural, economic, and environmental conditions of their local and global communities (OER commons). Building on the recommendations in the white paper *Developing a Virginia STEM Network* (2020), and ongoing collaboration through the STEM commission meetings, the subcommittee for STEM literacy for all has addressed and expanded on 5 of the 7 strategic recommendations. The committee identified problem statements in 4 major areas: K-12 Education, Higher Education, Informal Education, and Network systems. For each problem statement there is a rationale and broad solutions. Each solution has suggested action items that are included as links. We will begin with Network systems as it is vital to the success of STEM in Virginia, as together we can do more than when we stand alone.

Network Systems

Problem statement:
While regional STEM collaboration is happening in pockets, there is a need to systemize and provide support and structure to regional STEM efforts.

Broad Solutions:
The following are the broad solutions that are recommended by this committee to create a system and network across the commonwealth to achieve the vision of STEM Literacy for all.

A. State: Identify and create a network of regional STEM hubs across the Commonwealth.
B. State: Create a governing Advisory board that connects stakeholders and regional hubs
C. Connect and support regional hubs though regular collaboration and through supporting

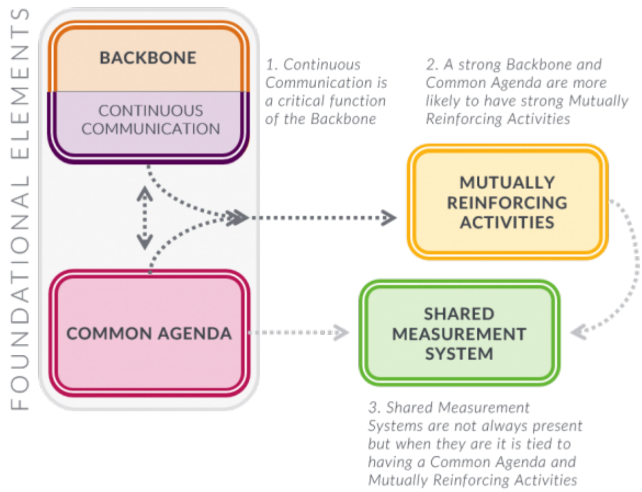
documents.

D. Create a 501C3 to support the STEM network and leverage our largest business sectors to support the work.

Across the Commonwealth, school districts are doing their best to meet all of the demands placed on K-12 education while simultaneously attempting to innovate and push instruction towards deeper learning. In addition, there are several active regions in VA where STEM collaboration is already happening. However, due to various limitations (i.e. location, poverty, expertise, and limited resources) some school divisions are unable to provide rigorous and meaningful STEM experiences for their students. It is important to provide equity across the Commonwealth as we look to “engage and networked communities of practice” (AIR STEM 2016, p. 7). Together school divisions can do more than when we stand alone.

Through activating the strategy of collective impact, and creating a statewide STEM network we can access systems thinking and collective knowledge management to achieve equity in Virginia (https://osln.org/about/faq/). Systems thinking is a STEM practice and describes how many parts in the system work together to achieve the desired effect. Through a network, we will be able to develop and enrich strategic partnerships and foster STEM ecosystems that unite communities. Regional hubs would allow for the blending and sharing of successful practices across the commonwealth and “more effectively leverage resources and expertise from strategic partners to provide seamless wrap-around support to prepare the workforce of the future” (Project 2061, p. 19). The research on collective impact is strong with five guiding principles: common agenda, shared measurement system, mutually reinforcing activities, continuous communication, and a backbone organization (Kania, Kramer, 2011).

In order for this plan to be enacted fully it will be very important to have a strong group of passionate and dedicated people to share the responsibility of the magnitude of this work. Collaboration is a key habit of mind in STEM education and no one entity can be successful in realizing the mission of this STEM Commission alone. There are many models of success found in other state STEM plans and Virginia can build on these models to create a system of stakeholders that help to carry this important work from isolated or pockets of innovation to scale so that it can ultimately impact each student's learning experience.



need reference

In order for regional STEM to flourish, it will be essential that they receive support both systemically and financially and that they can leverage regional partnerships to generate revenue. The grassroots efforts of this regional initiative can be enhanced through a systematic approach by providing some parameters while also allowing for the organic needs and unique needs of each region to flourish. Regions need all of the documents, rubrics and supports given to the schools in order to thrive. The regional hubs also need to know what the parameters are for regional STEM literacy support. Just as school districts and schools need to know what is expected to better align their work so do regional hubs. In addition it will be important to provide ongoing communication with the regions and to bring the leaders of those organizations together quarterly to share and collaborate. This group can provide a great deal of support to many of the initiatives that are set forth in this plan. The regional hubs will be instrumental in providing the much needed PD that is described by this committee. This will promote collaboration rather than competition throughout the regions. A professional organization could also result as part of this collaboration that would allow for STEM advocates to address policy that impacts STEM literacy for all.

A STEM network is a large undertaking and can not rest solely on the shoulders of the VDOE. Many of the solutions posed here will help ease that load, however, other successful STEM networks have created separate entities that live outside the public sector. These nonprofits allow for the network to fundraise and solicit donations from the largest companies and businesses in the state.

> “Backbone organization: A separate organization and staff with a very specific set of skills will need to serve as the backbone for the entire initiative. Coordination takes time, and none of the participating organizations has any to spare. The expectation that collaboration can occur without a supporting infrastructure is one of the most common reasons for failure.A more complete implementation of these conditions results in greater impact. Reflecting on their success, initiatives that achieved change in their target populations frequently prioritized two collective impact conditions: backbone support

and a common vision."(p.1) (Turner,S.,Merchant, K., Kania, J., Martin, K. 2012).

Additional action item suggestions network

K-12

Problem Statement:
Across the Commonwealth, there is no cohesive formal system to provide policy, teacher preparation, and accountability guidelines related to assessing, implementing, and revising STEM teaching and learning to produce STEM literate students.

The subcommittee recommends the following strategies to address this problem:

A. Regional collaboration: A robust professional development model composed of two frameworks must be created to include essential components of effective STEM lessons and sound pedagogy with knowledge of how students learn in tandem with strategies for lesson facilitation.
B. State: Create documents, protocols, and web presence as systems of support that address the inequities and misconceptions around how STEM is being implemented around the Commonwealth.
    a. Creation of a STEM rubric to support schools in evaluating practices, providing professional development and reporting to the state and a STEM school and school divisions designation.
    b. State/regional: Create a rubric to vett high quality exemplar STEM lessons based on the definition and outcomes of STEM literacy and engage regional partnerships and organizations to vett and share.
    c. State: Create a website that shares exemplar STEM models and repository of STEM lessons that integrate SOLS and ISTE standards.
    d. Create a STEM Endorsement/Certification/Micro Credentialing for teachers to earn as a part of their teacher certification.

Currently, in some regions of the state, there is a lack of teachers understanding of the logical interdisciplinary connections for relevant STEM Education, the pervasive implementation of STEM habits of mind, and working knowledge of how to implement evidence-based teaching strategies. For equitable access to STEM Education for all students in the Commonwealth to be possible, many K-12 educators need to be supported and feel confident to engage their students in integrative STEM activities that result in students who are STEM literate. Therefore, creating a formal system for policy, teacher preparation, and accountability are vital to creating STEM literate citizens across Virginia.

Several other reasons support this rational and strengthen the case for having a formal system to provide policy, teacher preparation, and accountability guidelines related to assessing, implementing, and revising STEM teaching and learning to produce STEM literate students within the Governor's STEM plan:

- STEM Education is clearly a major initiative in the Commonwealth but currently there is no explicit direction from VDOE on how all teachers can participate.
- The research suggests that effective elementary schools share common elements, namely, strong leadership, professional capacity among teachers, strong ties to parents and the community,a student-centered learning climate, and instructional guidance for teachers. These elements have been shown to support learning gains even in schools in areas of extreme poverty and hardship (p.25 NAP Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics).
- Relevant, systematic, and continuous professional development (PD) for effective teaching and learning is essential to preparing teachers for STEM education. According to Desimone (2009), educational reform depends on teacher professional development, which leads to improvements in students' learning experiences and achievement. Moreover, all PD is not created equal, and if teachers continue to struggle with appropriate pedagogical strategies for lessons following PD, then achieving mastery of STEM-related content will not positively impact the learning of all their students.
- Not receiving the appropriate PD causes frustration and negatively impacts the attitudes of teachers who are tasked with teaching STEM. As per Desimone and Phillips (2013), the effectiveness of PD depends on the interaction and confluence of teacher knowledge and beliefs, and the use thereof, to improve the content and the pedagogy of their instruction. Furthermore, Desimone and Garet (2015) explain that there are five key features that make professional development effective—content focus, active learning, coherence, sustained duration, and collective participation.
- As stated in the NAP work Successful K-12 STEM Education, the key elements of effective STEM instruction are: a coherent set of standards and curriculum teachers with high capacity, a supportive system of assessment and accountability, adequate instructional time, and equal access to quality STEM learning opportunities.
- There is more of an emphasis on reading and math instruction in Virginia with required testing at several grade levels and less of a focus on science. The focus and time spent on Elementary Science education has been diminished resulting in students who are less science literate and less likely to take advanced STEM coursework.
- There is very little guidance on what it means to have a high quality STEM learning experience. Some areas of Virginia have less economic resources and are constrained by location or other factors. Without investing in an infrastructure that supports STEM education this gap will continue to widen.
- There is a concern that STEM standards are not clearly defined and integrated throughout the K-12 content standards in Virginia. For example, Computer Science standards are separate from an assigned content. This causes teachers to see STEM as an extra subject rather than one that should be integrated throughout the curriculum. As a result, teachers are less likely to address STEM through daily instruction due to the current accreditation focus (mathematics and English: Reading) and limited time to address a significantly high number of content standards in a given school year.

Additionally, there is a need to enhance and develop relevant and equitable secondary STEM education CTE career pathways that provide all students in the Commonwealth knowledge of STEM for impacting their interest in STEM-related coursework and careers. The lack of a formal system of support for STEM education causes inequities throughout the state. Several other reasons support this rationale and strengthen the case for developing relevant and equitable secondary STEM education CTE career pathways that provide all students in the Commonwealth knowledge of STEM for impacting their interest in STEM-related coursework and careers.

In school systems struggling to implement career pathways, there needs to be better collaboration between CTE departments and school counselors to ensure that Academic and Career Plans for each student are followed through and articulate career interests, and secondary coursework in tandem with additional learning opportunities, industry credentials, work-based learning opportunities, and postsecondary options. To ensure that CTE teachers remain up to date and are teaching with industry-relevant knowledge and skills, there is also a need for increased industry partner support for teacher extended learning opportunities (i.e., externships).

Currently, many teachers in the Commonwealth lack both STEM content knowledge and the pedagogical strategies required for both effective lesson design and facilitation that is project based (Sabarre, 2019). Therefore, professional development (PD) that is relevant to the needs of the workforce, systematic, and continuous for effective STEM teaching and learning is essential to preparing teachers for STEM education. Darling-Hammond and others have echoed this need as they called for the STEM Professional Learning Standards as they are important indicators of excellence (Darling-Hammond and McLaughlin, 1995; Kaser and Bourexis,1999). As yet, there are no standards for providers of STEM professional learning; moreover, there are no standards for any provider in the integration of these subjects. Consequently, school districts and educators have no guidelines to identify quality professional STEM learning providers.(CA STEM plan).

