INTEGRATING STEM INTO THOMAS H. HENDERSON MIDDLE SCHOOL

Applied Policy Project

UNIVERSITY of VIRGINIA
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Honor Statement

On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the authors, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

ACRONYMS

CBE – Competency Based Education

EOtC – Education Outside the Classroom

Henderson – Thomas H. Henderson Middle School

PBL – Project Based Learning

NGSS – Next Generation Science Standards

RPS – Richmond Public Schools

SOL(s) – Standards of Learning, Virginia Department of Education standards

STEM – Science, Technology, Engineering, and Math

VDOE – Virginia Department of Education

Executive Summary

Thomas H. Henderson Middle School has not been accredited in several years due to low student performance on state SOL tests and large academic proficiency and disciplinary gaps between black and white student. The wealthy white students zoned for Henderson attend private schools or abuse the districts open enrollment policy to attend a more desirable middle school. This has caused the school to be severely under enrolled and has decreased its racial diversity. Henderson has the capacity to serve over 1,400 students, but currently serves only 386. Of these 386 students, 94.4% are African American, making Henderson one of the largest minorities serving schools in the state by percentage.

In response to these issues, RPS created the DREAMS4RPS 5-year strategic plan that aims to revitalize the city's public-school system. The Passion4Learning project will transform every Richmond middle and high school into a specialized academy that focuses on a specific subject area, like STEM or Law. RPS is launching a pilot program for incoming 6th graders that will transform Henderson into a STEM academy during the 2020-2021 school year. The ultimate goal of this pilot is to increase student engagement in the classroom and to set students on a path to long term success by engaging them in this high value career field.

In order to assist RPS staff in the redesign, I have identified three key areas that have been shown to increase student engagement. These include:

Project-Based Learning: pushes learners to develop a stronger understanding of how class material can be applied in the real world.

Education Outside the Classroom: encourages students to engage with course material at a deeper level by giving them an outlet to connect with academic material in a less formal setting outside of a traditional classroom.

Competency Based Education: encourages students to move through material at their own pace.

Using these best practices as a guide, I canvased available STEM teacher training programs, activates, and curricula to determine programs that could help RPS succeed in its redesign. I identified a curriculum tool, three teacher training programs, two activity and lesson sources, and two major packages that combined all of the resources into one program. I analyzed these resources based on cost, utilization of best practices, evidence-based practices, and equity.

Based on the criteria, I recommend that RPS utilize a combination of resources to best serve Henderson Students. RPS's curriculum development team should train Henderson teachers using **STEM Teaching Tools** modules. **TeachEngineering's** curriculum guides should be combined to create a custom curriculum package**. NASA's** STEM activates should be supplemented into the curriculum to add verity. Combined, these resources will enable Henderson staff to successfully increase student engagement with STEM.

DEFINING THE PROBLEM

Background: An Overview of Richmond City Public Schools

The Richmond City Public Schools (RPS) system currently serves over 24,000 students across 26 elementary schools, 8 middle schools, and 8 high schools (VDOE, 2019). Over 80 percent RPS students are African American or Hispanic and over 55 percent are economically disadvantaged, meaning their family lives at or below the federal poverty line. This makes RPS Virginia's largest server of minority and underrepresented students.

On November 20th, 2017, the Richmond School Board named Jason Kamras, the former Chief Equity Officer of Washington D.C.'s Public Schools, superintendent of the division. In March 2018, Kamras and the School Board hired a new executive team to replace the previous chief executive staff (Mattingly 2, 2018). During Kamras's first month in Office, RPS commissioned The Education Trust, a D.C. based non-profit k-12 education policy specialist, to analyze academic equity issues throughout the division and The Council of the Great City Schools, a coalition of urban school systems dedicated to improve education in cities, to analyze RPS' bureaucratic operations (Mattingly, 2018). The Education Trust had several key findings (The Education Trust, 2018):

- Black students were disproportionally suspended compared to their white peers.
- One in five students were chronically absent.
- Wealthier/lower need schools had lower teacher turnover and less first-year teachers.
- There are major achievement gaps between white and black students.

