GREATER BALTMORE COMMITTEE

Education and Workforce Committee Report

October 2016

THE 3D TECHNICAL REVOLUTION

GBC Education and Workforce Committee Report

THE 3D TECHNICAL REVOLUTION

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EXECUTIVE SUMMARY

Introduction

Over an eighteen month period, the GBC Education and Workforce Committee researched the economic competitiveness of the greater Baltimore region in utilizing three-dimensional (3D) technologies in design, engineering, and additive manufacturing. The Committee met with industry leaders to learn about advanced manufacturing, 3D imaging and scanning, 3D digital modeling, rapid prototyping and digital fabrication.

A decade ago, 3D printing was used primarily for the fabrication of models. Today, additive manufacturing uses diverse materials to produce functional end-use components for various industries critical to Maryland's economy, including construction, architecture, military, defense, medicine, dentistry, jewelry, computer products, automotive, aerospace, art, research, and other fields.

The Committee also met with educators in elementary and secondary schools and higher education institutions as well as leaders of makerspaces and tech programs to discuss their work in connecting current and future workers with 21st century technologies.

Findings

The greater Baltimore region has a solid foundation in 3D design, engineering, and additive manufacturing and is poised to lead the nation in the application of 3D technologies. The region is home to several military installations and nationally ranked universities engaged in 3D research and innovation. Area colleges and universities have added academic programs, courses, and laboratory spaces devoted to 3D technologies. Elementary and secondary schools have adopted new science standards that support exploration, discovery, and creativity, and 3D technologies are used and taught in local schools throughout the region. Numerous makerspaces and digital centers provide space and equipment to allow students and adults to explore and create.

Despite these advances, the region has failed to fully capitalize on the 3D revolution.

- There is a stark lack of awareness on the part of the general public to the transformational changes taking place in industries due to 3D technologies.

- The public is unaware of the numerous educational pathways available to Marylanders to prepare for jobs in 3D design, engineering, additive manufacturing, and related fields.

- Educators at all levels of the spectrum lack training to effectively use 3D technologies and incorporate 3D technologies into the curriculum.

- While 3D printers are available at some educational institutions, educators lack access to and understanding of advanced software and equipment used by businesses and industries.

- More needs to be done to connect industry with educational institutions at all levels to ensure that academic programs are relevant and consistent with emerging industry standards and technology.

Recommendations

The GBC Education and Workforce Committee recommends the greater Baltimore region take focused, intentional actions to implement the following goals:

1. Improve the economic competitiveness of the greater Baltimore region by influencing the preparedness of the workforce to utilize 3D technologies in design, engineering, and additive manufacturing; and

2. Stimulate new economic activities by empowering residents with the knowledge and resources required to create new businesses based on 3D capabilities.

To support these overarching goals, the Committee recommends the region implement the following strategies:

- Establish tax incentives to encourage Maryland businesses to partner with local schools, college, and universities to provide access to specialized 3D equipment and software; offer professional development to teachers, faculty, and staff; support extracurricular opportunities and internships; speak at local schools; establish mentor programs; and work with educators to modify curriculum.

- Provide professional development opportunities to elementary, secondary, and postsecondary educators on utilizing 3D technologies; maintaining 3D equipment; and engaging students in active learning, problem solving, case studies, and simulations using 3D technologies.

- Expand opportunities for students to engage in creative thinking and innovation using 3D technologies by providing after-school programs, summer camps, and extracurricular programming, including 3D expos, challenge fairs, and competitions.

- Develop a comprehensive communications campaign to build awareness about the importance of the 3D revolution, its implications on the economy and the job market, the availability of makerspaces with 3D equipment and software, and the academic programs and educational pathways that prepare students to work with 3D technologies. The campaign should include a summit for community, education, and business leaders to showcase 3D technologies utilized by Maryland's businesses and researches.

Conclusion

Ten years ago, we would have found it fantastical that we would one day "print" human organs, or that our children would learn complex computer-aided design programs in grade school. And yet today, we live in a world where this is rapidly becoming the norm. We have a great charge and an excellent opportunity to prepare our workforce for the jobs of today and tomorrow. We must lay the groundwork to establish better and more agile relationships between industry and education to create a world-class innovation hub right here in the greater Baltimore region.

INTRODUCTION

Disruptive technologies are becoming accepted in traditional industries. The rise of new and affordable technologies, such as 3D printing, is revolutionizing the marketplace. Major industry players like Autodesk, Alphabet (Google), and Microsoft are evolving business models to align with these strategies. Furthermore, 3D design, visualization, modeling, engineering, drawing, drafting, and similar tasks are essential technological skills needed for numerous industries.

Ten years ago, we would have considered it fantastical that we would one day "print" human organs, or that our children would learn complex computer-aided design programs in grade school. And yet today, we live in a world where this is rapidly becoming the norm. We have a great charge and an excellent opportunity to prepare our workforce for the jobs of today and tomorrow. We must lay the groundwork to establish better and more agile relationships between industry and education to create a world-class innovation hub right here in the Greater Baltimore area.

In recognition of these transformational changes impacting businesses and industries, the GBC Education and Workforce Committee embraced two overarching goals:

1. Improve the economic competitiveness of the greater Baltimore region by influencing the preparedness of the workforce to utilize three-dimensional (3D) technologies in design, engineering, and additive manufacturing; and

2. Stimulate new economic activities by empowering residents with the knowledge and the resources required to create new businesses based on 3D capabilities.

Over an eighteen month period, the GBC Education and Workforce Committee met with industry leaders to learn about advanced manufacturing, 3D imaging and scanning, 3D digital modeling, rapid prototyping, and digital fabrication. A decade ago, 3D printing was used primarily for the fabrication of models. Today, additive manufacturing uses diverse materials to produce functional end-use components for various industries, such as construction, architecture, military, defense, dentistry, medicine, jewelry, consumer products, automotive, aerospace, art, research, and other fields. Furthermore, 3D design, visualization, modeling, engineering, drawing, drafting, and similar tasks are essential technological skills needed for numerous industries.

The Committee also met with educators in elementary and secondary schools and higher education institutions to gain an understanding of the academic programs, services, and resources currently available to train and educate workers at all levels of the education spectrum – certificate, undergraduate, graduate, and workforce training programs. In addition, the Committee met with leaders of makerspaces and tech centers, such as Digital Harbor, the Minority Male Makers Program, Direct Dimensions, and 3D Maryland, to discuss their work in connecting current and future workers with 21st century technologies.

IMPORTANCE OF 3D TECHNOLOGIES

Three dimensional and related technologies touch a wide variety of existing and growing industries in the greater Baltimore region -- healthcare, apparel design, architecture, engineering, construction, advanced manufacturing, computer gaming, and film animation are all immediate local examples where 3D technologies are driving change and innovation. Businesses, industries, research enterprises, and government entities utilize 3D printers to build satellites, create replacement parts, model components, fabricate consumer products, print prosthetics, design buildings, and much more.

Printer filaments combine thermoplastics with metal powder, carbon fiber, wood, and other compounds to create unique materials with distinct characteristics. Utilizing specific filaments, designers are able to print products that are rigid, flexible, transparent, luminous, dissolvable, biodegradable, water soluble, durable, heat resistant, conductive, weather resistant, or impact resistant. The versatility of the filament material coupled with the limitless imagination of the designers creates endless possibilities for practical applications.

Listed below are a few examples of companies and organizations in the greater Baltimore region that rely on workers with 3D expertise.

- **Aberdeen Proving Ground**

  For the past several years, the U.S. Army Research Laboratory at the Aberdeen Proving Ground has been researching the use of additive manufacturing technology for specific end-use applications. Today, researchers at APG can use 3D printers to create structures embedded with wiring, sensors, or energy storage. The goal is to use 3D printing to foster logistics innovations, such as in-field manufacturing to create replacement parts, medical products, and other structures to support American soldiers. In fact, researchers envision a future in which troops in the field can build their own drones in a matter of hours. Printing equipment and gear will give front-line fighters more options to carry out their missions and make it easier and cheaper to repair aging vehicles or adapt when enemies cut supply lines.

  In addition to military applications, the Army Research Lab at Aberdeen entered into an agreement last year with 3D Systems to jointly develop 3D printing technology and materials for automotive, medical, wearable, aerospace, and other commercial and defense applications. As part of the agreement, 3D Systems personnel will serve as guest researchers on-site at Aberdeen Proving Ground to collaborate with the Army scientists. Researchers involved with the project will have access to expansive high-tech materials and will work on hybridized manufacturing applications. This cooperative R&D agreement will lead to scientific discoveries and industrial innovations that will transform military and civilian life.

  Under an “Open Campus” initiative, launched by the Army Research Lab, companies, universities, and government agencies may apply to access ARL’s inventory of 3D printer technologies, including state-of-the-art equipment, such as Stereolithography, Direct Metal Printing, and MultiJet Printing machines.

- **Direct Dimensions**

Maryland-based Direct Dimensions, Inc. was established in 1995 in Owings Mills. The company uses 3D imaging technology to document complex objects in intricate detail for the purpose of finding unique solutions to modeling and manufacturing problems. DDI workers create exact 3D digital models. As data is collected, the object becomes visible on the computer screen as a point cloud and can be studied and manipulated in remarkable detail. The point clouds are then processed into digital models by engineers using a series of software. Depending on the final goal, the digital models can be used as visual animations, design intent CAD models, or physical replication at any scale. When the company was founded, it served the aerospace and military engineering industries. Today, the company specializes in on-site applications of digitizers, laser scanners, and the conversion of 3D data into 3D computer models for use in a variety of industries, including military, aerospace, medical, cultural preservation, and consumer products.