This can be remedied by preparing teachers to instruct students in following diverse but systemic approaches to solving problems *(i.e., Engineering Design, Design Thinking, Computational Thinking, the IB design cycle, and an invention cycle).* This will enable more teachers to participate and enhance the K-12 STEM pipeline.

Furthermore, without this essential knowledge for teaching and learning STEM integratively, educators will have difficulty implementing STEM curricula and resources.

- Relevant, systematic, and continuous professional development (PD) for effective teaching and learning is essential to preparing teachers for STEM education. According to Desimone (2009), educational reform depends on teacher professional development, which leads to improvements in students' learning experiences and achievement. Moreover, all PD is not created equal, and if teachers continue to struggle with appropriate pedagogical strategies for lessons following PD, then achieving mastery of STEM-related content will not positively impact the learning of all their students.

- Not receiving the appropriate PD causes frustration and negatively impacts the attitudes of teachers who are tasked with teaching STEM. As per Desimone and Phillips (2013), the effectiveness of PD depends on the interaction and confluence of teacher knowledge and beliefs, and the use thereof, to improve the content and the pedagogy of their instruction. Furthermore, Desimone and Garet (2015) explain that there are five key features that make professional development effective—content focus, active learning, coherence, sustained duration, and collective participation.

A statewide PD model comprising two distinct frameworks could be developed and implemented in the regions by curriculum coordinators and instructional coaches in collaboration with school administrators, K-16 educators, STEM professionals, and academic researchers(AIR-STEM2026_Report_2016.pdf). STEM Educational PD should be sustained over a longer period of time (50 hours) in order to solicit real change in the curriculum and instruction of the teacher (French, 1997). This framework builds on research that recommends varied approaches to PD and that professional learning experiences should blend theoretical knowledge with practice and feedback(Knight, J., & Cornett, J. (2009).. In addition, this framework will include readings, active engagement, discussions, simulations, modeling, and feedback (Rice, 2001).

One framework will need to focus on essential components of effective STEM lessons and can be designed to help educators integrate the following items:

1. Activities with alignment to both the Virginia Standards of Learning (SOLs), Standards for Technological Literacy, and the ISTE standards technology standards for educators and students.
2. STEM content knowledge essential for investigation, inquiry and design for K-12 educators (i.e., *Engineering Design, Design Thinking, Computational Thinking, the IB design cycle, and an invention cycle).*
3. Guiding and leading questions designed for launching inquiry and design in STEM lessons.
4. Partnerships with industry partners for connections to STEM careers in lessons.
5. Relevant student products aimed at improving local communities.
6. Peer collaboration between students, along with project management and team roles for enhanced career connections.
7. Reflection for metacognition.

The second framework of the model will need to focus on sound teaching practices with knowledge of how students learn in tandem with strategies for lesson facilitation and can be designed to support the following components:

1. Educational philosophy for determining a set of beliefs about how students learn and how they should be taught.
2. Creating a school and classroom culture conducive to STEM teaching and learning.
3. Classroom management (student behavior and lesson activities).
4. Student assessment (knowing types of assessment and selecting appropriate ones for

various transfers of STEM knowledge).
5. Supporting student STEM learning with instructional scaffolds.
6. Strategies for differentiating instruction in STEM lessons.
7. Equity based practices to support restorative justice and social emotional learning (SEL) for designing for the greater good.

In order to reduce the inequalities that exist within our current system so that all students create, design, build, explore and collaborate there is a need to develop a common language to describe the work of STEM integration (US Department of Education, 2015; NAE & NRC, 2014). According to the State STEM coordinator, there are at least 15 different versions of the STEM acronym (STEAM, STEM-H, STREAM, iSTEM, etc.). STEM education has become a catch-all for many agendas. This committee has the opportunity to impact the clarity of what high quality STEM education is and further define the acronym.

A high-quality STEM rubric should be developed to support schools in evaluating practices, providing professional development, and reporting to the state and a STEM school designation. Other states such as North Carolina and Tennessee have long since moved in this direction and provide rubrics for STEM Schools of distinction. Virginia already has a proven track record of success with the creation of the 22 Governor's STEM Academies through the office of CTE. Building on this success, additional rubrics for elementary, middle, and high school STEM would clarify expectations and enhance and could be used to provide guidance to schools and districts, depending on where they are on the continuum.

Overall, schools across VA are doing their best to implement STEM and some are experiencing great success. However, with a lack of training and understanding and valid student assessment targets, many schools are missing the mark and are not fully harnessing the potential of STEM education for students. Additionally, Performance assessment (PA) has pushed VA schools towards more in-depth learning, and we can build on that success as PAs are a natural fit for assessing STEM learning.

- Among these same populations, a new digital divide also has emerged, resulting innotable inequities between "students who use technology to create, design, build, explore, and collaborate and those who simply use technology to consume media passively," with the educa-tional benefits of technology use reserved for students in the former group (U.S. Department ofEducation, 2015, p. 14; Warschauer, 2012).
- Finally, disparities in access and participation exist in the afterschool space as well, particularly between rural, urban, and suburban locations, with urban locations having the highest frequency of STEM-focused offerings (Afterschool Alliance,2014).
- Afterschool programs that serve higher income students also have more STEM activities than programs that primarily serve low-income youth (Afterschool Alliance, 2014). AIR-STEM2026_Report_2016.pdf
- Recommendation 2:" Need to develop common language to describe their work"STEM integration in K-12 p. 138

Research informs us that constructivism and constructionism are the two leading theories that inform STEM learning with technology tools such as educational robotics (Sisman & Kucuk, 2019). Therefore, as elements of constructivism and constructionism inform the theory for many (if not most) of the popular STEM related instructional strategies, instructional planning approaches and scripted curriculum in schools (i.e., PBL, Understanding by Design, Engineering by Design, etc.), it is, therefore, important for classroom practitioners to understand why and how such practices help students learn and ways of leveling up their own instructional design (lesson planning) and teaching practices for enhancing the experience of their learners. Until this understanding is fully developed in tandem with STEM related content (in engineering, computer science, etc.) it will be difficult for educators in the Commonwealth to successfully comprehend and implement instruction with scripted curriculum and technology tools.

Therefore, developed rubric(s) for STEM lessons need to be closely aligned to the regional and statewide proposed STEM PD model and should be developed during PD sessions described in framework one that targets the essential components of effective STEM lessons. Moreover, building on the school rubric that provides a macro level set of expectations and guidance, a rubric that impacts the microlevel of instruction with lesson development will allow for further clarity and definition for high quality STEM instruction. According to the 2014 work by NAE and NRC,v*STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* , we " need to be explicit about the goals they aim to achieve and design the integrated STEM experience purposefully to achieve these goals" (p.147). This landmark publication also states that -"STEM experiences need to attend to learning goals of and learning progressions in the individual STEM subjects so as to not inadvertently undermine student learning in those subjects" Other states have also recognized the need to use "High-quality tools and supports– such as rubrics, self-assessments–to enable schools, programs and businesses to advance consistent understanding and application of the adopted STEM Attributes (NC STEM plan).

VDOE has many successes in this area to build on. VDOE successfully implemented a performance assessment rubric to support Local Alternative Assessment plans and this has enhanced the clarity and quality of performance assessments. Schools in improvement are provided rubrics that support their work in enhancing alignment and quality of instruction and have been successful in helping many schools improve their performance.

An important component of this solution is to engage and leverage our regional partnerships and organizations (i.e., VCTM, VTEEA, VSELA, VAST, etc.) to provide support in using the rubrics```to vett regional examples and submit these to the repository as well as increasing regional collaboration and understanding around this task.

In an age of Pinterest and Teachers pay Teachers, teachers now have access to a plethora of resources with only a click. The US STEM plan describes the complexity of STEM as "overlapping disciplines into a more integrated and interdisciplinary approach to learning and skill development. This new approach includes the teaching of academic concepts through real-world applications and combines formal and informal learning in schools,the community, and the workplace. It seeks to impart skills such as critical thinking and problem solving along with soft skills such as cooperation and adaptability" p.7 With no true vetting of online resources and a lack of high quality STEM exemplars teachers are choosing lessons that are not aligned and that do not meet the rigor or the standards or support STEM literacy. This committee recommends the creation of a Virgina website that is searchable, practical, functional and centralized to house the STEM lessons and units vetted using the rubric mentioned above.

To complement our state PD model, a lesson plan template consisting of sections that are inspired and consistent with the backwards design planning methodology (McTighe and Wiggins) should be developed for use during state and regional PD sessions and collaborative teacher planning sessions. Additionally, the template for lesson planning should include each of the components of framework one for PD:

1. Activities with alignment to both the Virginia Standards of Learning (SOLs) and the ISTE standards technology standards for educators and students.
2. STEM content knowledge essential for investigation, inquiry and design for K-12 educators (i.e., *Engineering Design, Design Thinking, Computational Thinking, the IB design cycle, and an invention cycle).*
3. Guiding and leading questions designed for launching inquiry and design in STEM lessons.
4. Partnerships with industry partners for connections to STEM careers in lessons.
5. Relevant student products aimed at improving local communities.
6. Peer collaboration between students, along with project management and team roles for enhanced career connections.
7. Reflection for metacognition.

To ensure that the developed STEM lessons are closely aligned to the regional and statewide proposed STEM PD model, they should be developed before PD sessions (and revised after) described in framework one that targets each of the essential components of the framework. This could possibly be a part of the state's current Open Educational Resources (OER) initiative. For content area teachers to participate in rigorous STEM education but not made to feel as if they are losing their identity as a core discipline (i.e., ELA, math, science, and social studies), we recommend they implement one high-quality STEM lesson per semester. Created policy to support this item would greatly encourage participation in STEM by all educators in the Commonwealth.

Additional Action Step Recommendations

Problem statement:

Engineering is a key component of STEM education and was recently added to the 2018 VA SOLS for Science, however the habits of mind, practices and engineering knowledge are not vertically aligned or fully professionally developed in pre and inservice teachers.

Broad Solutions:

A. State: Provide engineering framework documents that provides more coherent standards for curriculum and professional development
B. Vertical articulation of engineering habits of mind, practices and knowledge should be developed k-12.
C. State and Regional: Professional Development should be specific to engineering and how to integrate the habits of mind and practices into instruction for all students to have access.