The Council of the Great City Schools found (Carlson et al., 2018):

- Frequent turnover of key executive staff has hindered the district's ability to generate long-term and sustainable change.
- Interdepartmental communication is poor.
- RPS executive departments lack clear districtwide goals and priorities for planning and articulating a clear direction.

In short, the lack of high-quality directional leadership from RPS' former executive team enabled chronic educational disparities to flourish.

These systemic issues have been reflected in state accreditation reports, district level Standards of Learning (SOL) results, and in high-school graduation rates. For the last several years, none of the districts secondary schools have been fully accredited. In the last three years, there has been no division wide improvement in SOL scores (VDOE, 2019). In 2018, Richmond high schools had a 75 percent graduation rate, 17 percentage points lower than the state average and the worst in the state (VDOE, 2019) (Mattingly 3, 2018). These academic issues push wealthier and mostly white parents to send the children to private schools, to move out of the city, or to transfer their student to non-zoned RPS schools. For every 100 children born to Richmond residents six years ago, only 73 enrolled in first grade public schools during the 2018-19 school year (Oliver, 2018). White children born in Richmond were the least likely to attend one of the city's public schools. Only, 27 out of 100 white children born to city residents attended first grade in one of the city's public elementary schools (Oliver, 2018).

District level zoning policies enable racial educational disparities to persists. The divisions open enrollment policy allows students to sign up for a lottery to attend a non-zoned school. This enables students to flee 'failing' schools and to attended a more desired school. The majority of transfer students attend more predominately white and socio-economically wealthy schools; even if the non-zoned school has just as poor academic results.

DREAMS4RPS: RPS 5-Year Strategic Plan

To revitalize Richmond's school system and to establish long-term goals, Superintendent Kamras and the new executive team created the DREAMS4RPS 5-year plan. RPS staff held over 150 public meetings and met with 3,000 stakeholders to incorporate parent, student, and teacher feedback into the plan and to ensure that the broader Richmond community had buy in over the initiative. The 2018-23 strategic plan established five long-term priorities for RPS:

1. Exciting and Rigorous Teaching and Learning
2. Skilled and Supported Staff
3. Safe and Loving school Culture
4. Deep Partnerships with Families and Community
5. Modern Systems and Infrastructure

These priorities aim to improve the student and teacher experience in the classroom and close proficiency gaps. Each priority is made up of dozens of actions steps that will push RPS to meet its long-term goals.

Passion4Learning Project

The Passion4Learning project is the key action item under Priority 1: Exciting and Rigorous Teaching and Learning. It is focused on revitalizing the student experience at RPS. This multi-year effort will transform every traditional middle and high school in the division into a specialty focused school. The long-term goal of this project to give students agency over their education by enabling them to choose a focus early on in their educational career. To launch the project, RPS is creating a pilot program for all incoming 6th grader at Thomas H. Henderson Middle School that will transform the school into an open enrollment Science, Technology, Engineering and Mathematics (STEM) academy.

Thomas H. Henderson Middle School

Thomas H. Henderson Middle School (Henderson) is located on the North side of Richmond and serves 386 students, making it the smallest middle school in the division (Henderson, 2019). Built in 1973, Henderson was designed to serve 1,440 students and incorporates an open school plan the divides large octagonal spaces into split classrooms (RPS History, 2020). Unlike other middle schools in Richmond, Henderson is under enrolled, meaning that it has the capacity to serve more students. Henderson is classified as a Virginia Department of Education (VDOE) high poverty school, meaning that the majority of students come from low-income families. The school has the least diverse student body in the division, with African American's making up over 94% of the school's student body. According to the VDOE, 17.8 percent of Henderson teachers are provisionally licensed and 6.7 percent have been assigned to teach classes outside their field, 2.5 percentage points higher than the city average (Henderson, 2019). During the 2019-2020 school year, 47% of Henderson students faced disciplinary actions. Henderson has had high turnover among teachers and administrators' staff and currently has many vacancies. It faces similar racial and socio-economic academic and disciplinary gaps as other schools in the division and has not been fully accredited in several years.