- **Harbor Designs & Manufacturing**

Baltimore-based Harbor Designs & Manufacturing has designed, engineered, and manufactured products for over 30 years. The company offers full-service product design and product manufacturing to help clients bring ideas to the market. Company designers and engineers use cutting edge Computer-Aided Design (CAD) software to create solid model 3D graphical representations of products. Artistic renderings, 3D CAD concept models, and numerous rapid prototyping options are used to refine the product. After designing and engineering a product, Harbor Designs works with clients to establish pathways for cost efficient manufacturing.

Throughout its history, Harbor Designs has been involved in the production of thousands of parts and hundreds of products for the medical, consumer, rail, defense, and industrial markets. Working with clients, Harbor Designs has created numerous innovative and life-changing products. A few examples are highlighted below:

- The Laparoscopy Simulator uses 3-D imagery and force feedback to simulate laparoscopy procedures so doctors and students can hone their skills prior to actual surgery.

- The IV Bag Warming Cart keeps IV solutions at body temperature to prevent patients from going into shock when room temperature fluids are introduced to the body.

- The Garden Center Watering System is a solar powered automated plant watering system for use in garden centers.

- The Shark Fin antenna is installed on the roof of NASCAR vehicles. It beams the HD TV signal from the onboard cameras to provide a drivers-eye view of the action.

- The Noise Immune Stethoscope allows military evaculation medics to hear and diagnose fallen soldiers in environments which are so noisy traditional stethoscopes won't work.

- **Potomac Photonics**

Potomac Photonics, located in Baltimore County, is a leader in microfabrication. The company uses a broad range of technologies, including laser machining, micro Computer Numerically Controlled (CNC) machines, and 3D printing, to help clients develop miniature products the size of a micron or a grain of salt. Potomac is able to micro-machine polymers, metals, ceramics, and glass with feature sizes that cannot be achieved using conventional processes. The company manages projects for clients from the initial prototyping of the item through production, including small volume production and supply chain management responsibilities.

About 70 percent of Potomac's clients are biotech or medical institutions. For example, Potomac inserts small channels in sutures to allow doctors to inject radiation for localized treatment of breast and prostate cancer, and the company has worked with Johns Hopkins University to create devices to remove pre-cancerous cells linked to cervical cancer. In addition to biotech and medical applications, the company works with numerous other industries, such as automotive, military, defense, electronics, and research.

Potomac collaborates with several local colleges and universities to train and attract workers, including the Community College of Baltimore County and the Maryland Institute College of Art. The company also works with local research universities, such as Johns Hopkins University and the University of Maryland, Baltimore County, on research projects related to advanced manufacturing and innovation.

- **Under Armour**

Under Armour, the popular sports clothing and accessory company located in Baltimore, has ventured into the area of 3D printing with remarkable success. In March, the company unveiled the first-ever 3D printed training shoe called "Architech." The footwear features a printed "lattice structure" as the midsole of the shoe and a 3D "Auxetic" pattern on the upper part of the shoe. The 3D features are designed to adapt to the shape of the foot and give the wearer extreme comfort. For its first production run, Under Armour produced 96 pairs of Architech sneakers and marketed the shoe for $300 each. The shoes sold out in 19 minutes.

Kevin Plank, President and CEO of Under Armour, has pledged to test and learn more about the technology and the customization of products. Mr. Plank has said, "You can expect new 3D printed iterations this year." Given Mr. Plank's exceptional success in building Under Armour into arguably the most dynamic manufacturer of sporting goods in the world, it is likely that this company will be a leader in 3D printing innovation for years to come.

RELATED RESEARCH AND STUDIES

- **Advanced Manufacturing Survey 2014 (the Maryland Department of Business and Economic Development)**

In 2014, the Maryland Department of Business and Economic Development (DBED) worked with the Schaefer Center for Public Policy at the University of Baltimore to field a survey of manufacturing establishments. The Schaefer Center surveyed 4,457 companies involved in manufacturing (every firm employing four or more people), making 16,518 phone calls. The survey asked about employment and sales growth, workforce needs, advanced manufacturing capabilities, research and development activities, and financing issues. In the end, DBED received data from a statistically-significant 672 firms.

DBED reports manufacturing has consistently been an important contributor to Maryland's economic health. While the manufacturing industry in Maryland is not as large as in other states, it is an important driver of exports, research and development, and employment in multiple industries. Changes in technology, import duties, free trade agreements, and international competition have put the manufacturing industry under pressure in both Maryland and in the United States as a whole. Maryland's manufacturers have responded to these pressures by enhancing product lines, expanding markets, increasing productivity, and operating more efficiently.

Maryland, like the rest of the country, has seen significant changes in its manufacturing sector. In the late 1960's, manufacturing workers made up almost 20 percent of the State's total workforce. Today, that statistic is four percent. Numerically, manufacturing employment has decreased from 282,000 to 109,000 over the same time period. While employment has decreased, both the State's economy and the manufacturing industry has changed radically. Forty years ago, Maryland's largest manufacturing sector was the "primary metals" industry (establishments that refine and process metals) which employed almost 42,000 workers. Today, that industry is one of the smallest in the State, employing only 700 workers in the third quarter of 2013. Today's largest manufacturing industry in Maryland is Computer and Electronic Products manufacturing, which employs 19,000 workers and did not even exist as a separate sector 40 years ago.

Today, manufacturing plants most likely include automated computer controlled machinery or high-tech equipment being set up and operated by highly-skilled workers. Manufacturers are less likely to require large numbers of workers as they did in the past and manufacturing workers are generally paid more than the average worker. Maryland's average private sector pay per worker in 2012 was $51,910 per year, while the average manufacturing wage was $68,848.

The DBED survey of Maryland manufacturers found that many manufacturing establishments across the State are using advanced methods, equipment, or materials to manufacture their products, and the majority believe their business will grow in the immediate future. However, there are some firms that are not adopting advanced processes, and some firms feel that their future is uncertain.

DBED defines advanced manufacturing using the definition put forth in the *President's Council of Advisors on Science and Technology Report to the President on Ensuring American Leadership in Advanced Manufacturing*: Advanced Manufacturing is "a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies." In addition, "Advanced Manufacturing is not limited to emerging technologies; rather, it is composed of efficient, productive, highly integrated, tightly controlled processes across a spectrum of globally competitive U.S. manufacturers and suppliers. For advanced manufacturing to accelerate and thrive in the United States, it will require the active participation of communities, educators, workers, and businesses, as well as Federal, State, and local governments."

Based on the survey, more than half of Maryland's manufacturers report that there is a lack of qualified workers to fill vacant positions in their industry. Almost 40 percent of survey respondents reported having problems recruiting workers over the past year. More than two-thirds of firms with labor shortages reported that their shortages were long-term problems. To help combat skills shortages, and to keep existing workers current, the majority of Maryland manufacturers surveyed (74%) reported having internal training programs for their workers.

- **Maryland Center for Construction Education and Innovation (MCCEI)**

The Maryland Center for Construction Education and Innovation (MCCEI) is a cross-sector partnership between industry, education, and government with the primary mission of building a world-class education system for Maryland's construction industry. In December 2012, MCCEI published a report, *The Critical Path, Positioning Maryland as an Innovation Leader in the Global Construction Industry*. A total of 126 industry leaders throughout the mid-Atlantic region, who work in Maryland's construction business, education and government, were interviewed from July 2011 through April of 2012 on how they saw this business changing over the next 10 years. The *Critical Path* is a summary of their perceptions and recommendations. The report covers emerging technologies, building processes, business planning, and efficiencies the industry is adopting in order to remain competitive and deliver value to customers. It also covers skills gaps, educational attainment, and recommendations to Maryland's education system to teach and train the workforce of the future.

Among other things, the report recognizes the importance of expanding educational programs to include a focus on Building Information Modeling (BIM) and Integrated Project Delivery (IPD). BIM is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. IPD is a collaborative alliance of people, systems, business structures, and practices to create a process that harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

Technology is revolutionizing the construction industry in terms of process, materials, logistics, waste reduction, and increased efficiency. Opportunity exists for the Maryland construction industry to become an export leader by focusing on modular construction and related training as well as advanced engineering and design that improve safety and efficiency. These growth areas need to be recognized and related education and training need to be developed to keep companies competitive in world markets. This study concluded that Maryland's construction workers are simply not prepared for the industry's future.

In September 2014, MCCEI released a second report, *Digging Deeper, Aligning Skills, Technology and Attainment Between Industry and Education* as a follow up to *The Critical Path*. MCCEI held two events, one in the Baltimore region and one in the Washington, DC region with a combined total of 72 participants, which include 42 industry leaders, 21 educators, and 9 government officials. The participants pointed out the importance of science, technology, engineering, math, and three dimensional and spatial reasoning. The report identifies one overarching theme: It is not enough to know how to use the software. Practitioners at all levels and educational attainments must understand the entire process of design and construction. With the advancement of BIM, it is becoming a more holistic process.

- ***Maryland Out of School Time Network***

The Maryland Out of School Time (MOST) Network is a statewide youth development organization dedicated to more and better opportunities in the off-school hours for Maryland's young people. In 2014, MOST received a grant from the Abell Foundation to research and report on STEM opportunities in Baltimore City. MOST used interviews with key stakeholders, data mining, and workgroups to produce *Landscaping Baltimore's STEM Ecosystem,* which includes a school-by-school directory of STEM programs, STEM competitions, and out-of-school STEM Programs in the Baltimore City Public School System (BCPSS). The document is intended to be a resource for Baltimore City educators, parents, students, and funders to enhance collaboration and build awareness of STEM learning opportunities.

Based on the study, STEM education is happening in BCPSS schools, including informal and formal programs occurring during the school day, after school, and during the summer. While there are many partners participating in these STEM programs, the partnerships often are disconnected from each other and from a larger goal, vision, or strategic plan to address scale and gaps. The MOST report describes the survey as the "first step" and provides recommendations to expand STEM education opportunities.