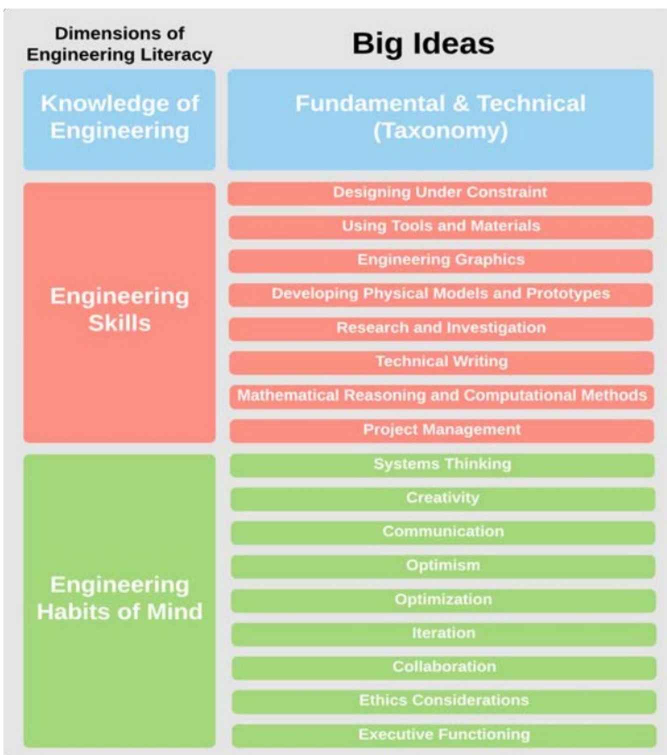
STEM education across the Commonwealth has grown in recent years with varying definitions and approaches. Many of these approaches minimize or do not include the "E" in STEM all together. This coupled with the inclusion of engineering into the 2018 science standards provide a strong rationale for providing more support and emphasis on engineering. Several other reasons support this rational and strengthen the case for engineering to be a focus in K-12 STEM education within the Governor's STEM plan:

- A strong indication that jobs related to engineering are a large part of our US economy (19%) (STEM Occupations: Past, Present, And Future 2015)
- A shift in the nation towards integration of engineering with the introduction of the Next Generation Science Standards (NGSS).
- A dramatic increase since 2012 in the number of high schools offering engineering course (growth between 92% and 240% depending on the model of the program) (Building capacity p.13)
- Virginia also recently adopted the 5C's and Profile of a Graduate. The Engineering Habits of mind correspond with these 5 C's Creativity, Collaboration, Citizenship (Engineering: persistence,optimism, conscientiousness) critical thinking (systems thinking), Communication.

Engineering a National Perspective framed the importance of engineering well,
"Our world is full of seemingly insurmountable challenges: poverty, food security, and climate change to name a few. Historically, engineering has provided solutions to the world's most daunting problems. Paramount among these challenges is the need to prepare the next generation of global citizens to solve issues of the ensuing century. While the demands of our world require creative, capable,and diverse problem solving, our children have limited opportunities to engage in engineering as part of a typical educational environment" (Engineering a National Imperative, 2018)p.

In STEM education Engineering "is uniquely positioned to support transdisciplinary learning experiences to foster rich connections and further knowledge and skills of academic disciplines. If implemented with fidelity and resolution, engineering is poised to deliver on many of the forgotten promises of STEM education" Report after report provide a rationale that states that engineering is the vehicle needed to connect STEM disciplines and provides a relevant context in which to situate STEM learning. The forgotten "E" in STEM "shortchanges students who need experiences applying mathematics and science to problem-solving fields like engineering in order to flourish in today's workplace" (CA STEM plan) Virginia is in a unique position to lead other states as it more fully creates supports that emphasizes engineering within the goals of the STEM commission.

State standards have been the backbone of curriculum and assessment for many years. These provide guidance to school districts and teachers on what to teach. These frameworks are essential and without them our state would not see the successes it has seen. STEM education and specifically engineering is no different, the absence of a framework creates an inconsistency in authentically educating students in engineering (Strimmel, 2020). NAP echoed this "Key elements that contribute to effective STEM instruction include a coherent set of standards and curriculum, teachers with high capacity, a supportive system of assessment and accountability, adequate instructional time, and equal access to quality STEM learning opportunities" (NAP Successful K-12 STEM Education: Identifying EffectiveApproaches in Science, Technology, Engineering, andMathematics). Once engineering frameworks and standards are established then curriculum, assessment, and instruction can begin to fully realize the true contributions of engineering and begin to professionally develop staff.



(this is not yet published but the following link is) https://81a49881-5397-41dc-8fba-0aa0ced249a0.filesusr.com/ugd/1ce4b3_552f58fc970c40d8bbc39343261113c6.pdf Concepts for the Dimensions of Engineering Literacy

STEM curricula should be aligned across disciplines from grades K-12.(Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics, National Academy of Sciences) The VDOE vertical progressions documents for subject areas have been instrumental in creating curriculum and guidance for school divisions to implement standards. Engineering habits and practices should be aligned for all students grades K-12. NAP Building capacity for teaching engineering calls for student learning progressions, age-appropriate expectations for engineering design thinking, and student conceptions in engineering, which will have implications for how K–12 educators at different grade levels are prepared and supported (NAP, 2020)

Teachers of Engineering, call for "K–12 teachers of engineering to be literate with respect to engineering design and engineering careers; acquire relevant pedagogical content knowledge, such as how teaching and learning in engineering is similar to, and different from, teaching and learning in science and/or mathematics; and appreciate how problem solving and engineering design can contextualize teaching standards of learning in other subjects (e.g., science, mathematics, language arts, reading)." p. ? This is no small task and therefore PD must be design–based and have teachers learn content by creating instructional materials. This can provide educators with both engineering content knowledge and an active learning experiences. In addition, providers of professional development opportunities and educators of prospective K–12 teachers of engineering (STEM teachers) should align their work with guidance documents that draw on the most up to date understanding of research and best practices in teacher education and professional development. The *Standards for the Preparation and Professional Development for Teachers of Engineering* provide a strong base on which to draw in creating professional development within the Virginia STEM network(2014).

To coincide with other recommendations regarding the vetting and sharing of curriculum, it will be important to provide models that emphasize the integration of engineering concepts that go beyond the design process. Model STEM curriculum should use the habits and practices of engineering to help students solve real problems and enhance instruction.

Additional Action Steps Recommendations

Computer Science

Problem Statement:

There is an unprecedented need for immediate professional development for teachers, administration, instructional coaches, and school counselors on the topic of computer science education so they can more effectively guide the development of student's skills and learning in this emerging and ubiquitous field of study.

Broad Solutions:

A. Create a centralized and coordinated effort to ensure equitable implementation of the VA SOLS for CS that includes:

    a. establishing and publishing expectations for implementation of the mandatory K-8 integrated Computer Science Standards,
    b. measure implementation goals,
    c. create a more formal relationship with CodeVA
B. Promote awareness of the state-funded CS teacher professional development initiative, CodeVA
    a. Formally endorse coach academy
    b. Reconsider endorsement during interim adoption period
C. Recommend consideration of alignment between acceptance of high school graduation credit coursework in computer science and university acceptance of computer science high school coursework toward college admissions.

Higher Education

Problem Statement:

All higher education institutions must collaborate both within their own respective institutions between colleges/schools as well as across institutions in the commonwealth to increase their STEM literacy offerings in teachers preparation that will help to both enhance teacher content knowledge and their pedagogical practices for teaching STEM using an integrated approach.

Broad Solutions:

A. Establish clear communication structures and work groups that need to collaborate within institutions between different colleges/schools and between institutions to align course offerings, dual enrollment opportunities and expand certifications opportunities for pre-service and in-service teachers (Burns, Crow and Becker, 2015; Ammy, Eddy and Ozaki, 2007).
B. Support professional development opportunities for educators (that includes both K-12 teachers, teacher leaders and faculty at higher ed) on pedagogical content knowledge as well as exchanging effective practices in STEM literacy to enhance student learning (Caffarella and Zinn, 1999, Schuster et. al., 2012).
C. Create conferences and/or summits for cross-sector collaboration between higher-education and K-12 to identify clear connections to shared outcomes and overlapping interests in research, professional development, or joint STEM literacy and curriculum initiatives (Knowlton et.al., 2015).

Problem Statement:

Additional efforts are needed to align programs between K-12 and post-secondary education that can help support successful student transitions as well as provide opportunities for students at risk and underserved populations, to enhance content knowledge and competencies required for life-long learning through integrated STEM education.

Broad Solutions:

A. Create comprehensive structures to collect and share longitudinal data across K-12, higher education, and the workforce in a consistent and clear way that can help understand and support student transition and retention (Kirst and Venezia, 2001, Garcia and L'Orange, 2012).
B. Establish common performance measures between K-12 and post-secondary education for both quantitative and qualitative success that helps to capture student growth mindset beyond just content knowledge but also competency development (Deming and Figlio, 2016).
C. Develop articulated and structured dual-enrollment opportunities providing academic and social support for college-level coursework in high school on interdisciplinary state-of-the-art areas that have the promise to better prepare a wide range of students for college success (Karp and Hughes, 2008; Lewis, M. and Overman, L. 2008; Hughes, K. L. 2010).

Problem Statement:

Instruction in higher education needs to mirror practices outlined and recommended for K-12 Education. There is a great need for understanding and pervasive implementation of STEM habits of mind, practices, competencies, and knowledge that can help students at institutions of higher education to make meaningful and interdisciplinary connections to relevant STEM education and learning. There is no formal cohesive system to provide preparation, accountability, and policy related to assessing, implementing and revising STEM instruction to create STEM literate students in higher education.

Broad Solutions:

A. Integrate rigorous academic concepts motivated by real-world problem contexts through effective instructional practices in STEM education that will help students to make meaningful connections between school, community and the world (Seshaiyer, et.al. 2014).
B. Create meaningful partnerships between higher education and K-12 education to develop student experiences that provide not just discipline based content skills but also competency based transferable skills that will help prepare students for life-long learning (Fehlinger, Ward and Fontecchio, 2014; Padmanabhan et.al., 2017).
C. Develop formal structures that will enable faculty at higher education to use their knowledge and passion about STEM to contribute to teachers' knowledge and STEM literacy both inside and outside classroom as well as help to build relationships between higher education and K-12 education in which both partners contribute unique and valuable strengths (Peters-Burton, 2015; Seshaiyer and Kappmeyer, 2016, Seshaiyer and Suh, 2019).

Informal/Nonformal Education

Problem Statement:

The connection between informal educational opportunities, experiences, and resources are not clearly aligned with formal education or with community partners and families regarding the efforts of STEM literacy for all.

The language used between informal communities, schools, and the public/communities is not consistent therefore leads to the breakdown of meaningful experiences and potential alliances/partnerships.

    - Expectations are not aligned since the language is not the same. (1. literally a shared common language between all groups. 2. professional development in STEM literacy needs to include informal education staff/leadership)

- Resources are not easily shared between informal education centers (i.e: professional/state organizations, afterschool programs) and public schools. (shared repository)
- Formalized relationships are hindered due to justifications needed to align informal opportunities, experiences, or resources with classroom settings. This could be a result of SOL alignment, funding, transportation, or marketing. Furthermore, research shows that extended experiences, both for youth and educators, provide a more measured positive outcome in comprehension, understanding, and application – and most classrooms/schools currently identify informal education as 'one-off' experiences. (Creating formalized relationships and potential MOU's for extended relationships. This should be between schools and informal institutions, however, should also create an alignment between informal institutions as well – possibly through a hub network?)
- Career pathway efforts between formal and informal education are not currently aligned and there is a need to provide research and evidence to support growing the STEM pipeline interests and enrollment.