Issues to be Addressed at Henderson by the STEM Redesign

The goal of the transformation is to better engage students in the classroom in order to improve academic achievement, reduce absenteeism, and decrease disciplinary rates. Through the redesign, RPS hopes to provide students with a structured career path through their educational career and increase student agency over their own future. If the STEM project is successful, RPS hopes to see more engaged students, improved SOL scores, and a more supportive staff.

Steps Taken in the Transformation Process

In 2019, RPS replaced Henderson's former principle with Antoine London, a former vice principle from Suffolk, VA, to lead the school during the transformation process. In December 2019, RPS hired two full time staff members to work on the redesign process. So far, the redesign team has held community and parent engagement nights and has started to survey incoming 6th graders about their ideal classroom experience at Henderson's feeder elementary schools. The goal of these events is to increase enrollment at Henderson in the fall and to get community feedback and buy-in over the STEM transformation initiative.

RPS Goals for the STEM Transformation

RPS believes that an interdisciplinary and project-based STEM curriculum fosters great opportunities for students and schools to connect with the world around them (RPS STEM Definition, 2020). As part of the initiative, RPS will partner with community organizations, including local businesses and Virginia Commonwealth University (VCU), to equip students with the ability to utilize technology in real world and non-traditional learning environments (RPS STEM Definition, 2020). The ultimate goal of the STEM transformation is to nurture the curiosity and passion for learning within each student and provide them with a long-term path over their educational career.

LITERATURE REVIEW & EVALUATIVE CRITERIA

Benefits of an Integrated STEM Curriculum

In America, the STEM job market has increased three times faster than the rest of the economy, but only 4.4% of undergraduate college students are enrolled in STEM programs (Land, 2013). The STEM field has failed to attract minorities; hurting the creativity, innovation, and quality of STEM products and services (Watson & Froyd, 2007) (Melguizo & Wolniak, 2011). A verity of variables contributes to this talent gap. Students are more likely to major in a STEM field in college when they have had a strong math and science curriculum in high school, when they have access to advanced placement (AP) courses, and when their parents have higher levels of academic attainment (Kienzl et al., 2009; Leslie et al., 1998; Melguizo & Wolniak, 2011). Without access to a strong high school education that emphasizes college level work, student will not major in STEM (Museus et al., 2011). Minority students who do major in a STEM field enjoy higher earnings than their peers in other majors (Melguizo & Wolniak, 2011). Through its STEM program, RPS can set Henderson students on this high value career track by providing them with the tools to succeed in a STEM field and by giving them more STEM focused educational opportunities in the classroom.

Introducing students to STEM early on in their education helps makes learning more connected and relevant and increases the likelihood students will engage with STEM through the rest of their educational career. (Stohlmann et al., 2012) (Museus et al., 2011). Integrated STEM education focuses on highlighting interconnectivity between STEM and humanities topics (Sanders, 2009; Moore et al., 2014). In practice, teachers combine math and science with technology and engineering to demonstrate the connections between the subjects, to mimic real world problems, and to enhance student learning (Moore et al., 2014; Kelley & Knowles, 2016). Integrated STEM curricula have been shown to make students better critical thinkers and problem solvers while increasing their interest in school and their motivation to learn (Morrison, 2006; Bragow, Grago & Smith, 1995; Gutherie, Wigfield & VonSecker, 2000; Stohlmann et al., 2012). For Henderson to properly introduce an interdisciplinary STEM curriculum, RPS must reengage students in the classroom through its transformation by revitalizing its curriculum and teaching practices.