- ***Opportunity Collaborative – Baltimore Metropolitan Council***

The Opportunity Collaborative is a coalition of local governments, state agencies, and nonprofit organizations in the Baltimore region. It has been working since February of 2012 to develop cooperative strategies to address the challenges facing the Baltimore region. In 2013, the Collaborative published the *Baltimore Regional Talent Development Pipeline Study*. The report provides information on opportunities for workers at all levels of educational attainment and also considers wages for jobs in 13 selected industry sectors in the region in order to identify

occupations that are most likely to offer a family-supporting wage. Information is presented on average annual job vacancies in the region as an indicator of opportunity.

Among the 13 selected sectors, the manufacturing sector is highly diverse and includes large employers in in food production and baking, printing, pharmaceutical manufacturing, machine shops, instrument manufacturers, shipbuilding, plastics, chemicals, and cement products. Between 2012 and 2020, the Collaborative forecasts 789 new jobs for this sector in the Baltimore region and job turnover will require replacement of nearly 11,000 workers, bringing the total hiring demand for the sector in the Baltimore region to nearly 12,000 over the period.

The study predicted that approximately 80% of the future hiring demand in the manufacturing sector is expected to be for jobs that require education less than a Bachelor's degree (total hiring demand of approximately 9,500 workers between 2012 and 2020). The manufacturing sector is expected to generate demand for about 2,170 new hires over the 2012 to 2020 period for jobs that typically require less than a high school diploma and for approximately 6,300 new hires that require a high school diploma or equivalent. This study concluded that Maryland's manufacturing sector is full of opportunities, especially for workers who have less than a Bachelor's degree.

- ***STEM Middle-Skill Career Pathways In the Baltimore Region*** **(Associated Black Charities and the Greater Baltimore Committee, January, 2016)**

The Associated Black Charities and the Greater Baltimore Committee engaged in a study to examine opportunities and provide recommendations to increase the talent pipeline of workers in middle-skill science, technology, engineering, and math (STEM) careers by uncovering career pathway opportunities; defining core knowledge, skills, and attributes that employers find desirable; outlining educational and credentialing along each career path; and highlighting challenges and barriers faced by workers that keep jobs out of reach.

Middle-skill STEM jobs represent a significant opportunity for the thousands of unemployed and underemployed Baltimore City residents who seek to move into a career that provides a family-supporting wage. In 2011, workers in middle-skill STEM occupations earned 61% more than workers in non-STEM occupations with similar levels of education. The average wage for middle-skill STEM workers was $58,504 per year, which is above the 2015 living wage in Baltimore City of $52,998 per year (or $25.48 per hour). For workers who move into STEM occupations, there are many opportunities for career advancement, specialization, and transfer into related occupations with even higher earnings.

The report identifies current and emerging middle-skill STEM career opportunities in six industry sectors that offer promising opportunities for lower-skilled workers to move into middle-skill STEM careers. Among the industries cited is advanced manufacturing. The report cites trends in technology and informed consumers as driving changes across the advanced manufacturing sector. The availability of information has given rise to a consumer who is highly informed of products and prices, buys with a few clicks, and wants products delivered immediately. Manufacturers are responding by increasing the speed of design and production to deliver better products at a competitive cost. New technologies such as 3D printing,

nanotechnology, predictive maintenance technology, and other fabrications are enabling businesses to create innovative, smart products that are better designed, customizable, and cheaper than a decade ago.

For advanced devices such as defense products or medical devices, there is also an increasing need for mechatronics technicians who can troubleshoot, analyze, maintain, and repair complex hardware and software systems. The scope of these work duties can be as diverse as designing and manufacturing a custom replacement part using Computer Aided Design and Drafting (CADD) and 3D printing, writing code to change the operation of a mechatronic system, or diagnosing and fixing micro-electronics.

The needs of Baltimore's machining employers are rapidly changing as Computer Numerically Controlled (CNC) machines replace old methods of producing metal and plastic parts, tools, and machines. Careers in machining offer excellent career opportunities for Baltimore's low-income residents with employment barriers. Many entry-level positions in machining do not require a high school diploma or GED, but do require basic math skills, especially the ability to work with decimals, fractions, and algebra. On-ramps for machining careers are available through pre-employment training programs, such as those offered at the Jane Addams Resource Corporation (JARC). JARC programs offer training in a simulated workforce environment that has been shown to better prepare trainees for the workplace. The programs address many of the basic skills, workforce readiness training, and technical skills training needed to prepare workers for placement in an entry-level position.

Training courses are also offered at the Community College of Baltimore County (CCBC) and some employers, in coordination with CCBC, offer apprenticeship training programs. Students completing the JARC or CCBC programs, and students enrolling in a qualified apprenticeship training program are qualified to apply for entry-level positions as a machinist helper, machine operator (trained on a single machine), entry-level CNC machine operator (typically working on multiple machines), or a position in production assembly. These positions can lead to progressively higher-skilled positions.

With experience, workers can progress into many positions that pay a family-supporting wage. As evidenced, training resources in advanced manufacturing are available and growing in the Baltimore region but as this sector continues to evolve, specifically the 3D printing industry, more should be done to promote and raise awareness of career and training opportunities.

- ***3D Printing: The Future of Manufacturing in Greater Baltimore***

The Economic Alliance of Greater Baltimore released a study completed by Patrick Dougherty, Chief Market Analyst, to highlight greater Baltimore as a hub for the development of new 3D printing applications. The study, *3D Printing: The Future of Manufacturing in Greater Baltimore*, summarizes the advantages available in the region to support 3D technologies, including a network of advocates and early pioneers for the use of 3D printing; a talented and educated workforce, a regional geography and infrastructure that allows easy shipping access to one-third of the US population, and regional businesses that can immediately benefit from 3D printing.

Colleges, universities, and military installations in the region are early adopters of 3D printing, and 3D printing technology is capable of adding value to a number of other local industries. Many of the region's largest companies are perfectly positioned to benefit from the growth of 3D printing. Examples include apparel design, product design and prototyping, biomedical research and patient care, pharmaceuticals, and defense contracting.

Based on the study, manufacturing plays a vital role in the economy of the greater Baltimore region, producing $10.4 billion worth of output, or almost 7% of the total regional output. In recent years, many firms have turned to advanced manufacturing to improve production, allow for greater flexibility, and reduce costs. The report concludes, "3D printing is an important technology, essential to the continued growth and success of greater Baltimore's culture of innovation. The region's overall economic strength can be improved by exposing students, engineers, entrepreneurs, and manufacturers to 3D printing. By impressing upon students the need for creative manufacturing processes, and the endless possibilities 3D printing creates, Greater Baltimore can lead the technology's transformation from a niche skill into a substantial, irreplaceable method for the production of goods."

EDUCATION AND TRAINING PROGRAMS

- *Elementary and Secondary Education*

In 2013, the Maryland State Board of Education adopted the Next Generation Science Standards, a set of rigorous and internationally benchmarked standards for K-12 science education. Over the past three years, the Maryland State Department of Education (MSDE) and the Local Education Agencies (LEAs) have engaged in ongoing statewide coordination and collaboration to implement the standards. The goal is to fully implement the new science standards in grades PreK-12 by the 2017-2018 academic year.

The Next Generation Science Standards start with four disciplinary core ideas: Earth and Space Sciences, Life Sciences, Physical Sciences, and Engineering and Technology. Unlike older content standards, these standards focus on outcomes rather than decontextualized material. The new standards look at science through the lens of inquiry and engineering through the lens of design – in other words, they reflect the practice of people who work in these fields. This is achieved through three major, integrated components: disciplinary core ideas, the ways that people in these fields think and work, and the concepts that cut across multiple content areas. These cross cutting ideas reach beyond the realm of science and engineering to address topics in mathematics and language arts.

As schools and districts seek ways to implement these new science standards, it is only logical to explore what role educational technology can serve. Tools that support exploration, discovery, and creativity move to the front of the list. Three-dimensional technologies support the underlying objectives of the Next Generation Science Standards both in the realm of science (inquiry) and engineering (design.)

Given the shift to new science standards, we anticipate these activities will proliferate over the next several years. Listed below are several examples of 3D technologies currently used and taught in local schools throughout the Baltimore region.

- ***Career Technology Education (CTE) Program***:

The Interactive Media Production CTE Program is available at three high schools in Anne Arundel County, six high schools in Baltimore City, and seven high schools in Baltimore County. The program includes a strong foundation in arts, technology, and communication. Students gain experience in internet technology and website development, computer graphics, electronic media and project management and have the opportunity to earn college credit from the Community College of Baltimore County, which serves as an affiliate partner for the program.

The Manufacturing Engineering Technologies CTE Program is available at the Baltimore City Carver High School. The program prepares students for a beginning career in manufacturing and machine technologies and aligns to the National Institute for Metalworking Skills (NIMS) Machine Level I Credentials. Students participate in hands-on education in precision machining

(manual and computer numeric control) while developing competency in process control, manual operations, process adjustment, part inspection, and machine safety.

The Pre-Engineering Project Lead the Way Program is available to students in Baltimore City and Anne Arundel, Baltimore, Carroll, Harford, and Howard counties. The program prepares students for further education and careers in engineering and engineering technology. Students complete foundation-level courses in engineering and then select an area of specialization, including computer integrated manufacturing, civil engineering and architecture, aerospace engineering, biotechnical engineering, computer science and software engineering, or environmental sustainability.

- ***STEM Achievement in Baltimore Elementary Schools (SABES)***

The STEM Achievement in Baltimore Elementary Schools (SABES) Program is a collaboration between Baltimore City Public Schools and Johns Hopkins University. The Program is funded by the National Science Foundation and focuses on community engagement in three Baltimore City neighborhoods. The goal of the project is to motivate Baltimore City elementary school students in grades three through five to improve academic performance and educational outcomes in STEM disciplines.