Broad Solutions:

A. Shared language pushed between all educational entities. This needs to be identified and delivered to all educational partners. A STEM 'hub' would be a potential collaborative effort.
B. Professional development for educators should include formal and informal/nonformal educators so we are considering similar strategies, tools, resources, and language used. This would also allow for collaborative programming within and outside of the classroom setting
C. Any resource banks for curricular and scaffolding purposes used by formal educators should be accessible and editable by 'certified' informal/nonformal educators
D. STEM Hubs used as collaborative efforts would help align interests and goals among formal and informal/nonformal educators. This would help with resources, language but also in creating sustainable partnerships that would extend past common one-off experiences.
E. Formalizing partnerships through identified agreements, such as MOUs, would ensure

that all parties understood their contributions and gains through partnerships as well as assist in identifying efforts to help towards common goals hopefully, long term.

F. Create a means to better market or share informal/nonformal educational experiences with students and their families. This can be done through a school communications network or through a database/website that would help centralize these opportunities.
G. Through Hubs or website/databases, help promote informal and nonformal experiences that have helped create relevancy and identity with STEM careers helping youth consider this pathway through school.

Addition documentation and research

References

Afterschool Alliance (2014). (2020). Retrieved 3 June 2020, from http://www.afterschoolalliance.org/documents/AA3PM-2014/AA3PM_National_Report.pdf

Amey, M. J., Eddy, P. L., & Ozaki, C. C. (2007). Demands for partnership and collaboration in higher education: A model. New directions for community colleges, 2007(139), 5-14.

Burns, B., Crow, M., & Becker, M. (2015). Innovating together: Collaboration as a driving force to improve student success. Educause Review, 50(2), 10-20.

Caffarella, R. S., & Zinn, L. F. (1999). Professional development for faculty: A conceptual framework of barriers and supports. Innovative Higher Education, 23(4), 241-254.

Darling-Hammond, L. and M.W. McLaughlin, Policies that support professional development in an era of reform. Phi Delta Kappan, 76: 597-604, 1995

Deming, D. J., & Figlio, D. (2016). Accountability in US education: Applying lessons from K-12 experience to higher education. Journal of Economic Perspectives, 30(3), 33-56.

Desimone, L. (2009). Improving Impact Studies of Teachers' Professional Development: Toward Better Conceptualizations and Measures Volume: 38 issue: https://doi.org/10.3102/0013189X08331140

Developing a Virginia STEM Network, 2020. 4VA collaboration

Engineering a National Perspective (2018). Advancing Excellence in P-12 Engineering Education. Retrieved March, 2020, https://www.p12engineering.org/publications

Farmer CL, Klein-Gardner SS, Nadelson L. 2014. Standards for the preparation and professional development for teachers of engineering. Available online at https://www.asee.org/conferences-and-events/outreach/egfi-program/k12-teacher- professional-development (accessed March, 2020).

Fehlinger, D., Ward, J., & Fontecchio, A. (2014, October). Increasing 11th grader's interest in STEM majors via a NAE Grand Challenge: Securing cyberspace-themed project. In 2014 IEEE Frontiers in Education Conference (FIE) Proceedings (pp. 1-3). IEEE.

French. V. 1997. Teachers Must Be Learners, Too: Professional Development and National Teaching Standards. National Board for Professional Teaching Standards. (Vol: 81, 585, 38-44). Retrieved from: https://doi.org/10.1177/019263659708158507(Knight, J., & Cornett, J. (2009)

Frequently Asked Questions | Ohio STEM Learning Network. (2013). Retrieved 3 June 2020, from https://osln.org/about/faq/

Garcia, T. I., & L'Orange, H. P. (2012). Strong Foundations: The State of State Postsecondary Data Systems--2012 Update on Data Sharing with K-12 and Labor. State Higher Education Executive Officers.

Hughes, K. L. (2010). Dual enrollment: Postsecondary/secondary partnerships to prepare students. Journal of College Science Teaching, 39(6), 12-13.

International Society for Technology in Education. (2000). ISTE national educational technology standards (NETS). Eugene, OR :International Society for Technology in Education.

Karp, M. M., & Hughes, K. L. (2008). Study: Dual Enrollment Can Benefit a Broad Range of Students. Techniques: Connecting Education and Careers (J1), 83(7), 14-17.

Kaser, J.S., Bourexis, P.S., Loucks-Horsley, S., & Raizen, S.A. 1999. Enhancing Program Quality in Science and Mathematics.

Kania, J. & Kramer, M. (2011). Collective Impact. Stanford Social Innovation Review. Retrieved 29 May 2020, from https://ssir.org/articles/entry/collective_imp

Kirst, M., & Venezia, A. (2001). Bridging the great divide between secondary schools and postsecondary education. Phi Delta Kappan, 83(1), 92-97.

Knowlton, S., Fogleman, J., Reichsman, F., & de Oliveira, G. (2015). Higher education faculty collaboration with K-12 teachers as a professional development experience for faculty. Journal of College Science Teaching, 44(4), 46-53.

Lewis, M., & Overman, L. (2008). Dual and concurrent enrollment and transition to postsecondary education. Career and Technical Education Research, 33(3), 189-202.

National Academy of Engineering and National Research Council, 2014. *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18612.

National Research Council. 2011. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13158.

National Research Council (U.S.). Committee on Highly Successful Schools or Programs for K-12 STEM Education. (2011). Successful K-12 STEM education : identifying effective approaches in science, technology, engineering, and mathematics. Washington, D.C. :National Academies Press,

National Academies of Sciences, Engineering, and Medicine. 2020. *Building Capacity for Teaching Engineering in K-12 Education*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25612.

National Research Council. 2011. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13158

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Padmanabhan, P., Baez, A., Caiseda, C., McLane, K., Ellanki, N., Seshaiyer, P., Kwon, B. & Massawe, E. (2017, March). Design thinking and computational modeling to stop illegal poaching. In 2017 IEEE Integrated STEM Education Conference (ISEC) (pp. 175-181). IEEE.

Parker, C.E., Pillai, S., Roschelle, J. 2016. Next Generation STEM Learning for All: A report from the NSF supported forum. Waltham, MA: Education Development Center.

Peters-Burton, Erin E., Padmanabhan Seshaiyer, Stephen R. Burton, Jennifer Drake-Patrick, and Carla C. Johnson. "The STEM road map for Grades 9–12." In STEM Road Map, pp. 124-162. Routledge, 2015.

Project 2061 (American Association for the Advancement of Science). (1989). Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology. Washington, D.C: American Association for the Advancement of Science.

Rice, J.K. 2001. Fiscal Implications of New Directions in Teacher Professional Development. School Business Affairs, 67 (4), 19-24.

Schuster, D., Buckwalter, J., Marrs, K., Pritchett, S., Sebens, J., & Hiatt, B. (2012). Aligning University-Based Teacher Preparation and New STEM Teacher Support. Science Educator, 21(2).

Seshaiyer, P., Sun, J., Peixoto, N., Long, M., Corcoran, M., & Grewal, V. (2014, October). Inquiry-based approaches in K-12 classrooms to empower the next generation STEM workforce. In 2014 IEEE Frontiers in Education Conference (FIE) Proceedings (pp. 1-8). IEEE.

Seshaiyer, P., & Kappmeyer, K. (2016). Transforming Practices in Mathematics Teaching and Learning through Effective Partnerships. In Mathematics Education (pp. 105-120). Springer, Cham.

Seshaiyer, P. and Suh, J. (2019). Mathematical Modeling in Problem Solving: A Big Idea across the Curriculum. Big Ideas In Mathematics: Yearbook 2019, Association Of Mathematics Educators, 167 - 186.

Sisman, B., & Kucuk, S. (2019). An Educational Robotics Course: Examination of Educational Potentials and Pre-service Teachers' Experiences. *Undefined*. Retrieved from https://www.semanticscholar.org/paper/An-Educational-Robotics-Course%3A-Examination-of-and-Sisman-Kucuk/2af38ceba30a37553508f3
STEM 2026: A Vision for Innovation in STEM Education. 2016. Retrieved 29 May 2020, from https://www.air.org/system/files/downloads/report/STEM-2026-Vision-for-Innovation-September-2016.pdf

Strimel, G., Huffman, T., Grubbs, M., Kim, E., & Gurganus, J. (2020). Establishing a Content Taxonomy for the Coherent Study of Engineering in P-12 Schools. *Journal of Pre-College Engineering Education Research (J-PEER), 10*(1), Article 4. https://doi.org/10.7771/2157-9288.1232

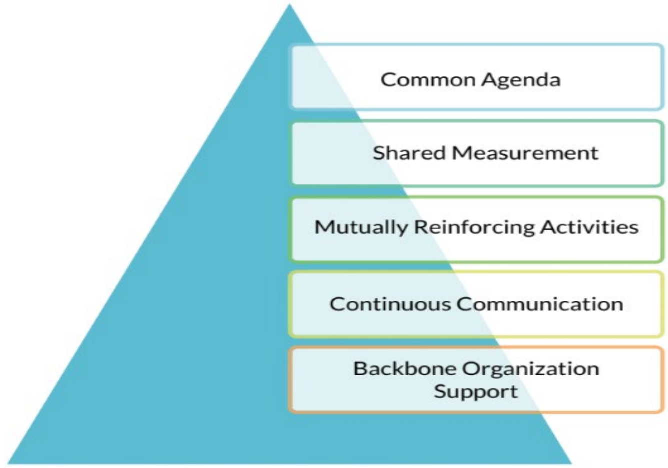
Turner, S. et all (2012), Understanding the Value of Backbone Organizations in Collective Impact: Part 1 (SSIR). (2020). Retrieved 29 March 2020, from https://ssir.org/articles/entry/understandin

US Bureau of Labor Statistics, 2015. STEM Occupations: Past, Present, And Future. Retrieved 29 May 2020, from https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf

Zollman, A. (2012). Learning for STEM Literacy: STEM Literacy for Learning. *School Science And Mathematics*, *112*(1), 12-19. doi: 10.1111/j.1949-8594.2012.00101.x

Still need references for
US Department of Education, 2015;.
U.S. Department ofEducation, 2015, p. 14; Warschauer, 2012).
NC STEM plan
McTighe and Wiggins
oregon rfp, Iowa STEM plan
CA STEM plan

Figure 4. Collective impact framework.



Next generation STEM learning for all

Equity, Inclusion, and Access Subcommittee
Research Summary

Committee Members: Barbara Kanninen (facilitator), Marie Culver, Rebecca Dovi, Pamela Leigh-Mack, Kate Matthew, Paula Robinson, and Matt Shields

Problem Statement:
A variety of factors lead to inequities in student exposure and interest in STEM, the development of STEM skills, and/or pursuit and attainment of STEM degrees and careers. Inequities occur over a number of demographic measures, including zip code, economic, race, gender, English-learner, and disability status, and have led to a lack of diversity in many STEM professions. The factors leading to inequities include:

- Varied STEM awareness, understanding, and/or emphasis across families, demographic groups, and regions;
- Opportunity gaps, including lack of access to quality early learning experiences, gaps in developing foundational STEM skills in K-12, and access to rigorous STEM courses and experiences;
- Disparities in opportunities to keep the “spark” alive, build on the spark, and/or strengthen STEM skills, including access to camps, programs, clubs, competitions, and internships;
- Variation in educator capacity across schools and school districts, including potential teacher shortages in some STEM areas, gaps in STEM content knowledge, best practice pedagogy, and/or cultural competencies; and
- Disparities in school and academic institutions’ funding and resources available to students, including tools, technologies, and broadband.