Key Components of School Transformations

School redesigns aim to provide students with alternative educational experiences that take learning beyond the traditional classroom structure and environment. The majority emphasize bottom-up, locally designed solutions rather than cookie-cutter models to ensure that redesigns solve division wide or school specific problems (Jerald et al., 2017). Though redesigns are typically locally driven, several common themes have emerged. These themes have been proven to increase student engagement with educational material in and outside the classroom.

Competency-based education (CBE) rejects the traditional model in which students earn credits by putting in enough seat time and earning passing grades (Jerald et al., 2017). Instead, students master learning goals at their own pace and then demonstrate their skill before moving on in the curriculum (McClarty & Gaertner, 2015). This system gives students flexibility to quickly move through material that comes naturally to them and slowly through more difficult topics. This model also encourages educators to provide more personalized learning opportunities and support for their students. A 2016 study conducted by the American Institutes for Research found that having a clear sense of learning targets and the opportunity to have extra time to engage with challenging material was linked to a positive increase in student self-efficacy, learning capacity, and intrinsic motivation, especially in math classes (Haynes et al., 2016). Allowing for variability in student advancement through a curriculum is the key principle of this model.

Project-based learning (PBL) emphasizes hands-on learning wherein students create tangible products in response to 'real-world' questions that promote collaborative problem solving and authentic inquiry (Hall & Miro, 2016). Through trial and error, students are encouraged to tackle problems from multiple angles and to reflect on their successes or failures. A literature review of existing PBL studies conducted by Durham University found that successful PBL approaches maintained strong student and teacher support, promoted high quality group work, emphasized self and peer evaluation, balanced traditional learning with skill building activities, and encouraged students to develop a sense of ownership over their learning (Kokotsaki et al., 2016). When these conditions are met, students are more engaged with the material and gain higher order reasoning skills (Hall & Miro, 2016). A 2015 study endorsed by the National Council of Professors of Educational Administration (NCPEA) found that 7th graders from an urban school district in Texas who utilized PBL in the classroom had higher academic achievement in math and reading on standardized tests then non-PBL students (Cervantes et al., 2015). The majority of the students in the study were economically disadvantaged Hispanic students. Henderson students mimic those in the study. The key principle of this model is for learners to develop a stronger understanding of how class material can be applied in a real-world setting or situation.

Education outside the classroom (EOtC) is often adopted in tandem with CBE and/or PBL. It is a teaching method that relocates some curriculum-based teaching activities from the classroom to places outside the school building (Bølling et al., 2018). It takes place in nearby locations, such as parks, or in places that require transportation, such as a museum or local business (Bølling et al., 2018). EOtC promotes a student-led approach that pushes learners to use their time outside of the classroom to pursue learning goals in creative ways. This process is guided by teachers or community mentors who act as informal educators by providing professional advice or guidance on projects that fall within their area of expertise (Kotys-Schwartz et al., 2011). Results from a University of Copenhagen quasi-experiment found that when Dutch students were exposed to between two and seven hours of EOtC experiences a week, they reported increased intrinsic motivation towards school (Bølling et al., 2018). EOtC can be expanded to include 'anywhere, anytime' learning strategies that promote student academic engagement outside of traditional school hours (Jerald et al., 2017). These can include apprenticeships, service learning, and at-home learning through online courses and digital activities. The primary goal of EOtC and anywhere, anytime learning is to encourage students to engage with course material at a deeper level by giving them an outlet to connect with academic material in a less formal setting.

Successful school redesigns create innovate learning environments that push students to better engage with class material through hands-on collaborative investigation of real-world problems in and outside of the classroom. Using these principles of school redesigns as a guideline, the following section will explore how teachers and administrators can use these principles in a STEM specific curriculum.

STEM Focused Support

One of the most important factors in keeping students engaged with STEM material is parental involvement and support (Museus et al., 2011). Henderson teachers and administrators must work with parents to set expectations for STEM students and to explain any changes in the grading system. Parents must have a clear understanding of the importance of STEM courses and understand how to help their student with homework. Teachers and parents can hold students accountable, by establishing clear educational expectations with students at the beginning of the school year and by using CBE to set clear learning goals (Museus et al., 2011).