To date, the SABES Program is available in nine elementary schools. Participating schools host afterschool programs where students collaborate on engineering projects with mentors from JHU and tech companies. The program focuses on third to fifth grade students, because research shows that students who take advanced classes in STEM fields were hooked on STEM while in elementary school. In effect, students decide early if they like science and math. The program provides hands-on, minds-on classroom experiences to "hook" students on STEM. Participating students have an opportunity to exhibit their learning at fall and spring STEM showcase events.
The SABES Program also provides four training academies for existing elementary school teachers. The academies are designed to strengthen STEM instruction by providing content-focused professional development and are accredited by the Maryland State Department of Education for Continuing Professional Development Credit.

- ***Baltimore City Public School System***

Project Lead the Way

City Schools is committed to graduating students who are ready for the next steps toward college and career. A big part of that commitment is the district's award-winning programs in Career and Technology Education (CTE). In a CTE pathway, students take rigorous academic courses and participate in work-based learning opportunities, including job shadowing, mentoring with industry professionals or internships. City Schools offers two Project Lead the Way pathways—Biomedical Sciences and Pre-Engineering.

PLTW Pre-Engineering is a specially designed program that prepares students for further education and careers in engineering and engineering technology. Foundation courses include Principles of Engineering, Introduction to Engineering Design and Digital Electronics. Students

then select an area of specialization: Computer Integrated Manufacturing, Civil Engineering and Architecture, Aerospace Engineering or Biotechnical Engineering. In the final course, students work with industry professionals to complete a project in Engineering Design and Development. PLTW Engineering and Manufacturing Engineering Technologies students place in a postsecondary Maryland institution two quarters after graduation at a rate of 68.42%. The PLTW Engineering program at Baltimore Polytechnic Institute achieved full college certification in the spring of 2014, while Bluford Drew Jemison Stem Academy West and Maryland Academy of Technology and Health Sciences (MATHS) have undergone technical assistance and certification visits through the spring of 2016 (note, MATHS PLTW program has been moved to Western for SY1617).

Students in PLTW Biomedical Sciences follow a sequence of four courses — Principles of the Biomedical Sciences, Human Body Systems, Medical Interventions and Biomedical Innovations. Successful completion with a minimum Grade Point Average and results on final examinations can lead to 4 credits from Stevenson University. PLTW Biomedical Sciences students also have the opportunity to participate in two summer enrichment programs, the Baltimore Alliance for Careers in Healthcare (BACH) Fellows program, and a summer program at the Biotechnical Institute of Maryland designed for rising senior Biomedical Sciences students who are entering the Biomedical Innovations course.

Pathway	**# Schools offering pathway**	**Enrolled students (SY14/15)**
PLTW: Biomedical Sciences	6	405
PLTW: Manf., Engr. and Tech	8	645

DEVICES (3D printers)

Schools	**# devices**	**Pathway**
Augusta Fells Savage Institute of Visual Arts	3	CADD
MATHS	1	PLTW
REACH Partnership	1	Carpentry

Carver Vo-Tech	3	Carpentry; Manufacturing
Patterson	1	PLTW

Pathway	# Schools offering pathway	Enrolled students	Total seats	Utilization
IT	14	2184	3375	65%
Manf., Engr. & Tech	12	891	1500	59%

P-TECH

P-TECH schools are innovative grade 9 to 14 public schools that create clear pathways from high school to college and careers from young people from all academic backgrounds. Students are not pre-screened for admission and in six years or less; they graduate with a high school diploma and a no cost, two-year associate degree in a growth industry field. Each P-TECH school works with a corporate partner and a local community college to ensure an up-to-date curriculum that is academically rigorous and economically relevant. Hallmarks of the program include one–on-one mentoring, workplace visits and skills instruction, paid summer internships and first-in-line consideration for job openings with a school's partnering company.

City Schools is home to the first two P-TECH sites in the state. The two P-TECH sites are located at Dunbar High School and Carver Vocational Technical High School, and school year 2016-17 marks the inaugural year. Key features include:

- Carver
    - IBM is the P-TECH partner at Carver. The partnership includes an IBM staff member that serves as a liaison with district office and the school to ensure fidelity of program implementation, work based learning and internships, mentorships, and job placement.
    - Baltimore City Community College serves as the college partner and will work with students on dual enrollment and degree attainment and completion. P-TECH at Carver students will have the opportunity to receive an Associate Degree in either Cyber Security of Computer Information Science. The degree

opportunities are in alignment with workplace demands and projected job growth.

- Dunbar

    - Johns Hopkins University (JHU), University of Maryland and Kaiser Permanente are the P-TECH partners at Dunbar. The partnership also includes a JHU staff member that will serve as a liaison with district office and the school to ensure fidelity of program implementation, work based learning and internships, mentorships, and job placement.

    - Baltimore City Community College serves as the college partner and will work with students on dual enrollment and degree attainment and completion. P-TECH at Dunbar students will have the opportunity to receive an Associate Degree in either Surgical Technology, Respiratory Care, or Health Information Technology. The degree opportunities are in alignment with workplace demands and projected job growth.

Construction and Development

Labor market projections indicate that, for the year 2016, there will be 12,535 core construction-related job openings. In 2007-2008, construction-related post-secondary programs available in the Baltimore region graduated 1,676 individuals. Through marketing and outreach, the goal of BCPSS is to continue graduating additional students in the construction industry who are prepared for the 21st century workforce. In addition, special attention will be focused on ensuring that student learning opportunities are developed in conjunction with the 21st Century Building Initiative for City Schools.

For students interested in carpentry, plumbing, electrical work or masonry, the Construction Trades Professions program offers both classroom and real-world experiences. Graduates meet Apprenticeship Training requirements and may earn industry certification and college credit (in carpentry, 3 credits from the Community College of Baltimore County or 9 from Baltimore City Community College; in electrical, plumbing or masonry, 9 credits from BCCC). The Construction Maintenance program prepares students for further education and careers in heating-ventilation-air conditioning (HVAC), industrial maintenance or welding. Additional curriculum modules cover project management and project supervision. Graduates meet Maryland Apprenticeship Training requirements and may earn industry certification and college credit (in welding, 9 credits from BCCC). The state-approved local program in computer-aided drafting and design (CADD) allows students to become Autocadd-certified associates and to gain 6 credits from the Community College of Baltimore County or 9 from Baltimore City Community College.

Manufacturing

Students enrolled in the Manufacturing pathway strengthen their understanding of STEM topics. They work in specialized teams to complete challenging, real-world projects related to design,

manufacturing processes, supply chain logistics and quality improvements — and prepare themselves to use the advanced technologies of the 21st-century workplace. Employers in the manufacturing and engineering sectors need a pipeline of highly qualified employees to remain internationally competitive, and this CTE pathway is designed to meet that need.

Carver Vocational Technical High School's Manufacturing program is moving into year three of enrollment and working closely with their Program Advisory Committee as they progress towards full implementation. Funding for this cluster will support upgrades to materials, equipment, supplies, textbooks and software, as well as professional development geared towards student test preparation and direct support for teachers to support increases in technical skills attainment and placement two quarters after graduation. The goals for this cluster are to increase technical skill attainment and placement two quarters after graduation.

Pathway	**# Schools offering pathway**	**Enrolled students (SY14/15)**
Construction & Development • HVAC • Welding • Carpentry • Electrical • Plumbing • Masonry • CADD	6	428
Manufacturing	1	25

- *Postsecondary Education*

Many of Maryland's colleges and universities, including several in the greater Baltimore region, offer programs and courses designed to prepare students to work with 3D technologies. In addition, several colleges offer makerspaces and/or laboratories equipped with 3D printers and related equipment.

Listed below are several examples of courses and technology spaces available at Maryland's institutions of higher education. **This is not an exhaustive list of academic courses or technology spaces available at Maryland's colleges and universities, but provides examples of the opportunities available to students throughout the region.**

MARYLAND COMMUNITY COLLEGES

- **Anne Arundel Community College (AACC)**

Anne Arundel Community College offers several credit and noncredit courses in 3D technologies, which prepare students to work with concepts, techniques, and technology commonly used in gaming, entertainment, architecture, and engineering. Three-credit courses are available in 3D Computer Graphics, 3D Game Prototyping, Animation, Game Character Design, and Spec Topics in Art-Animation. Noncredit continuing education courses are available in Introduction to 3D Printing, 3D Art Master, Maker Labs: 3D Creation, AutoCAD 3 -- Basic 3D Modeling, and AutoCAD 4 - Adv 3D Basic Rendering.

The Introduction to 3D Printing allows students to design and build 3D models. Topics covered in the course include the theory of operation, technology inside 3-D printers, printing applications, basic maintenance, preparation of models and design considerations. In addition, students prepare a 3-D printer for use and learn the basics of 3-D CAD modeling.

- **Baltimore City Community College (BCCC)**

Baltimore City Community College offers several three-credit courses in Computer-Aided Drafting and Design (CADD), including courses in 2D/3D CADD applications, 3D Modeling, Architectural Application, Technical Graphics, Geographic Information Systems (GIS), Civil and Mechanical Engineering Applications. The CADD AAS degree program at BCCC offers a balanced course of study in drafting and design with the aid of state-of-the-art software, computers, and input/output devices. Students learn conceptual and technical skills with current CADD software package used by the industry including AutoCAD 2D and 3D, MicroStation, Revit Architecture, Autodesk Inventor, SolidWorks, 3ds Max, Civil 3D and ArcGIS desktop. Specific software applications include 3D modeling, animation, rendering, and lighting. Advanced CADD courses are designed to provide students with 3D CADD techniques and applications to increase productivity in the creation and editing of 3D models. Topics discussed include 3D coordinate systems, wire frame modeling, surface modeling, solid modeling, rendering, 3D primitive solids, and plotting 3D models typically found in mechanical, electrical, and civil engineering and in architecture. Students use a large size plotter and a 3D printer to print drawings and 3D models created in the CADD courses.