The current COVID-19 situation has shone a bright light on, and exacerbated, some of these inequities, especially regarding broadband access, teacher and District readiness for distance learning, and family capacity for supporting distance learning from home (Goldstein 2020).

Building equity in STEM will require an expansion of STEM opportunities across schools, school districts, community colleges, and universities across every region of the Commonwealth to reach all students. It will also require *intentional outreach* to students from disadvantaged backgrounds and those who are under-represented in STEM, who might not be aware of, or feel they belong on, STEM pathways. We can reach these students by pursuing a variety of strategies at the local, regional, and state levels.

Broad Solutions:

Curriculum, Resources, and Educator Capacity

The curriculum, resources, and practices that teachers and faculty use every day in the classroom have profound impacts on students. They can invite, and they can disinvite, interest and engagement. When students of color, for example, do not see STEM professionals of color in their learning materials, they feel disinvited. Similarly, when girls do not see STEM professionals in fields that are traditionally male dominated, their interest, and even confidence, wains (White 2018). We need to be *intentional* about providing curriculum materials and experiences that are inclusive, inviting, as well as engaging, to all students. Students need to see STEM as being part of their daily lives and accessible to them. They need to see STEM professionals who look like them. In order to complete the invitation, school counselors, together with administrators and educators, must be available to encourage students to explore STEM pathways and support them along those pathways, including with academic support and advising. Students' families must also have the opportunity to be engaged and informed about STEM and STEM pathways so that they can support and encourage their children.

It is fundamental that all students must be given the opportunity to learn from high-quality teachers who have the relevant STEM content knowledge. Teacher shortages in STEM fields must be addressed. Furthermore, all teachers, across subjects, need access to ongoing professional development and coaching in STEM-related content and pedagogy. In addition to content knowledge, educators need ongoing training and support in understanding and overcoming their implicit biases, as well as in cultural competence. Because the actions educators take can, unintentionally, derail a student's confidence, performance, and decision-making, it is important that they are supported in developing their understanding and awareness of their own biases and well trained and prepared with action steps. Furthermore, cultural competence training should impart an understanding of the factors that motivate under-represented populations toward STEM and provide tools for encouraging and supporting those students.

It is important that all students develop the foundational STEM skills they will need to succeed. If gaps emerge in student learning, opportunities in STEM diminish. It is essential that the development of foundational STEM skills begins *for all students* in early childhood[1] and

[1] The first five years are a critical period with the brain growing more in these years than during any other point in life. We know that many children are not exposed to high-quality or equitable experiences during these early years. According to the Virginia Kindergarten Readiness Project (VKRP), 44% of children in Virginia are arriving at kindergarten unprepared. Unfortunately, it is worse for children identified as having a disability (66% not ready) or those economically disadvantaged backgrounds (56% not ready). The state's Advancing Effective Interactions and Instruction (AEII) initiative recently found that the majority of Virginia's state-funded preschool classrooms (approximately 71%) are not meeting the threshold of quality for the types of strong and instructionally supportive interactions that promote "STEM" skills (deep thinking, reasoning, and problem-solving). When children show up to school behind, they tend to stay behind. There is great opportunity to make significant changes in STEM

continues into the elementary grades with developmentally appropriate math, science, and inquiry skill building. Students throughout these years need opportunities for problem-solving, reasoning, active exploration, investigation, discovery, and collaboration using integrated, hands-on, and project-based learning approaches. These experiences must continue through secondary education, albeit at a higher level, to ensure that all students develop the skills needed, especially in science and mathematics. Students who perform well in these areas are more likely to declare STEM as their majors in postsecondary education (NSB-2019-6).

At the postsecondary level, colleges and universities, in collaboration with community colleges, need to develop and implement innovative scientific and engineering curricula, particularly for the first two years, and provide academic support structures to retain students historically underserved and underrepresented in particular STEM disciplines. Curricula review should be performed periodically to ensure academic institutions are addressing the needs of the State as well as nationally and globally. Pedagogical reform is required as a companion to curricula reform to maximize results. African-American/Black, Hispanic, and female students are groups historically underrepresented in STEM.[2]

To ensure equity, inclusion, and access for all students, the following recommendations are provided:

Recommendations:

Local/Regional

- Implement district policies and practices to ensure STEM curriculum materials reflect the diversity of Virginia's population and connect to students' experiences and societal concerns.
- Integrate foundational STEM skills across the preK-12 curriculum to educate all students in science and engineering and provide sufficient course opportunities and experiences for those who plan to become scientists and engineers.

---

education and the STEM-work pipeline by focusing on an early start. Without doing so, we are creating a gap that we need to work twice as hard to fill with interventions focused in the later years.

Also, during this period, children are forming their sense of self-- their perceptions of themselves as individuals, including beliefs about gender, race, skills, or associations that they consider most important about themselves. All children have the right to these "STEM" careers or education pathways. They must believe they belong and are capable. We need to get this message to families and children early, during this critical development of their perceptions of themselves, to increase interest and confidence in STEM.

[2] Colleges and universities have a major role to play to meet the demands of the technological needs, nationally and globally. Equity, inclusion, and access for all are paramount in meeting these demands. There continues to be a lack of parity in science and engineering education and employment for those underrepresented and underserved in these fields. While degree attainment for women has reached or approached that of men in some disciplines, differences remain in the fields of mathematics, computer science and engineering where they have traditionally been in this status. Blacks and Hispanics are underrepresented at all or nearly all degree levels, respectively (National Science Board NSB-2019-7).

  - STEM learning should be integrated into all core subjects.
  - Incorporate scientific and engineering practices, as well as inter-disciplinary core linkages among engineering, technology, science, and society (National Research Council 2012).
  - Ensure quality, developmentally appropriate early learning opportunities.
  - Expand opportunities for hands-on and project-based learning.
  - Consider "STEAM" opportunities to expand participation and build engagement.
  - Provide easy-to-use family resources, starting at the youngest ages, so parents become comfortable with the idea that STEM is everywhere--it's a part of their daily lives and their kids can do it.
- Professional school counselors and administrators need to be knowledgeable of opportunities across State higher education institutions; aware of STEM careers and pathways; and have the tools and resources to advise students of any background to help them find an appropriate pathway.
- Schools and school districts should provide professional development to aid all educators in making the shift to STEM-enabled, STEM-infused learning experiences.[3]
  - Professional learning should be individualized, targeted, and subject-specific.
  - It is important to be data-driven to provide the most support where there is the greatest need.
  - Consider STEM specialists or coaches (in-person or virtual) to provide ongoing support.
  - Organize regional and statewide professional networks for teachers.
- Ensure teachers have STEM-specific cultural competency training to help them overcome biases and be intentional about encouraging all students to consider STEM pathways (Coleman 2018).

State

- Integrate foundational STEM skills across all subjects and grade levels in the Virginia Standards of Learning.
- Transform Standards of Learning assessments to project-based, inquiry-based, performance-based assessments.
- Prioritize diversity in state textbook adoption.
- Increase access to high-quality early education for all children. This effort cannot *just* include adding additional state-funded early learning classrooms across the state for low-

[3] STEM is the world we live in. It permeates every aspect of life and should permeate every aspect of schooling. With this perspective, every teacher is a STEM teacher. Schools should not be looking to hire one or two STEM instructors to add STEM extensions to existing content. Schools should be providing professional development to aid all educators in making the shift to STEM-enabled, STEM-infused learning experiences. Every teacher in the state needs individualized, targeted, and subject-specific professional development opportunities to ensure that they are best preparing their students to succeed in a connected and digitized world.

income children. While that is a crucial step, it must include increasing the *quality* of existing classrooms and ensuring any new classrooms are supported to ensure quality.

- Develop a robust and culturally relevant messaging campaign that explains STEM and its importance, and promotes STEM professions.
- Using the Virginia Portrait of a Graduate as the basis: define a wide array of STEM pathways. These pathways should offer a diversity of academic levels so that any student can both meet the criteria and see themselves being successful.
- To address teacher shortages, consider providing financial incentives. One type of financial incentive would be a simple lump sum payment to teachers who commit to two or three years of teaching in a STEM-challenged school or school district. Another approach could be to provide retired teachers with an incentive to return to teaching by allowing them to continue to receive their retirement benefits while earning a salary.
- Provide grants for programs within higher education institutions to perform curricula and pedagogical reforms.

Disparities in Funding

Disparities in school funding and resources hinder STEM growth in communities where STEM opportunities and aspirations are most needed. In Virginia, there are school districts that spend approximately $20,000 per pupil, while there are others that spend less than $10,000 per pupil. While one might expect schools in low-income communities to receive extra resources, the reverse is often true; a U.S. Department of Education study found that 45 percent of high-poverty schools received less state and local funding than was typical for other schools in their district. (https://www.ed.gov/equity, Equity of Opportunity) This means that many of our most vulnerable school communities are being asked to do more with less. These gaps in funding and school resources require a commitment to equity and intentional human and monetary investments at the local, regional and state levels supported by strategic partnerships.

Recommendations:

Local/Regional

- PreK-12 school systems should partner with local and regional institutions of higher education to support STEM exposure and teacher prep programs.
- PreK-12 school systems should partner with local and regional institutions of higher education for federal and industry grant opportunities with a STEM focus, e.g.:
    - Upward Bound Math/Science,
    - Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP),
    - NASA's Minority University Research Enhancement Project,
    - National Science Foundation grants.
- Establish regional teacher development and professional community networks or communities of practice (McKay, et al., 2018).
- Establish public-private partnerships to support local and regional workforce demands, e.g., entrepreneurship programs, youth apprenticeships, and internships.

- Create mentoring programs. It is important to recruit diverse mentors so that all students can see themselves in STEM fields.
- Provide funding for school and community-based opportunities for students and families to learn about STEM, including access to science centers, maker spaces, camps, nature centers, and museum programs. Extensive outreach is needed to ensure all families are aware of, and can take advantage of, programs. If local opportunities do not exist, provide transportation and/or develop mobile events.