Principal London and RPS administrators must revitalize Henderson's school culture and learning climate to ensure that students and teachers understand the importance of a high-quality STEM education (Museus et al., 2011). Successful cultural transformations deemphasize hierarchical principal driven leadership and empower teachers to reshape their own professional cultures by encouraging collaborative planning and shared risk taking (Hargreaves & O'Connor, 2017; Hargreaves & Fullan, 2012; Thumlert et al, 2018). For this leadership style to be effective, teachers' self-efficacy, their beliefs about their own capabilities to successfully impact student learning, must be positive (Stohlmann et al., 2012). When teachers have a positive feeling of self-efficacy, student motivation increases and their own self-efficacy in their ability to thrive in STEM coursework (Caprara et al., 2016) (Museus et al., 2012). To ensure that teachers maintain a positive outlook over their own abilities, RPS must properly train teachers to integrate STEM into the curriculum using CBE, PBL, and EOtC to increase student engagement in their education.

Teaches can make math and science classes more impactful for Henderson students by using culturally relevant teaching practices that connects curriculum, instruction, and assessment to the experiences, cultures, and traditions of minority students (Museus et al., 2011). Incorporating Black social issues into a mathematics curriculum has positive impacts on student interest and success (Tate, 1995). Most importantly, culturally relevant teaching pushes teachers to set high expectations for all students, regardless of prior achievement, and instill in them a desire to learn (Museus et al., 2011) (Ladson-Billings, 1995). PBL gives teachers the opportunity to incorporate important social issues into a math or science curriculum. For example, a teacher could create an engineering project that tasks student with redesigning a local cultural center or park while explaining the history of their neighborhood.

Henderson staff can leverage community partners and professional mentors to increase student engagement with STEM materials to further transform school culture. Students who are exposed to role models in a selective field early on in life can raise their self-efficacy, their belief that they can achieve the same outcomes (Bandura, 1977) (Museus et al, 2011). EoTC experiences offer students the chance to see professional mentors working in STEM environments. This helps students make connections between classroom work and the real world; grounding their educational experience in reality.

RPS can increase student engagement by incorporating traditional school redesign principles with STEM focused support that gives teachers the ability to take on an active school or department wide leadership role while encouraging students to succeed in STEM by expanding their educational opportunities. The following section will explore STEM based tools that will cultivate student's passion for learning and empower teachers to succeed.

Evaluative Criteria

In order to evaluate each of the selected curriculum tools, teaching aids, and activities, I will use the following criteria:

Cost

One of the major goals of this project is to identify low cost methods to engage students in the classroom and to prepare teachers for the rigor of integrating a STEM curriculum. While my original goal was to determine how much a program would cost to operate year over year in Henderson, due to a lack of information provided by most companies and the potential to negotiate prices, this proved to be infeasible. To this effect, I have created a cost scale that categorizes each resource in a broad sense based on a rough estimate. This rough estimate considered the yearly cost of operating the program in several classes. The scale works as followed:

$ - low cost, $0 -$500 per year.

$$ - medium cost, $500 - $3000 per year

$$$ - high cost, $3000+ per year

Best Practices

This criterion considers whether a given teaching tool or training resources emphasizes PBL, EOtC, or CBE. As an alternative measure, I also considered if the resource adhered to one of several common science standards. The most commonly used standards are Next Generation Science Standards (NGSS) and Common Core. NGSS was created by a consortium of STEM educators from across the country that were chosen by the National Science Teachers Association and the Council of State Science Supervisor. This standard enables students to learn science by doing science through the use of collaborative learning (NGSS, n.d.). NGSS has been adopted by nationally recognized STEM education programs and state departments of education. A link to NGSS middle school standards is located here. Common Core standards were created by a commission of 48 state through the National Governors Association. The main goal of Common Core is to create a nationwide standard for education to ensure that every student, regardless of where they live, has access to the same information. Importantly, Virginia has not adopted Common Core standards; however, these standards emphasis several best practices for student engagement. If it a program follows NGSS or Common Core standards, it is likely that they utilize best practices for student engagement.