- **Carroll Community College**

Carroll Community College offers a three-credit course in Mechanical Applications of Solid Modeling Software. The course introduces students to mechanical applications of solid modeling software that are used in industry and includes the use of Inventor software's analytical tools to perform part inspections, mass properties, stress and inference analysis, and dynamic simulations as well as creation of molds for manufacturing. Students also explore the integration of Inventor software with 3D printing and CAM software to prepare parts for prototyping and manufacturing.

- **Community College of Baltimore County (CCBC)**

The Community College of Baltimore County (CCBC) has a Fab Lab, which is used by students and the broader community. Fab Labs began as an outreach project through MIT's Center for Bits and Atoms. The labs are comprised of off-the-shelf, industrial-grade fabrication and electronics tools, wrapped in open source software and programs written by researchers at MIT's Center for Bits & Atoms.

The CCBC Fab Lab supports students enrolled in the Associates of Arts in Science (AAS) degree program DFAB "Design, Fabrication and Advanced Manufacturing" and a community of users including entrepreneurs, inventors, educators, and students in a variety of disciplines. The DFAB program is designed to prepare students for employment or advancement in the fields of design, fabrication, manufacturing, and industrial technology with an emphasis on emerging technologies and strategies. Students will be able to compete in today's job market with a combination of CADD, prototyping, and CNC skills. The program combines traditional fabrication tools and software with new design and fabrication processes. Students have the opportunity to learn advanced fabrication principles using digital design and prototyping as a problem solving tool. These principles include advanced knowledge of each machine's operations and a working knowledge of related software.

The lab is also available for use by a variety of people from the community. Users take a course so they know how to use the software and hardware in the lab. There are also specific courses on any of the lab equipment; laser cutter, 3D printers, scanner, router, vinyl cutter and plasma cutter. Workshops are offered on topics of interest however workshops can be designed to meet the individual needs of any group. CCBC is able to offer 3D printing workshops off campus by utilizing portable printers that can be easily moved to a user's site.

CCBC recently signed a letter of intent with the Maryland Center for Career and Technology Studies (MCCTES) to enable teachers to earn 2 credits in 3D printing and design.

In addition, CCBC offers a variety of options for students 18 and older to earn credit and certificates, including:

- Four certifications in Computer Assisted Manufacturing (CAM) - CNC Machinist, CNC Programming, CNC Manual Machinist, and CNC Auto CAD.

- Four certificates in Computer Aided Drafting and Design (CADD) - Auto CAD, CAD Mechanical, CAD Management, and CAD Architecture.

Two national industry certifications are available to CCBC students who are taking certificate courses -- National Institute in Metal Working Skills and Manufacturing Skill Standards Council. In addition, students in a certificate program may use their credits and enroll in the AAS degree DFAB program.

The AAS degree DFAB program is in its first year. CCBC is working with a number of four-year colleges in the area to develop articulation agreements for the future. They include, but not limited to UMBC, Stevenson University, and MICA.

Presently there are three Baltimore regional counties that offer high school programs in manufacturing: Carroll, Anne Arundel, and Harford. Students can use their articulated credits to transition to the related manufacturing programs at CCBC.

CCBC also offers a number of professional development and job skill programs through its Continuing Education and Economic Development department: Industrial Maintenance Technician, Machining-Manual and CNC, Manufacturing Processes and Production, as well as Transportation, Distribution and Logistics.

- **Harford Community College**

Harford Community College offers a two-credit course on Introduction to 3D Printing, which is an introduction into the world of 3D printing, including the equipment and software used in the technology. Students assemble a 3D printer kit, and learn and use various open source software to model and print objects. The class is offered in a workshop format with hands-on lab based instruction and activities.

The College also offers an intermediate course in 3-D printing, which expands the application of 3D printing techniques learned in the prior course. Students use calibration files and other techniques for print optimization and finishing. Basic 3D scanning and enhancement of scanned files are introduced. Open source modeling software and meshing software are explored. Rapid prototyping and additive manufacturing concepts used in the production process are explained.

- **Howard Community College**

Howard Community College offers a three-credit course in Introduction to Building Information Modeling (BIM). Students learn the concepts, basic skills, and techniques for developing architectural floor plans and creating BIM models using Revit architecture, mechanical, electrical, and plumbing and Revit structural software. As part of the program students develop a 3D model and database.

At this time, Howard Community College is constructing a new science, engineering, and technology building, which will feature an engineering build room and labs for 3D printing and digital fabrication. The building is scheduled to open in 2017.

MARYLAND INDEPENDENT COLLEGES AND UNIVERSITIES

- **Capitol Technology University**

The Fusion Lab at Capitol Technology University is an open lab designed to foster collaborative projects between astronautic engineers, electrical engineers, cyber engineers, computer scientists, and business majors in an environment conducive to creative thinking and innovation. The lab is stocked with computers, software, 3D printers, tools, equipment, commercial off-the-shelf (COTS) parts, and miscellaneous supplies. The Fusion Lab is used to support senior capstone

projects, student club activities, undergraduate research, and training for specific courses. In addition, the lab is available to local high schools in the region.

The Fusion Lab operates as a guided open research laboratory. Students generate the ideas, create the designs, produce the products, and carry out the projects. In many instances, students use 3D printing to create cases, brackets, support structures, and other items to allow them to create new uses for COTS parts. Examples include a drone with a metal detector, a telescope with a balloon frame, and a model rocket with an altitude sensor. Students have even designed and produced small satellites using capsules printed with 3D printers.

- **Johns Hopkins University**

The Johns Hopkins Whiting School of Engineering offers various courses with components and modules on additive manufacturing (3D printing), starting with "Freshman Experiences in Mechanical Engineering" and extending to dual level courses such as the Department of Civil Engineering's "Topology Optimization and Design for Additive Manufacturing." 3D printing also is a key component of the capstone engineering courses for students in the departments of mechanical, biomedical, and electrical and computer engineering.

In additional to these courses, research into the advancement of 3D printing/additive manufacturing is occurring in the School of Medicine's Carnegie Institute and in the Whiting School's departments of mechanical and civil engineering, as well as in the Laboratory for Computational Sensing and Robotics (http://lcsr.jhu.edu/) and in the Hopkins Extreme Materials Institute (http://hemi.jhu.edu/) .

A recent story in *JHU Engineering* (http://hub.jhu.edu/2016/07/29/3d-printed-bone-for-facial-reconstructive-surgery/) describes how Dr. Warren Grayson and his team at Johns Hopkins are working to create ready-to-implant plastic bone that can turn into living tissue for patients undergoing facial reconstructive surgery.

- **Loyola University Maryland**

Various aspects of 3D printing is taught and used by faculty and students in science, engineering, fine arts, business, and the School of Education classes at Loyola University Maryland as described below.

The undergraduate engineering program at Loyola makes extensive use of 3D technologies in instruction. The department has two 3D printers in its mechanical and design labs—a high end ultraviolet object unit from Stratasys and a more basic and traditional fused deposition modeling (FDM) unit from MakerBot. In the junior-level Computer Aided Simulation and Design course, engineering students construct virtual 3D parts using SOLIDWORKS software and then fabricate their creations directly from their digital files using both 3D printers. This class, together with many others, paves the way for Loyola's senior-level Capstone Design Experience course, where teams of students work together on multidisciplinary design projects. The two 3D printers, as well as other computer-controlled manufacturing machines, are used by the student teams to fabricate evolving versions of their products. This rapid prototyping capability has

dramatically reduced the design cycle time, allowing the students to test and refine their designs more effectively.

Loyola's Computer Science department has a 3D printer that is used for teaching in a few project based courses as well as relevant senior design projects. The University also uses 3D printing in Camp Balti-Code, a 2-week summer program to introduce 7th and 8th grade girls to coding and technology. Loyola's Engineering Department is collaborating with the School of Education to better prepare high school teachers on 3D printing technology and curriculum. Through demo and tour of the 3D capabilities, the Engineering Department is also supporting some of the graduate level business courses. Student enrolled in studio arts courses also learn 3D technologies in at least three courses: Digital Mixed Media, 3D Design, and Contemporary Digital Art. Some of the skills taught in these courses are 3D scanning, problem solving in three-dimensions, designing three-dimensional structures for real world applications, and best practices for 3D printing. Studio Arts currently has one MakerBot Replicator printer and two iSense scanners. Loyola anticipates measurable expansion for this program in the future.

- **Maryland Institute College of Art**

As technologies such as 3-D printing have become increasingly popular, the Maryland Institute College of Art (MICA) has stayed on the cusp of the technological revolution. One of the most dynamic hubs of activity at MICA is the Digital Fabrication Studio, a facility housing 3-D printers, milling machines, laser cutters, a computer lab, and additional tools for creating interactive electronics, located in Mount Royal Station.

MICA students and faculty members across all disciplines embrace these tools and technologies to create innovative works of art. Most of these projects start either with the studio's 3-D scanners, which can be used to replicate or modify already made objects, or in the studio's computer lab, where computer aided drafting takes place or through our 3D printer which can print out of photopolymers, plastics, or a powder-based material similar to plaster.

MICA is also currently launching a new degree in Product Design. The key strategic goal of this new professional degree is to educate a new generation of product designers who create user centered objects to think and act differently towards the advancement of human dignity, social health, equitable economic progress, and environmental sustainability. Product engineering goes hand in hand with product design. Bringing cutting edge technology to their design processes will allow students to cross the line between the world of physical objects and the world of the supporting technology that is changing the way we think and make things. At MICA, Product Design, will focus on the role of engineering in the optimization and fabrication of products and the understanding of material transformation processes from one of mass production.