State

- Develop a state “D-STEM Equity” agenda to formalize the idea of diversifying STEM policies.
- Use data to identify “STEM-challenged” schools or school districts, based on assessment data or under-represented student populations, and target funding to address those inequities.
- Build STEM technologies and resources into the State Standards of Quality to ensure availability at every school and school division.
- Provide sufficient resources to colleges and universities in order to attract and retain those students and faculty in underrepresented STEM disciplines, particularly in mathematics, computer science and engineering. Make additional support available for first generation college students.
- Establish a funding mechanism for sustaining STEM interest and performance in STEM education in the community and in PK-20 particularly for those underserved and underrepresented.
- Provide funding for higher education institutions to support students from low socioeconomic status and underrepresented communities who are pursuing majors consistent with the Commonwealth’s high need technical areas.
- Incentivize provision of STEM-related dual enrollment through VCCS to support schools, even if outside of community college designated service area.
- Create a STEM workforce development plan. A STEM workforce plan should include strategies for creating a vigorous STEM teaching corps. (Incorporate STEM pipeline development requirements in agreements with new corporations entering the state, i.e. Amazon, Microsoft, etc.).
- Create inclusive STEM high schools (ISHSs) that are connected through state-run or public-private collaborative networks. The ISHSs’ mission is to recruit and prepare students who are interested in STEM and who are from diverse backgrounds rather than targeting only those who have demonstrated math and science talent before high school (Young).
- Provide universal access to high-speed internet.

References

Coleman, A. (in press). D-STEM Equity Model: Diversifying the STEM Education to Career Pathway. Athens Journal of Education.
Retrieved from https://www.athensjournals.gr/education/2018-2539-AJE-STEAM.pdf.

Department of Education, Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service, Comparability of State and Local Expenditures Among Schools Within Districts: A Report From the Study of School-Level Expenditures, by Ruth Heuer and Stephanie Stullich, Washington, D.C., 2011. https://www2.ed.gov/rschstat/eval/title-i/school-level-expenditures/school-level-expenditures.pdf

"Educational Equity: What Does It Mean? How Do We Know When We Reach It?"_Center for Public Education, National School Boards Association, January 2016.

Goldstein, Dana, "Research Shows Students Falling Months Behind During Virus Disruptions: The abrupt switch to remote learning wiped out academic gains for many students in America and widened racial and economic gaps. Catching up in the fall won't be easy." *New York Times*, June 5, 2020.
Iowa Strategic Plan for STEM Education (2011).
https://www.iowastem.gov/sites/default/files/STEMEducationRoadmap2011.pdf

Mashburn, A. J., Pianta, R. C., Hamre, B. K., Downer, J. T., Barbarin, O. A., Bryant, D., ... & Howes, C. (2008). Measures of classroom quality in prekindergarten and children's development of academic, language, and social skills. *Child Development*, *79*(3), 732-749.

McKay, Susan R. , Laura Millay, Erika Allison, Elizabeth Byerssmall, Michael C. Wittmann, Mickie Flores, Jim Fratini, Bob Kumpa, Cynthia Lambert, Eric A. Pandiscio, and Michelle K. Smith. "Investing in Teachers' Leadership Capacity: A Model from STEM Education." Maine Policy Review 27.1 (2018) : 54 -63, https://digitalcommons.library.umaine.edu/mpr/vol27/iss1/15.

National Science Board Science & Engineering Indicators 2020: K-12 Education: Elementary and Secondary Mathematics and Science Education, NSB-2019-6, September 4, 2019. https://ncses.nsf.gov/pubs/nsb20196/

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

National Science Board Science & Engineering Indicators 2020: Higher Education in Science and Engineering, NSB-2019-7, September 4, 2019. https://ncses.nsf.gov/pubs/nsb20197/

National Research Council. (2005). *Mathematical and Scientific Development in Early Childhood: A Workshop Summary*. National Academies Press.

https://www.nap.edu/catalog/11178/mathematical-and-scientific-development-in-early-childhood-a-workshop-summary

National Research Council. (2000). *From Neurons to Neighborhoods: The Science of Early Childhood Development*. National Academies Press. https://files.eric.ed.gov/fulltext/ED446866.pdf

Pianta, R. C. (2016). Teacher–student interactions: Measurement, impacts, improvement, and policy. *Policy Insights from the Behavioral and Brain Sciences*, *3*(1), 98-105.

Cochran, Geraldine, and Gary White, (eds.), "A Second Call and RESPONSE," *The Physics Teacher,* Volume 58 Issue 5, May 2020.

White, Gary, "Sex, gender, and physics, and the introductory physics classroom," Phys. Teach. **56**, 580 (Dec. 2018).

Young, Viki, Sharon Lynch, Barbara Means, Ann House, Vanessa Peters, and Carrie Allen, Bringing Inclusive STEM High Schools to Scale: Policy Lessons from Three States. https://inclusivesteminsights.sri.com/downloads/inclusive-stem-high-schools-to-scale-policy-lessons-brief.pdf

STEM Workforce Pipeline Subcommittee
Research Summary

Committee Members: Casey Roberts (facilitator), Dr. Albert Byers, Michael (Todd) Estes, Margaret Mayer, Dr. Tinell Priddy, Eric Robertson, Zuzana Steen, Elizabeth (Beth) Wright

Category #1: Educators and Skill Development

Problem Statement:

The effectiveness of any STEM initiative, curriculum, or program is anchored in the quality of training and expertise of teachers in the classroom. Unfortunately, the talent pipelines for teachers with the knowledge, experience, and training are shallow and disjointed with the needs of industry and the 21st-century workforce needs. Here are two key barriers that have stymied the efforts of developing a robust STEM education experience for all students across Virginia:

- A lack of opportunity, resources, and interested talent among several stakeholder groups has contributed to an incoherent strategy to recruit, retain, and develop a highly qualified STEM teacher corps.
- Lack of state policy and legislation that modifies/removes barriers between the PreK-20 system and industry to create innovative consortiums (to scale) to drive curriculum development, teacher preparation programs, and bridges access to STEM-related employment opportunities.

Barriers/Challenges:

- Lack of exposure for educators to gain awareness for STEM-related jobs; and the lack of integration with CTE programs/opportunities.
- No coherent strategy between the Pre-K-20 system (weak teacher preparation programs and also too few programs) and industry to train and retain (no real incentives to attract and retain) talent to sustain a teacher corps that could, in turn, produce a STEM competent workforce.
- Lack of professional development opportunities for educators to develop a robust and aligned curriculum at the local level aligned with the state level.
- Not enough opportunities to educate and inform the PreK-20 system to develop curriculum alignment opportunities between STEM curricula and CTE programs.

Solutions:

- Developing more teacher preparation programs in collaboration with industry in order to increase access for interested candidates. Integrate STEM-focused teacher preparation programs with CTE related opportunities (work-based learning, teacher externships, etc.) to gain relevant industry exposure not attainable in the classroom setting.
- Improve opportunities for "ongoing" professional development in support of teacher learning through work-based learning opportunities (teacher externships, summer learning opportunities, etc.) for existing teachers in the classroom.
- Develop a PreK-20 policy that integrates talent acquisition, training, and program development between the K-12, colleges/universities, and VCCS systems.
    - Drive integration of STEM and CTE related opportunities
    - Work with all institutions of higher learning across the state to align curriculum with regional industry needs and opportunities so as to maximize reach and scope.
    - Work closely with industry to vet and tweak policy so as to remain nimble to changing trends.
- Develop robust incentives to attract/retain talent starting at the secondary level (i.e.- Teachers of Tomorrow, Career Switcher Programs, etc.)
    - VDOE STEM Licensure Credential (Portfolio Based)
    - Attach state/industry-funded STEM credential to the attainment of said credential.
- Expand Teacher Externship opportunities and programs with industries
    - Northrop Grumman Teachers Academy
    - NASA Teacher Externship Program
    - NNS Teacher Externship Program
    - GWU Teacher in Industry Program

Recommendations:

- Create a permanent Education/Business Taskforce to continually review progress and integration of initiatives and projects across multiple agencies for alignment and effectiveness. This group would make recommendations for action to the Virginia Board of Education, VCCS, and the Secretariat of Education. **Refer to Regional Hub recommendation**
- Develop a state-wide STEM teacher preparation program (using the NISE Certification Framework) that offers an assortment of credentialing options, that is outside of the college/university system. This program would be a public/private partnership between industry leaders and VDOE.
- Create a STEM add on licensure credential or microcredentials (attach with an industry/state-funded stipend) if certification is obtained. This credential recognizes those individuals that have distinguished themselves as highly qualified educators in the STEM field.
- Create the conditions (tax incentives, etc.) necessary for industry to build and offer teacher externship opportunities for current and future teachers during the summer months.

Appendix

Perkins Collaborative Resource Network

VDOE Work-based Learning Learning Guide

Institute for Education Sciences--Career and Technical Education

SkillsUSA CTE and STEM Integration Article

ACTE Issue Brief--CTE's Role in Science, Technology, Engineering & Math

NextGen-WA STEM Teacher Preparation Project

The University of California Berkeley-Teacher Externship Guide

Northrop Grumman Teachers Academy

NASA Teacher Externship Program

NNS Career Pathway Teacher Internship Program

GWU Teacher in Industry Program

Article: Educators in Industry: An Exploratory Study to Determine how Teacher Externships Influence K-12 Classroom Practices

Idaho STEM Action Center--Summer Externships for Classroom Teachers

Iowa STEM Teacher Externships Program

STEM Education Certificate Program--Drexel University

National Institute for STEM Education--National Certification for STEM Teaching

Category #2: Partnerships and Community Resources

Problem Statement:

A lack of coordination among key workforce development contributors, including education sectors, nonprofit and public agencies, and industry partners, results in missed opportunities to leverage shared creativity, expertise, and resources in pursuit of common priorities. Developing the infrastructure needed to improve communication and collaboration among these actors will increase the likelihood of producing innovative, scalable workforce solutions.

Barriers/Challenges:

- Workforce development actors/agencies/organizations working independently to address similar goals result in missed opportunities to leverage shared resources and limit the ability to scale solutions.
- Workforce development initiatives working independently often compete for employer attention ultimately confusing and overwhelming potential industry partners.
- Lack of a clearinghouse system that engages and supports all stakeholders in participating in or seeking meaningful partnerships

- Lack of business partners actively participating in STEM education program delivery (experiential locations/space, student mentorship, etc.)

Solutions:

- Create a formal STEM workforce development network to promote workforce development actor engagement and collaboration.
- Actively promote STEM training and education provider alignment to provide greater clarity for potential industry partners
- Establish a central repository for STEM-related literature, best practices, and available resources accessible by all public workforce development actors.
- Seek innovative solutions to help employers better understand how they can support STEM education while limiting the burden on their organization.

Recommendations:

1. Create a STEM Network Leadership Committee (NLC), as part of the overall STEM Council, chartered to coordinate and lead activities in the regional STEM Hubs.
    a. Members for the committee to be selected from all regions and sectors (corporate, K12, foundation, mission-based government agencies, business chambers, etc.), recognizing that our state has diverse needs, and different regions will want to focus their partnerships on local benefit. Members shall be appointed by the Virginia Secretary of Education (?) for a two-year period with the option for renewal.
    b. STEM NLC chartered to:
        - Define the goals and objectives for the regional STEM Hubs including agreed-upon baseline deliverables for success (activities, inputs, outputs, outcomes) with operationalized (measurable/observable) metrics across the hubs to capture progress, document annual impact and drive data-driven iterative improvement over time.
        - Identify and create one or more statewide activities that elevate and celebrate promising STEM students
        - Convene quarterly to review regional STEM Hub progress
        - Appoint co-chairs, in a manner patterned after other state STEM networks, to include a representative from 1) private industry and 2) PreK-20 education with experience in and commitment to strengthening STEM education in the Commonwealth.