X – the program follows NGSS, Common Core standards, or uses best practices

? – it is unclear if the program follows NGSS, Common Core Standards, or uses best practices.

Evidence Based

This criterion considers whether a given resource has been proven to increase student engagement or academic performance through a peer reviewed study. Since this information is not available for several of the free or low-cost resources, I also considered if a program was created or backed by an accredited university or government agency. By considering if a program is evidence based, I aim to ensure that RPS utilizes legitimate resources to aid in the transformation process.

XX – fully peer reviewed

X – created or backed by a university or government agency

? – unclear if they program has been peer reviewed or is backed by a university or government agency

Equity

A major goal of the transformation is to engage every student in the classroom, regardless or race or gender, and to close racial achievement gaps while improving overall student academic performance. It is crucial that any activity or curriculum ensures that every student is able to participate and engage with the material. To that effect, I attempted to measure if a given program had been proven to increase minority student engagement or academic performance. This was done to ensure that these programs would help Henderson students. Since many of the low cost or free resources has not been professionally reviewed, this information was difficult to find. Ultimately, teachers would have to ensure that the curriculum tools and activities are equitably implemented.

X – the resources has been proven to increase minority student engagement and academic performance

? – evidence unclear or not provided

EVALUATING ALTERNATIVES

Curriculum Tools

This section will explore example curricula that are designed to increase student engagement with STEM materials.

Full Option Science System (FOSS) is a nationally recognized program that is designed to a provide meaningful science education to all students, regardless of their social economic background. FOSS encourages students to actively participate in scientific practices through their own investigation and analyses (FOSS, 2019). The main goals of the program are to increase scientific literacy among K-8 students, ensure instructional efficiency, and to reform schools through increased engagement (FOSS Program goals, 2019). The FOSS Program is administered through Delta Education which provides curriculum packages that includes lab materials, teaching guides, and other resources. Individual courses kits can be purchased a-la-cart and Delta Education will provide a sample kit to divisions to try out on its students. The FOSS program description guide and program overview is linked in here. It details individual course offerings. FOSS's middle school program is linked here. Importantly, FOSS focuses on science but does integrate other STEM elements more broadly into its curriculum and activities.

Costs: The cost of Delta Education custom curriculum program varies by division. A complete curriculum kit costs around $1,700 - $2,000 and is designed for a class of 32 students. Kits contain everything teachers will need to complete a lesson. Additional textbooks and refill kits can be purchased (FOSS Middle School, n.d.).

Best Practices: The programs curricula utilize several best practices to increase student engagement including PBL and NGS.

Evidence Based: FOSS is the nations most adopted science education program. It is used by over 100,000 teachers and 2 million students (Bayer Corporation, 2016). The program has been peer reviewed in Hampton, VA and other divisions across the country.

Equity: Hampton City Virginia Public Schools has adopted a FOSS program within its elementary science classes. Before implementation in 2014, the districts science SOL pass rate was 63.6 percent, 13 percentage points lower than the states average (FOSS Hampton City, 2017). During the 2016-2017 school year, after two years of implementation, Hampton's science SOL scores improved 14 percentage points and was only 2 percentage points below the state's averaged 79 percent pass rate. Since Hampton Virginia is demographically similar to Richmond and must abide by the same SOLs, this case provides strong evidence that FOSS would improve Henderson's science SOL scores if properly implemented.

Costs	Best Practices	Evidence Based	Equity
$$$	X	XX	X

Teacher Training Resources

Content knowledge and mastery plays an important part in shaping teacher's self-efficacy (Stohlmann et al., 2012). This section will canvas existing STEM teacher training resources and programs to help RPS prepare Henderson teachers to implement an integrated STEM curriculum.