"We teach our students to think critically about these tools, which are reshaping our world physically, socially, and economically," Ryan Hoover, MICA's Director of Digital Fabrication Studio said. "While they are learning technical skills for their art and design practice, which are currently in high demand, they are also developing the knowledge to be thoughtful leaders in these new fields."

MICA launched the Product Design program, because the manufacturing tradition, social vitality, and well established higher education centers make Baltimore City the ideal location for a diverse economy in which the product designer may become a direct contributor to the local economy rather than a mere translator of client needs. From small production, high design products with a social tag; to advanced products that support the health care research conducted at Johns Hopkins University or the University of Maryland; to the professional opportunities that local companies such as Under Armor or Stanley Black & Decker may offer, Baltimore is ripe to become a design hub that breeds and supports the new kind of product designer who will be trained in all the latest 3-D Technologies so they can enter the workforce and add immediate value.

- **McDaniel College**

McDaniel College has five 3D printers in the Art and Art History Department, the Biology Department, and the English Department. Three dimensional technologies are taught in three courses: 1) Encompass, Make it, Market it, Sell it; 2) Comparative Anatomy of Vertebrates; and 3) Topics in Biology: Animals as Machines. In addition, 3D forms of art are practices in the following courses – sculpture, ceramics, jewelry, and advanced studio.

- **Stevenson University**

The Stevenson University School of Design offers 3-D designing and printing skill development as parts of its foundation studies program. The University's philosophy is that knowledge of 3D design and printing – using additive manufacturing and advanced digital prototyping tools – is essential for any practicing designer. Students who wish to continue to develop their skills beyond the foundation year have 24-hour access to the 3D printers in the University's labs. The School of Design opened new facilities in August 2016, which includes a dedicated fabrication studio.

MORGAN STATE UNIVERSITY

- Innovative Learning Program (formerly Minority Male Makers)

Through a partnership, the Verizon Foundation and faculty in the Morgan State University Department of Electrical and Computer Engineering launched the *Innovative Learning Program* (formerly Minority Male Makers) in 2015. The initiative is led by Dr. Kemi Ladeji-Osias and provides 6th - 8th grade African-American and Hispanic males with the opportunity to pursue their creative talents in the areas of science, engineering, technology and mathematics (STEM). The program establishes a "Maker Community" in Northeast that introduces 3D modeling software, use of 3D printers, mobile application development and entrepreneurship to Baltimore City Public School students and their teachers. Student participants attend a four-week summer program and a bi-monthly Saturday program during the academic year.

Furthermore, the Innovative Learning Program introduces students to the idea that their designs and software can lead to wealth creation in their communities. The program provides instructor-

guided design, and the development of student 3D designs to include key chains, chess sets, game controllers, bus shelters, phone accessories, 3D models of artwork, and the development of mobile applications with images, sound, and Internet links. To encourage self-efficacy among the students, the program provides the opportunity for them to pitch an idea for a new business, and to interact with local technology entrepreneurs and corporate leaders, minority inventors, college student mentors, and other speakers. The instruction for the program is provided by Morgan State University faculty, staff and graduate students using a Makerspace and computational facilities in the School of Engineering.

- Center for Excellence in Mathematics and Science Education

The Morgan State University Center for Excellence in Mathematics and Science Education offers a "Teachers Workshop" designed to support the develop of transdisciplinary lesson plans that integrate 3D modeling and printing among science, mathematics, engineering and technology teachers. The workshop is a one-week summer workshop that utilizes the lessons in their classroom during the academic year. The program serves 15 Baltimore City Public School teachers.

- Engineering

The Advanced Engineering Design Center established by the Department of Industrial and Systems Engineering comprises two laboratory facilities that engages 3D printing. One laboratory houses computational resources and machines for Computer Aided Design and Manufacturing (CAD/CAM), rapid prototyping, material analysis and coordinate measuring. The second facility is designed to advance technology manufacturing. The Center allows undergraduate and graduate students to "take an idea from inception, to design, to prototype, to manufacture, and to testing, and to engage in quality control." The Clarence M. Mitchell, Jr. School of Engineering is poised to graduate student innovators that move manufacturing technology into a purchasing system in our country that allows parents the option for their children to make their own toys.

In the Engineering Visualization Research Laboratory, additive manufacturing is used to conceptualize new ideas, experiment with various designs, and to construct various components needed for research activities. Specifically, the Laboratory uses the Makerbot 3D printer to iteratively design various components, such as external housings for sensors, and support frames for quad-copter unmanned aerial vehicles. The process sometimes involves dozens of iterations to obtain optimal performance and utility. In addition the 3-D printer is occasionally utilized within computer graphics/vision courses to explain various concepts like "shape from shading" and "hyper dimensional projection". The physical manifestation of conceptual models enables students to better connect with some of the mathematical principles behind the models, which improves their ability to implement these models in code.

UNIVERSITY SYSTEM OF MARYLAND

The University System of Maryland has three major investments in 3D printing and programs in the Baltimore area:

- The University of Maryland Baltimore County (UMBC) Imaging Research Center utilizes 3D printing and technologies. In addition, UMBC has related programs in digital imaging and engineering;

- The University of Baltimore offers gaming design and computer science programs that utilize 3D technologies; and

- A professor of the Towson University Art and Design program is working with Digital Harbor students teaching 3-D technologies.

- *Makerspaces and Targeted Programs*

    - **Digital Harbor Foundation**

The Digital Harbor Foundation (DHF) was established in 2013 in a closed-down recreation center in Baltimore City. The mission of the Center is to foster learning, creativity, productivity, and communication through education. In 2014, DHF launched the Center of Excellence to train others and foster additional learning environments. Today, DHF offers several programs to elementary and secondary students in the greater Baltimore region and coaches educators on how they can bring technology into their learning environments.

        - *DHF Programs for Youth*

The DHF 2016 Maker Camp is open to students in grades 3 to 12 and is designed to give students the opportunity to engage in camp experiences focused on 3D printing, circuits, and electronics, Minecraft, and other technologies. Students are able to learn and sharpen their skills while working hands-on with materials. The DHF Camp provides age-appropriate, engaging, and creative pathways to technology and engineering knowledge. Elementary school students may enroll in programs to learn how to design fun images and graphics – then put that knowledge to use with 3D printing or learn the basics of electronics through hands-on projects. Middle and high school students may enroll in more advanced classes to learn how to use software and 3D printers to design and fabricate customized objects, learn basic problem solving skills through an exploration of the intersection of electronics and code, or solve puzzles working together to construct a Minecraft world.

DHF also provides an introductory course for middle and high school youth through a 14-week program. Students explore emerging technology topics, design and 3D print their own creations, learn to program games and make game artwork, make a website, and create interactive

electronics. The focus of the program is to deepen interest in technology and prepare students for a future in technology and engineering.

DHF hosts a monthly family-focused workshop designed for families of up to six people to work together on a project. Each month is a different theme and project. There are sample projects to work from and all materials needed to complete the project are provided.

Through the support of donors and supporters, DHF offers a limited number of field trip opportunities free of charge to Baltimore area public schools. Last year, DHF hosted 676 students on 33 distinct 3D printing field trips.

- *DHF Programs for Educators*

DHF offers a two-day workshop to provide educators with the knowledge they need to bring immersive hands-on experiences into their learning programs. The workshop teaches educators how to create makerspaces for youth. Participates are eligible for one Continuing Professional Development (CPD) credit through the Maryland State Department of Education.

Educators who are interested in technical training on 3D printing may enroll in a multi-day program offered by DHF. Participants receive hands-on instruction and practice with 3D hardware and software and are taught methods and approaches to teaching the technology. Participants are eligible for 2 CPD credits through the Maryland State Department of Education.

The Internet of Things is a workshop for educators, which was launched earlier this year. The workgroup teaches educators how to program connected devices to monitor and interact with the world around them. Educators learn to use materials to support step-by-step projects that allow youth to interact with and monitor their environment while collecting real-world data. For example, participants may use temperature and humidity sensors to collect and upload data to the Internet or Google spreadsheets and use the data to find averages, highs, lows, and trends.

Interactive Game Design is a rapidly developing field that exists in the intersection of physical components and computer programming. DHF launched a workshop this spring to teach educators how to program basic game mechanics that integrate physical components.

DHF also convenes educators who are currently making or interested in making as part of their learning programs. Educators meet regularly to explore new technologies in the field, discuss practical applications of these technologies for teaching, and network with one another.

- **Verizon Minority Male Makers**

Verizon Minority Male Makers (MMM) partners with 11 institutions across the country, including Morgan State University, to cultivate STEM talent in middle school boys from minority groups. Minorities are significantly underrepresented in STEM fields, and many boys struggle academically in elementary and secondary school. The MMM Program matches middle school students with colleges and universities to provide free, hands-on experiences with projects in science, technology, engineering, and math (STEM). Students attend the Minority Male Makers program for four weeks of summer classes, plus additional classes and mentoring during

the school year. *(Additional information about the MMM Program led by Morgan State University is included in the "Postsecondary Education" section of this report.)*

- **Open Works Baltimore**

In 2012, the board of the Robert W. Deutsch Foundation formed the Baltimore Arts Realty Corporation (BARCO), a non-profit development company with a mission to create safe, affordable, and accessible space for Baltimore's creatives. In 2013, BARCO purchased a former distribution warehouse for the Railway Express Agency on Greenmount Avenue to pursue the development of a makerspace, Open Works, which is a place for craftsmen, artists, and small manufacturers. Open Works houses a wood shop, metal shop, and digital media studio along with a digital fabrication shop (CNC routers and laser cutters), a 3D imaging and 3D printing studio, a microelectronics lab, and a textiles studio. The facility provides 150 individual micro-studios (50-square-foot workspaces) for designing, assembling, and finishing projects.