2. Establish regional STEM Hubs as conveners of stakeholders in an effort to improve communication and collaboration among industries, organizations, agencies, and educational sectors.
    a. Participants in the STEM Hubs should include regional secondary and postsecondary education institutions, nonprofit and public agencies, and

key regional industry partners and associations. Hub participant list submitted for STEM NLC review annually.

b. STEM Hubs chartered to:
    - Build active and beneficial partnerships within their region
    - Share activities and resources among STEM Hub partners
    - Create employer resources to encourage greater participation in STEM programs
    - Develop a messaging strategy for key regional industries
    - Report out quarterly to the STEM NLC
    - Select co-chairs to include a representative from 1) private industry and 2) PreK-20 education with experience in and commitment to strengthening STEM education. Co-chairs shall be approved by the STEM NLC for a two-year period with the option for renewal.

Appendix

1. Center for Educational Networks and Impacts, Blueprint document: Toward a statewide Virginia STEM Network
2. Jobs for the Future (JFF), Promising Trends and Challenges in Work-Based Learning: A Market Scan of Organizations and Tools
3. National Governors Association, Aligning State Systems for a Talent-Driven Economy: A Road Map for States
4. National Science & Technology Council, Charting a Course for Success: America's Strategy for STEM Education
5. Northeastern University Center for the Future of Higher Education and Talent Strategy, Designing and Implementing Work-Based Learning: A Call to Action for CHROs
6. Oregon Chief Education Office, STEM Education Plan: Driving Individual, Community, and State Prosperity
7. Sondergeld & Walten, Assessing the Impact of a Statewide STEM Investment on K-12, Higher Education, and the Business/Community STEM Awareness Over Time
8. Urban Institute, Expanding and Improving Work-Based Learning in Community Colleges
9. VA Chamber of Commerce, Blueprint Virginia 2025

Category #3: Pathways and Pipelines

Problem Statement:

Disconnectedness between STEM pathways and pipelines exist. Not staying abreast of current and future pipeline needs and challenges with pathway implementation results in a general difficulty/inability for education systems torespond to market needs with a timely and scalable strategy.

Barriers and Challenges:

- Outcomes are overly focused on degrees and not enough on skills, certifications, and ultimately real jobs.
- Lack of funding for industry-recognized certifications.
- Accreditation barriers prevent high school teachers from delivering dual-credit classes.
- Lack of teacher capacity in STEM subjects, especially in high schools and two-year colleges.
- Lack of diversity narrows the candidate pool for STEM.
- Lack of awareness among parents, students, teachers, and counselors about the importance of STEM careers and about in and out of school programs that lead there.

Potential Solutions:

- STEM NLC to guide the following initiatives and collaborate with regional Hubs:
  - Increased partnership with industry and acknowledgement of labor market trends and job qualifications.
    - Create seamless pathways ensuring all students are postsecondary and career-ready including CTE for PreK-20.
      - Examples include YearUp; NOVA-Amazon partnership; GMU and NOVA's ADVANCE program; ODU-VCCS partnership.
    - Significantly increase paid and unpaid internships for STEM students at younger ages (16-20 year-olds) and externships and training for teachers.
      - Examples include CodeVA, NOVA SySTEMic Professional Development for Teachers, GW Teachers in Industry, NASA program.
  - Increased access for students to career counseling and guidance with qualified counselors aligned to industry needs.
      - Example includes ADVANCE program with their coaches in high schools, NOVA and GMU.
  - SACS waivers for high school teachers to deliver dual-enrollment courses.
  - Increased funding for the Fast Forward Workforce Credential Grant program.
  - Increased funding and focus to raise awareness among parents, students, teachers, and counselors about the importance of STEM careers and about in and out of school programs that lead there.
    - Special emphasis on programs and messaging for middle schools and underserved audiences (girls, underrepresented minorities) to expose, excite and empower them to pursue more STEM.
  - Increased pay for (female) STEM teachers, especially in schools with underserved populations.

Appendix

Tennessee STEM Plan
Iowa STEM Plan
Developing a Virginia STEM Network

Creating Sustainable Partnerships Subcommittee
Research Summary

Committee Members: Dr. Sue Magliaro (facilitator), Blair Blanchette, Dr. David Eshelman, Megan Graybill, Helen Kuhns, Amy White

Overview - Case Statement

High-quality STEM education opportunities for all are essential to ensure that all Americans can participate in our technological world, advance our nation's innovation economy and build a collaborative, equitable, and inclusive community (Handelsman & Smith, 2016). Further, Virginia's New Economy is predicated on the development of a STEM workforce to fill current jobs, as well as the jobs of the future. However, regional differences in terms of culture, educational and economic opportunities, resource availability, and infrastructure underscore the need for a concerted effort to address this challenge by intentionally advancing STEM learning across the entire state (Virginia Economic Development Partnership, 2017).

Multi-sector partnerships at the local, regional, and state levels are foundational for success for basic STEM literacy as well as workforce development (NSB, 2020; Weld, 2017), especially across our regions in rural Virginia (Rural Virginia Initiative, 2018). Throughout our nation, partnership models are yielding positive outcomes for stakeholders when collaborations are launched based on needs, commitment, and evidence of a return on investment (e.g., statewide STEM networks, regional and local STEM ecosystems). Statewide STEM networks comprised of regional hubs to coordinate and support STEM experiences are reporting increased STEM and STEM career awareness, industry engagement, preparation of students, and opportunities for workforce development (Magliaro & Ernst, 2018; Sondergeld, Johnson, & Walten, 2016). Led by a state coordinator, these regional hubs facilitate communication through information sharing, aid in the development and support for partnerships, coordinate across hubs, facilitate the sharing of resources, and assist in conducting evaluation of activity for continuous improvement.

At the regional and local levels, partnerships based on needs, having common vision and language, and have created specific plans for their work together have yielded great success in meeting the partnership goals and extending the longevity of the collaborations (e.g., STEM Ecosystems, 2019; Zinth & Goetz, 2016). That said, while partnerships are relatively easy to suggest as a solution, developing and sustaining partnerships are equally as challenging as the range of needs that we see across our Commonwealth. A myriad of problems beset even the most promising of partnerships. However, given the research on partnership development and sustainability, as well as the numerous program and partnership models available across the nation and our own state to replicate, the case is clear that to advance Virginia's STEM literacy and workforce goals for all citizens we must invest in the creation of an organized, coordinated, and financed partnership network system with accessible resources to launch, develop, and sustain productive collaborations.

Our report is organized according to these three basic issues, along with solutions supported by the literature and easily accessible given the extant expertise and models available in our own state.

Problem #1 – How to launch a sustainable partnership?

The foundation of a sustainable partnership begins with a common goal and language bound by common culture (NSB Vision 2030, 2020). All partners must have a shared understanding of the definition of STEM and who constitutes a STEM student before the process of building a partnership can begin. After language, a common curriculum is the cornerstone to informing partners on how to build relevant, meaningful field experiences, workforce development opportunities, and professional development trainings (Katz 2010).

Only through these factors can partners create a shared set of standards for success and a plan for sustaining the partnership when leadership inevitably turns over.

Partnership-specific/Regional Solutions:

- Build a common STEM culture and language, supporting a common curriculum.
- Allow opportunity or partners to learn each other's customs, cultural (within regions or sectors) norms, and processes.
- Define, identify, and bring to the table all partners and leaders, recognizing that students, parents, teachers, schools, businesses, nonprofit organizations, and regional and state administration all play a part. The National Science Board (2020) provides a representation of an inclusive approach to a comprehensive approach to STEM partnerships in Figure 1.

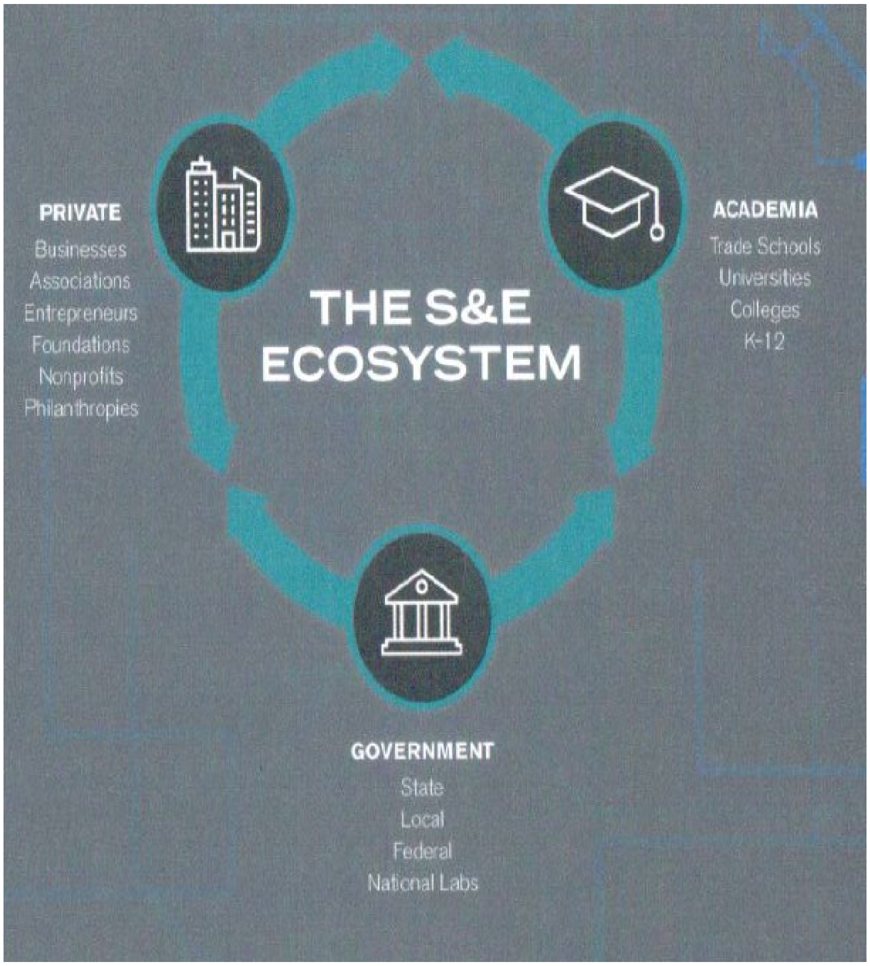


Figure 1. An inclusive approach to key stakeholders who provide leadership for advancing STEM programming.

- Given that reasons for partnerships may vary across stakeholders, include visions and goals that may extend beyond specific workforce needs to focus on education, training, service, community engagement, life-skills development, sustainability and resiliency in a changing world.

Regional/State Solutions:

- Create a statewide STEM network which works from regional hubs that serves as a clearing house of information, expertise, and support.
- The statewide office, in collaboration with regional coordinators, should host a centralized, state/regionally-sponsored website (in a standing government or organization office) to coordinate and provide information and resources to students, parents, educators and other partners.

Problem #2 – How to develop a sustainable partnership?