ASSET Inc. (Achieving Student Success through Excellence in Teaching)

ASSET Inc. (Achieving Student Success through Excellence in Teaching) is a nonprofit that provides online and in person professional development for K-8 teachers (Bayer Corporation, 2016). ASSET utilizes a 'teachers teach teacher' model where professional development sessions are facilitated by an ASSET facilitator (Nedley, 2016). Their courses are broken down into educator essentials and STEM content courses. Educator essential courses provide teachers with a holistic knowledge of STEM, different methods of engaging students with STEM materials, and dynamic teaching techniques. Classes include; Understanding the Holistic Nature of STEM, Project-Based Learning, and Foundations for Engineering. During STEM content courses, participants engage in three-dimensional learning, share teaching strategies to support inquiry-based learning, identify learning goals of the material, examine assessment opportunities for students, and develop teaching notes (ASSET STEM Education, 2019). STEM classes are offered under packages that focus on different subjects within STEM. The course catalogue is linked here.

Cost: The cost of each course is unlisted.

Best Practices: ASSET offers a wide variety of teacher training classes that fall under several common curriculum standards including FOSS and NGSS.

Evidence Based: ASSET Inc.'s teach training program has been shown to increase science test scores. A 2008 study of Pennsylvania schools found that fourth grade students enrolled in an ASSET member school scored statistically significantly higher on the state's science standardized test than non-participating students (Banilower et al., 2008). These findings have been replicated.

Equity: The majority of the students in ASSET studies are white and the program has not been used in demographically diverse divisions that is similar to RPS.

Costs	Best Practices	Evidence Based	Equity
?	X	XX	?

Pearson, one of the nation's leading education service providers, offers in depth professional development training for teachers. In its Dynamic STEM Instruction course, teachers develop best practices and create lesson that put STEM into action (Pearson Professional Development, n.d.). Classes are focused on exploring different methods to engage student in higher order thinking, inquiry-based problem solving, and the engineering design process (Pearson Professional Development, n.d.). Pearson's middle school STEM packages are administered in three-day periods and can accommodate up to 30 teachers at a time.

Cost: The cost of the program is unlisted on the website; however, school officials can requests more information about the program here.

Best Practices: Pearson's middle school STEM professional development packages utilizes NGSS practices and encourages the use of PBL.

Evidence Based: Pearson has not released any peer reviewed studies on their professional development courses.

Equity: The results on student engagement or academic performance are unknown.

Costs	Best Practices	Evidence Based	Equity
?	?	?	?

STEM Teaching Tools is an online depository of professional development modules and teaching tools that has been created by the University of Washington Institute for Science+Math Education through federal grants (Bell et al., 2015). The modules and tools are free for school divisions to utilize. The organization has created two professional development courses that are designed to be run by a division's curriculum team. Each course is broken down into separate sessions that include a PowerPoint, facilitator guide, and session overview. An example session is linked here. In addition to professional development service, STEM Teaching Tools offers a broad range of teacher created practice briefs that outline how to overcome a specific challenge with teaching STEM or details best practices to increase student engagement through STEM. Practice briefs cover several broad topics including assessment, equity, instruction, and best practices that can be filtered through. As an example, one practice brief outlines why teachers should expand a student's definition of engineering. Additional articles are linked here. Additionally, STEM Teaching Tools has a master depository of every teaching tool that has been published on its website. The master file is located in a google drive folder located here. Importantly, these teaching tools are focused on the professional development aspect of STEM education. The website does not provide activities or lesson plans for teachers to utilize but aims to provide them with knowledge to create their own engaging lessons.

Costs: These tools are free; however, the professional development course must be administered by someone who has taken the time to understand the model and training course.

Best Practices: The project briefs emphasize PBL, EOtC, and CBE and follow NGSS best practices.

Evidence Based: STEM Teaching Tools utilizes teacher and professor generated content. Though the curriculum has not been tested through a peer reviewed study, it was created through a partnership between the University of Washington and the National Science Foundation.