Financing for the project comes from a blend of public and private sources. Grants from the Robert W. Deutsch Foundation, the Abell Foundation, the Maryland Department of Housing and Community Development, and the Maryland Department of Business and Economic Development provided initial financing for the facility's renovation and redevelopment. The Goldseker Foundation also has invested in the project through a grant for BARCO's operating expenses.

The mission of Open Works is to make tools, technology, and the knowledge to use them accessible and affordable to artists, hackers, micro-manufacturers, investors, students, teachers, entrepreneurs, and builders. Open Works provides a place for people to learn from one another and collaborate on building a new economy.

- **3D Maryland**

3D Maryland was a state-wide leadership initiative to increase engagement between 3D printing and additive manufacturing and regional businesses, industry, and entrepreneurs. By building on their regional strengths and growing a local advanced manufacturing ecosystem, the program collectively moved to strengthen Maryland's economy and looked to increase the awareness of 3D printing and additive manufacturing technologies and the competitive advantages these technologies offer. Through the increased awareness 3D Maryland helped to drive business growth, facilitate engagement and implementation, transform existing companies, and create new start-ups. The program was funded by the Howard County Government. No funds were provided in the fiscal 2016 budget, and the future of the program is uncertain.

FINDINGS

The greater Baltimore region has a solid foundation in 3D design, engineering, and additive manufacturing and is poised to lead the nation in the application of 3D technologies. The region is home to several military installations and nationally ranked universities engaged in 3D research and innovation. Area colleges and universities have added academic programs, courses, and laboratory spaces devoted to 3D technologies. Elementary and secondary schools have adopted new science standards that support exploration, discovery, and creativity, and 3D technologies are used and taught in local schools throughout the region. Numerous makerspaces and digital centers provide space and equipment to allow students and adults to explore and create.

In recent years, there have been several reports published on the employment opportunities available in STEM related fields and additive manufacturing in the greater Baltimore region. Groups have analyzed the educational requirements needed to work in these fields. Studies have been conducted on the availability of education and training opportunities in the Baltimore area to support these careers.

Despite these advantages, the region has failed to fully capitalize on the 3D revolution. After 18 months of gathering information from industry leaders, educators, nonprofit organizations, and researchers, the GBC Education and Workforce Committee identified the following barriers and challenges:

- There is a stark lack of awareness on the part of the general public to the transformational changes taking place in industries due to 3D technologies.

- The public is unaware of the numerous educational pathways available to Marylanders to prepare for jobs in 3D design, engineering, additive manufacturing, and related fields. Parents, students, educators, and others have failed to understand the importance of 3D technologies to the economic health of the region.

- Educators at all levels of the education spectrum lack training to effectively use 3D technologies and incorporate 3D technologies into the curriculum.

- While 3D printers are available at some educational institutions, educators lack access to and understanding of advanced software and equipment used by businesses and industries.

- More needs to be done to connect industry with educational institutions at all levels to ensure that academic programs are relevant and consistent with emerging industry standards and technology.

RECOMMENDATIONS

There are numerous employment opportunities available to residents who have an understanding of 3D technologies. Baltimore area industries, such as healthcare, defense, architecture, engineering, construction, advanced manufacturing, apparel design, computer gaming, consumer products, and film animation, are using 3D technologies to drive change and innovation. These employers require entry-level workers, trained laborers, artists, designers, technicians, engineers, computer scientists, chemists, and researchers who can work with 3D technologies. The educational requirements for these positions are diverse and include all levels of the education spectrum – workforce training; certificates; and undergraduate, graduate, and post-graduate programs.

The GBC Education and Workforce Committee recommends the greater Baltimore region take focused, intentional actions to implement the following goals:

1. Improve the economic competitiveness of the greater Baltimore region by influencing the preparedness of the workforce to utilize 3D technologies in design, engineering, visualization, computer-aided design and drafting (CADD), and additive manufacturing; and

2. Stimulate new economic activities by empowering residents with the knowledge and resources required to create new businesses based on 3D capabilities.

To support these overarching goals, the Committee recommends the region implement the following strategies:

- Establish tax incentives to encourage Maryland businesses to partner with local schools, colleges, universities, and makerspaces to:
    - Provide access to advanced and specialized 3D equipment and software;
    - Offer professional development to teachers, faculty, and staff;
    - Support extracurricular opportunities and/or internships to area youth;
    - Facilitate opportunities for industry representatives to speak at local schools, colleges, and universities about 3D technologies and the implications on the job market and the economy;
    - Establish mentor programs for area youth;
    - Work with educators to develop and modify curriculum to effectively incorporate 3D technologies and active learning into classrooms and laboratories; and
    - Workplace learning opportunities.

Responsible Parties: The Greater Baltimore Committee should take a leadership role in seeking legislation to grant tax incentives to area businesses to implement this strategy. Local schools, colleges, universities, makerspaces, and businesses and industries that rely on 3D technologies should work with GBC to secure passage of the legislation.

- Provide professional development opportunities to elementary, secondary, and postsecondary educators on utilizing 3D technologies; maintaining 3D equipment; and engaging students in active learning, problem solving, case studies, and simulations using 3D technologies.

  Responsible Parties: The Maryland State Department of Education (MSDE) should authorize Continuing Professional Development (CPD) credits to elementary and secondary educators who participate in high-quality professional development to advance their knowledge and utilization of 3D technologies. Colleges and universities should encourage faculty throughout the institution to implement 3D technologies, as appropriate, into the academic curriculum.

- Expand opportunities for elementary, secondary, and postsecondary students to engage in creative thinking and innovation through the use of 3D technologies by providing after-school programs, summer camps, and extracurricular programming, including 3D expos, challenge fairs, and competitions.

  Responsible Parties: Local schools, colleges, and universities should work with industry partners and makerspaces to expand after-school programs, summer camps, and extracurricular programs. Multiple institutions should partner to create challenge fairs and competitions, similar to the Robotics Challenge, to motivate students and stimulate interest in 3D technologies.

- Develop a comprehensive communications campaign to build awareness about the importance of the 3D revolution, its implications on the economy and the job market, the availability of makerspaces with 3D equipment and software, and the academic programs and educational pathways that prepare students to work with 3D technologies. The communications campaign should be targeted to students, parents, communities, and government leaders. The campaign should include a "summit" for community, education, and business leaders to showcase 3D technologies utilized by Maryland's businesses and researchers with a focus on recommendations to position the greater Baltimore region as a leader in this transformational development.

  Responsible Parties: The communications campaign should be coordinated by area business and industry associations working in collaboration with STEM organizations, State agencies, local governments, and educational institutions. Every effort should be made to incorporate this message into existing activities, such as messages and reports published by the Greater Baltimore Committee; Maryland Department of Commerce; the Maryland Department of Labor, Licensing, and Regulation; the Maryland Higher Education Commission; the Maryland State Department of Education; local school systems; industry organizations; economic alliances; and institutions of higher education.

A D D E N D U M

PRESENTERS:

Listed below are short bios of the individuals who presented to the GBC Education and Workforce Committee. The biographical information is based on the positions the individuals held at the time the presentations were made to the Committee.

Aslan, Kadir
Assistant Dean for Research, Morgan State University

Kadir Aslan is the Assistant Dean for Research and Graduate Studies and Professor of Department of Chemistry at Morgan State University. His research interest is in Nanotechnology and Biotechnology, such as Plasmonics, Metal-Enhanced Fluorescence, Metallic Nanoparticles, Medical Biotechnology and Biosensors.

Aydukovic, Robert M.
President, Maryland Center for Construction Education and Innovation (MCCEI)

Robert Aydukovic is the President of the Maryland Center for Construction Education and Innovation (MCCEI). MCCEI is an industry driven public-private partnership working in tandem with private industry, government, and Maryland's universities, community colleges, apprenticeships and secondary schools to position construction as a career of choice, to promote the economic vitality of construction in Maryland, and serve as an industry resource. In addition to MCCEI, Aydukovic serves as an adjunct faculty member at the University of Baltimore teaching Community Economic Development in the undergraduate Real Estate and Economic Development (REED) program and at the Johns Hopkins University teaching Managing Construction Projects in the Master of Science in Real Estate and Infrastructure program. Aydukovic also serves as Executive in Residence at the University of Baltimore strengthening relationships between the Merrick School of Business and industry.

Baum, Jan
Executive Director, 3D Maryland

After a six-year stint on the west coast, Jan Baum returned to the east coast as Director of the Metalsmithing & Jewelry program at Towson University in Baltimore, Maryland. She also serves as the Executive Director of 3D Maryland, which is a state-wide leadership initiative to advance the engagement of 3D printing and additive manufacturing among business, industry, and entrepreneurs across industries in the state of Maryland. In addition, Baum is the Director and founder of Object Lab, a comprehensive, research-based, state-of the-art rapid technologies and digital fabrication lab based in the Baltimore, Maryland region. Object Lab engages in the full range of digital technologies for next generation making and manufacturing: 3D imaging and

scanning, 3D digital modeling, rapid prototyping, and digital fabrication. The Lab has six 3D printers, three open source and three proprietary, and utilizes four different 3D printing technologies. Object Lab is an open regional resource educating and engaging audiences in a 21st century digital age mindset.

Burch, Kenneth
Project Specialist, Community College of Baltimore County

Kenneth Burch serves as a Project Specialist at the Community College of Baltimore County (CCBC.) He joined CCBC in 2007 as the Director of Technology and Innovation in Manufacturing and Engineering (TIME) Center. Prior to accepting this position, he worked at the Western School of Technology and Environmental Science for more than 30 years, including twelve years as Assistant Principal and 15 years as Principal.