Effective partnerships represent valuable opportunities for numerous community members, but practices must be in place to ensure that partnerships can get started effectively and benefit all parties involved. Without standardized best practices and guidelines, partnerships may be only somewhat successful or fail to get started entirely. Partners often do not know what their responsibilities are, and there is not clear leadership driving the partnerships. Multiple solutions exist and for effective partnerships to be formed, these should be implemented and followed consistently.

Partnership-specific Solutions:

- A Memorandum of Understanding (MOU) that reflects curriculum goals of a defined STEM pathway and the commitment of all parties must be developed and used when formulating all partnerships. This MOU will define the timeframe of the partnership (some partnerships need to dissolve when need and commitment is no longer in place), articulate roles and responsibilities and outline the potential successes, a satisfactory return-on-investment (ROI) for the partnership and a plan for succession. Measures of success and their schedule for data collection and reporting also must be articulated in the MOU. Leadership changes should be addressed through a plan of succession by both the private sector, public schools, and a STEM hub.
- Not-for-profit and business partners must guarantee a commitment for a specified period; roles and responsibilities will be articulated for clarity through the MOU to provide work-based learning opportunities for middle and high school students and teachers.

Regional/state Solutions:

- Regional STEM hubs should be established throughout Virginia and identify statewide and/or regional leadership to set timelines, coordinate, and communicate activities within regions:
    - Identify resources such as informal learning opportunities, potential partnerships with not-for-profit and for-profit businesses, and capitalize on and synthesize information currently available (e.g., VEDP, GO Virginia, etc.).
    - Assess regional needs as they correspond to the state's goals and prioritize collaboration and community interaction by participating in regional job fairs and provide information about opportunities for educators, parents, and students to learn about regional career possibilities and openings.
    - Develop regional scholarships and STEM funding for promising projects. This funding would be made available by application and awarded by the STEM hub.
    - Creatively approach in-kind contributions and flex as these change with evidence of initial success, etc.
- Regional coordinators should commit time to partnerships and nurture a culture of collaboration and partnership that supports open communication. Partnerships should be assessed periodically and changes should be made to ensure that everyone benefits.

- Informal learning opportunities should align with or enhance curricula and student focused activities.
- Regional coordinators will identify opportunities for students to participate in informal learning, educators in professional development, and partners in training and resource access. Leaders will share through and across hubs in an established culture of collaboration and networking.
- School divisions will develop teachers able to liaise with the partner sectors (e.g., school-university liaison, school-business liaison, or dedicated partnership liaison/coordinator). Liaisons act as central brokers of activity embedded contextually within the partnership culture. Funding could be shared and the opportunities could be awarded as a sabbatical type of experience for teachers.

Problem Statement 3 – How to sustain an effective partnership?

Preparing students for the jobs of tomorrow requires a teacher willing to open their doors to the community and world around them. Instructional methodology must provide true transdisciplinary experiences. The Profile of a Virginia Graduate expects school divisions to be expanding Workbased Learning opportunities. In order to do this effectively, sustained partnerships are no longer a "nice to have" - they are a must.

As careers naturally evolve based on promotion and retirement, the Virginia business community has an interest in partnering with secondary and postsecondary institutions to meet their workforce needs for the future. As indicated above, secondary and postsecondary programs have a need to ensure students are prepared to meet the workforce demands of tomorrow. WBL is critical in providing students the opportunity to apply their knowledge and skills through internships, job shadowing, mentorships, and apprenticeships just to name a few. Sustained partnerships help make this a reality and only happen with a concerted effort to collaborate (Weld, 2017). In order to create the best learning opportunities in STEM-related careers, it is critical for Virginia to develop tools and consolidate resources to enhance communication and collaboration to meet the specific workforce demands throughout the Commonwealth and beyond (Carraway, Rectanus, & Ezzell, 2012; Committee on STEM Education of the NSTC, 2018; Vance, Nilsen, Garza, Keicher, & Handy, 2016; Zinth & Goetz, 2016).

Virginia STEM must build on current cross-agency work focused on providing Virginians a clear, consistent understanding of career pathways and sector partnerships. An industry-specific sector or regional approach will enhance collaboration and lead to sustainable partnerships. A directory of current multi-sector partnerships would provide knowledge of partnerships, along with contact names and descriptions outlining the partnership. Further, a hub-and-spoke, networked system for STEM education across the state provides a logical next step in the directory creation, as well as providing opportunities to broker partnerships where needed. The regional hub coordinators should be able to support potential partners on the features and examples of successful collaborations, facilitate the development and maintenance of partnerships, ensure the tools for adequate and appropriate communication, and provide information about how partnerships work differently in different regions.

Commitment to a partnership requires that all stakeholders continue to value the efforts. Two issues emerge. First, sustainability of the partnership is threatened when measures of success are not in place at the formation of the partnership and, thus, return on investment for all stakeholders is often vague and immeasurable. Partners must see or experience success in the experience to continue to invest time and resources. Second, leadership turnover can derail a successful enterprise losing the advocate(s) and institutional memory of the partnership.

Partnership-Specific Solutions:

- Formative and summative evaluation of the partnership, based on the goals and measures of success outlined in the MOU, are conducted on schedule.
- Data are analyzed, including the identification of successes, challenges, and ideas for improvement.
- Written reports or marketing summaries are shared with all members.
- Using the succession plan outlined in the MOU, members of the sector will be identified early as aspiring leaders and be given opportunities and time to learn the role and responsibilities (e.g., for teachers, summer assignments, a time period during the day, opportunities to meet the other partners in situ, etc.).
- A smooth leadership transition is completed with an adequate transition time and conversation.

Regional/State Solutions:

- Regional coordinators work collaboratively with partnership leaders to identify acceptable, reasonable, and valued measures of success that are outlined in the MOU.
- Partnership organizations and STEM hubs will have MOU's that clarify expectations and establish guidelines for a recurring, renewing association.
- Evaluation of partner relations will provide evidence of success (which should be celebrated), elements that need to be improved, and interesting possibilities for future work. Model partnerships should be identified and shared via a regional or statewide website. Assessments throughout the MOU period can red-flag potential issues including lack of motivation, gaps in leadership, or having the appropriate partners at the table.
- Students who have participated in the STEM program will be eligible for newly created incentives to stay in the region (e.g., tax incentives, housing possibilities, childcare opportunities, etc.) and offer Virginia a highly qualified, engaged STEM worker.

Summary

Multi-sector partnerships are based on a broad range of reasons with stakeholders who represent all precincts of the STEM ecosystem. *Sustainable* partnerships, however, begin with intentionality and collaboration. Through the development of structures, such as an MOU and leadership board, based on needs, a common vision, and best practices, partnerships avoid random activity, wasted resources, dissatisfied stakeholders and participants, and short-lived programs. Ensuring that all stakeholders realize a return on investment through data-based evaluation provides a clear picture of success and direction for continuous improvement. Communication of outcomes through marketing and public sharing enables partnerships to serve in the best interests of the community, region, and state to advance quality of life, economic development, and promising futures for all Virginians.

References

Brandon Hall Group (2015). *Measuring the ROI of informal learning: Research brief.* Delray Beach, FL: The Brandon Hall Group. Retrieved from http://go.brandonhall.com/measuring+Roi+informal+learning.

Carraway, A., Rectanus, K., & Ezzell, M. (2012). *The do-it-yourself guide to STEM community engagement.* Research Triangle Park, NC: NC STEM Community Collaborative.

Committee on STEM Education of the National Science and Technology Council (2018). *Charting a course for success: America's strategy for STEM Education.* Washington, DC: Office of Science and Technology Policy.

Darling-Hammond, L., Wilhoit, G., & Pittenger, L. (2014). *Accountability for college and career readiness: Developing a new paradigm.* Stanford, CA: Stanford Center for Opportunity Policy in Education.

Farley, J., & McNair, L. (2020). *Exploring boundary spanning in a school-university partnership*. American Society of Engineering Education (ASEE) Conference Proceedings, June 21-24, 2020.

Fullan, M. (2020). *Leading in a culture of change* (2nd ed.). Hoboken, NJ: Jossey-Bass.

Handelsman, J., & Smith, M. (2016). STEM for All: Ensuring high-quality STEM education opportunities for all students. Washington, DC: Office of Science, Technology and Mathematics. Retrieved from: https://obamawhitehouse.archives.gov/blog/2016/02/11/stem-all.

Jesiek, B. K., Mazzurco, A., Buswell, N. T., & Thompson, J. D. (2018). Boundary spanning and engineering: A qualitative systematic review. *Journal of Engineering Education*, 107(3), 380-413.

Katz (2010). *STEM in the early years.* Retrieved from https://www.olaweb.org/assets/CSD/CSDFall2013BrainSTEM/stem%20in%20the%20early%20years%20-%20katz%20article.pdf

Magliaro, S. G., & Ernst, J. V. (2018). *Inventory of statewide STEM networks*. Center for Educational Networks and Impacts, Virginia Tech.

Minner, D., Ericson, E., Wu, S., & Martinez, A. (2012). Compendium of research instruments for STEM Education. Part 2: Measuring students' content knowledge, reasoning skills, and psychological attributes. Retrieved from http://cadrek12.org/resources/compendium-research-instruments-stem-education-part-ii-measuring-students-content-knowledge.

National Science Board (2020). *Vision 2030*. Alexandria, VA: National Science Board.

Ryan, J. E., Sands, T. D., & Abdullah, M. M. (2018). *Moving rural Virginia forward: Ideas for action and investment.* Retrieved from https://rga.lis.virginia.gov/Published/2018/RD374.

Sondergeld, T. A., Johnson, C. C., & Walten, J. B. (2016). Assessing the impact of a statewide STEM investment on K-12, higher education, and business/community STEM awareness over time. School Science and Mathematics, 116(2), 104-110.

STEM Ecosystems (2019). Building and strengthening STEM learning ecosystems: A growing guide to success. Retrieved from https://1va22l4dun7a16k87y2j3tfx-wpengine.netdna-ssl.com/wp-content/uploads/2019/09/ecoguide2019bookletR2.pdf.

Vance, F., Nilsen, K., Garza, V., Keicher, A., & Handy, D. (2016). Design for success: Developing a STEM ecosystem. San Diego, CA: University of San Diego School of Leadership and Education Sciences.

Virginia Economic Development Partnership (2017). 2017 Virginia Economic Development Partnership strategic plan. Retrieved from https://www.vedp.org/strategicplan.

Weld, J. (2017). *Creating a STEM culture for teaching and learning*. Arlington, VA: National Science Teachers Association.

Wenger, E., McDermott, R., Snyder, W. M. (2002). Cultivating communities of practice. Boston: Harvard Business Press.

White, E. S. (2018). State of STEM. Washington, DC: STEMconnector. Retrieved from https://www.stemconnector.com/state-stem-report/.

Zinth, J. (2018). Work-based learning: Model policy components. Denver, CO: The Education Commission of the States. Retrieved from https://www.ecs.org/work-based-learning-model-policy-components/.

Zinth, J., & Goetz, T. (2016). A state policymaker's STEM playbook. Denver, CO: The Education Commission of the States. Retrieved from https://www.ecs.org/a-state-policymakers-stem-playbook/.