Carey, Michael
Executive Dean of Continuing Education and Economic Development, Community College of Baltimore County (CCBC)

Michael Carey is the Executive Dean of Continuing Education and Economic Development for the Community College of Baltimore County. Carey is also a member of the National Council for Continuing Education and Training, the National Council for Workforce Education, and the American Society for Training and Development.

Coy, Andrew
Executive Director, Digital Harbor Foundation

Andrew Coy is an educator, technologist, mentor, entrepreneur, and Executive Director of the Digital Harbor Foundation. He has received numerous awards including 40 Under 40 by *Baltimore Business Journal,* Innovator of the Year by *The Daily Record,* Champion of Change by Economic Alliance of Greater Baltimore, and Ashoka Changemaker's Emerging Innovator. His work has been highlighted in *Forbes* Magazine, *Smart Cities*, *Baltimore Sun*, *Education Week*, and *K12 Magazine*. He has presented across the United States, including the White House Maker Faire, Executive Round Table on Computer Science Education & Careers in US, International Society for Technology in Education (ISTE) annual conference, the Education Technology Innovation Summit, and was the lead organizer for the 2015 SXSWedu Technology Education Summit. Coy has sat on numerous workgroups focused on technology and education, and currently serves as an advisory board member to the Maker Education Initiative.

Dodd-O, Michael
Faculty, Hereford High School

Michael Dodd-O is a Technology Education Instructor at Hereford High School in Baltimore County where he teaches courses in Engineering Principles and Applications, Advanced Technical Applications, Advanced Design Applications, Engineering Research and Design, and Engineering Tech/Gifted and Talented. In 2014, Dodd-O received the Technology and Engineering Educators Association of Maryland award.

Hannum, Terence
Artist, Musician, and Assistant Professor of Art, Stevenson University

Terence Hannum is a Baltimore based visual artist and musician who performs solo, with the avant-metal band Locrian (Relapse Records) and the dark synthpop duo The Holy Circle. Hannum is an Assistant Professor of Art at Stevenson University. He has had solo exhibitions at Guest Spot (Baltimore), Western Exhibitions (Chicago, IL), Stevenson University, Museum of Contemporary Art, Chicago, Gallery 400 at UIC (Chicago, IL), and in group shows at TSA (Brooklyn, NY), sophiajacob (Baltimore, MD), Allegra La Viola (NYC), City Ice Arts (Kansas City, MO) & Jonathan Ferrara Gallery (New Orleans, LA).

Hostalka, Amanda Gingery
Dean, School of Design, Stevenson University

Amanda Gingery Hostalka, MA, MFA, is a leader in curricula development and assessment, community outreach, and career development. As Dean of the School of Design at Stevenson University, she is responsible for overseeing all aspects of the school, comprised of programs in Business Communication, Fashion Design, Film and Moving Image, and Visual Communication Design. Her teaching and community service accomplishments were recently recognized with the 2013 *Stevenson University Fostering Learning Award*.

Kang, Sung Hoon
Assistant Professor, Johns Hopkins University Whiting School of Engineering

Sung Hoon Kang has been an Assistant Professor in the Department of Mechanical Engineering and Hopkins Extreme Materials Institute at Johns Hopkins University since 2015. Prior to his appointment, he was a postdoctoral fellow in Materials Science and Mechanical Engineering at Harvard University working with Prof. Katia Bertoldi. He has been studying complex behaviors of material systems and structures with novel properties based on inspiration from nature as well as rational design followed by rapid prototyping using a 3D printer. By designing experimental model systems and/or using computational models, he has been working on identifying key design parameters of systems to enable changes to the structures and properties of those systems.

Kirkner, Robert
Student at Stevenson University, Intern at 3D Maryland

Robert Kirkner is a Junior at Stevenson University studying Visual Communication Design in the Interactive Design Track. Kirkner is currently an intern at 3D Maryland, a state-wide initiative to promote 3D printing and additive manufacturing in the regional business, industrial, and education communities. In addition to being a full-time student and an intern, Kirkner maintains a busy freelance design practice.

Kroiz, Gabriel
Associate Professor & Undergraduate Department Chair of School of Architecture & Planning, Morgan State University

Gabriel Kroiz is Associate Professor & Undergraduate Department Chair of School of Architecture & Planning at Morgan State University. He also founded Kroiz Architecture. An award winning designer and preservationist, Kroiz has over 15 years of experience as an architect, builder, and educator. His primary focus has been sustainable building solutions which Kroiz has explored since his early projects. In addition to his practice, Kroiz has taught in the US and abroad and has been the Director for the MICA Summer Study Abroad Program in South Korea.

Ladeji-Osias, Kemi
Associate Professor and Associate Chair for Graduate Studies in the Department of Electrical and Computer Engineering, Morgan State University

Kemi Ladeji-Osias is the Associate Professor and Associate Chair for Graduate Studies in the Department of Electrical and Computer Engineering at Morgan State University. She teaches undergraduate and graduate courses in computer engineering. Her involvement in engineering curricular innovations includes outcomes-based articulation and online delivery of undergraduate engineering degrees. In addition to conducting research on color image fusion and real-time implementation of algorithms, she is the immediate past chair of the Middle Atlantic Section of the American Society for Engineering Education and a member of the Institute of Electrical and Electronics Engineers. Ladeji-Osias enjoys observing the intellectual and professional growth in students as they prepare for engineering careers.

Marietta, Sally Scott
Program Managaer, Corporate Citizenship and Corporate Affairs, IBM Corporation

Sally Scott Marietta is the Program Manager for Corporate Citizenship and Corporate Affairs in Maryland, Virginia, and Washington, DC for the IBM Corporation. Marietta's commitment to and involvement with education and economic development has been a lifelong journey. In support of IBM's primary focus areas, Marietta represents IBM on the Association of Baltimore Area Grantmakers and Washington Grantsmakers. She is a member of the Technology Council of Maryland's Governmental Relations Committee. She is also a member of the Maryland Business Roundtable for Education's Steering Committee. Prior to joining IBM, Marietta was

Executive Director of the Maryland Economic Development Commission. She was previously vice president of The Greater Washington Board of Trade.

Rudolph IV, Alvin L.
Staff Architect, Ayers Saint Gross

Rudolph L. Alvin, IV is currently a Staff Architect in the Baltimore office of Ayers Saint Gross. He received his Bachelors of Science in Architecture and Environmental Design, as well as a Masters of Architecture from Morgan State University. He has been involved in the development and production of both digital and physical models at ASG for the last two years, and currently manages the operations, training and maintenance of the in-house model shop at Ayers Saint Gross.

Ruiz, Rudy
Executive Director of Office of College and Career Readiness, Baltimore City Public Schools

Rudy Ruiz, Executive Director of Office of College and Career Readiness, orchestrates collective impact among local, regional, and national partners to increase students' postsecondary success. Ruiz provides leadership for systemic high school improvements, focusing school and district staff on college and career readiness efforts to engage the community in improving the life chances of the City's youth. Ruiz and his team align and coordinate the work of various internal and external groups, including direct oversight for the offices of career and technical education, school counseling, and school scheduling, as well as leadership in city-wide consortia connecting higher education partners and agencies from other sectors.

Russell, Brian
Integrated Practice Manager, Ayers Saint Gross

Brian Russell is the Integrated Practice Manager at Ayers Saint Gross and has over 10 years of experience working in the Architecture and Construction fields. He is an expert in Building Information Modeling (BIM), Design Visualization, and has been actively implementing BIM and building SMART methodologies at Ayers Saint Gross for the last seven years. Russell is a member of the National Building Information Modeling Standards (NBIMS) design project committee and is involved in shaping the future of Integrated Project Delivery and BIM.

Sadusky, Bernard
Executive Director, Maryland Association of Community Colleges (MACC)

Bernard Sadusky was appointed Executive Director at MACC in July 2012, after completing a year of service as Interim Superintendent at the Maryland State Department of Education (MSDE). Sadusky served as Superintendent of Schools in Maryland's Queen Anne's County

from 1994 to 2007, and spent more than 30 years in the Queen Anne's school system as an administrator and teacher. He was recognized as Maryland's Superintendent of the Year in 2007. Following his retirement in Queen Anne's County, he joined MSDE as policy liaison to the local school systems, before being appointed by the Maryland Board of Education to serve as Interim State Superintendent in 2011. With this extensive background in K-12 education in Maryland, Sadusky is recognized as having played an important role in achieving and maintaining "Maryland's status as the number one school system in the nation." In his role as the Executive Director of Maryland's 16 community colleges, Sadusky is working with the Governor's P-20 Council to integrate and enhance the alignment of K-12 with Maryland's postsecondary education and training.

Craig Spilman
Education Consultant, Lecturer at the Maryland Institute College of Art, and Principal/Academic Director at Creative City Public Charter Schools

Craig Spilman is an education consultant. He currently serves as a lecturer in the Master of Arts in Teaching Program at the Maryland Institute College of Art and is the Principal and Academic Director at Creative City Public Charter School. He has also served as the Executive Director of the CollegeBound Foundation, which is one of the nation's premier college access programs serving students in the City of Baltimore. Spilman was recognized for leading the transformation of three urban middle schools in Baltimore. He also served ten years as the Executive Director of the Maryland State Middle School Association and fifteen years as the education director for Baltimore City's Sister Cities International Program.

Thomas, Michael
Director, Career Readiness, Baltimore City Public Schools

Michael Thomas directs the Baltimore City Public Schools Office of Learning to Work. A proud U.S. Marine, Thomas has a long history of working to support young people in maturing into successful adults. The primary question that guides his work is "how is this benefiting students?" His office oversees the Farm as well as Career and Technology Education, JROTC, Guidance and Counseling, and Work-Based Learning for the entire school district.