Equity: It is difficult to determine if STEM Teaching Tools emphasizes equitable teaching practices. RPS curriculum team would ultimately be responsible for ensuring the professional development course engages teachers, regardless of their initial skillset. Teachers would be responsible putting the practices into action in the classroom and engaging Henderson students.

Costs	Best Practices	Evidence Based	Equity
$	X	X	?

Activities

This section will explore sources for and examples of specific STEM activities teachers can use in the class room. Example of activities include: Engineering Challenges, Online Tools, Science Lessons, etc.

NASA's Jet Propulsion Laboratory in partnership with the California Institute of Technology offers a vast array of free lesson plans that include games, demonstrations, labs, writing assignments, and many more. These lessons can be filtered by activity type, subject, recommended grade level, and topic. Each lesson is accompanied by a teaching guide that lays out step-by-step instructions on how to administer the activity and provides detailed background information that relates the lesson to the real world. As an example, the Soda-Straw Rocket activity tasks students with using the engineering design process to create a rocket that can be launched from a soda straw (NASA Soda-Straw Rockets, n.d). After the initial launch, students will modify the design to see how changing the fin shape, length and angle impacts the rockets performance. This activity is designed to simulate the process engineers use to develop new rockets. The teaching guide for this activity is linked here. A link the activity catalogue is located here.

Cost: NASA's online teaching guides and actives are free resources intended to supplement a rigorous STEM curriculum.

Best Practices: Activities follow NGSS or Common Core standards for STEM subjects. Many activities are designed to engage students through PBL.

Evidence Based: These tools were created by NASA in partnership with the California Institution of Technology, a leader in the STEM field.

Equity: There is no peer reviewed study on the activity's ability to engage students in the classroom or on the impact they have on academic measures. This makes it difficult to determine if these tools would engage Henderson students in the classroom. The easy to follow teaching guides would empower teachers to implement activities effectively, making it more likely that students will stay engaged.

Costs	Best Practices	Evidence Based	Equity
$	X	X	?

TeachEngineering is a digital library comprised of STEM curricula for K-12 educators that was created by the University of Colorado Boulder and Oregon State University (TeachEngineering About, n.d.). The website has an extensive filtering tool that allow educators to find activities, lessons, maker units, and entire curricular units at the push of a button. Results can be further filtered by grade level and subject area. As an example, the Energy of Motion curriculum unit contains five lessons that each contains several activities. Each lesson is accompanied with detailed learning objectives, relevant student vocabulary, teaching guides, and sample assessments among other helpful information. Each activity provides detailed instructions that explains how it connects to the overall lesson and provides a materials list and expected cost metric. An example of curriculum unit can be found here. While TeachEngineering does not provide an entire comprehensive middle school curriculum, it would be possible for RPS to use SOL guidelines to create its own STEM package by combining several relevant curriculum units together.

Costs: TeachEngineering's curriculum tools and activities are free.

Best Practices: Activities use NGSS standards and emphasize hands-on PBL.

Evidence Based: The activities and curricula have not been peer reviewed, so the effects of the activities on student engagement and educational metrics are unknow. The program was created through a partnership between the University of Colorado Boulder and Oregon State University. Most curricular activities are created by professors, graduate students, and teachers associated with colleges from across the country (TeachEngineering About, n.d.)

Equity: Each activity and curricular unit is accompanied by an in-depth teaching guide that connects the unit and activity to the real world and to overall learning goals. These guides provide teachers with tools to ensure that the activities will be academically rewarding and engaging. Ultimately, the burden will be on Henderson teachers to ensure that the activities are implemented in an equitable manner.

Costs	Best Practices	Evidence Based	Equity
$	X	X	?

Packages (Combine Resources)

This section will explore all-in-one STEM packages that combine curricula, activities, and teacher training resources into a single program.

Project Lead The Way (PLTW) is the nation's leading non-profit provider of middle and high school STEM programs (Stohlmann et al., 2012). The organization's Gateway experience is designed to engage, excite, and empower middle school students to lead their own discovery (PLTW Gateway, 2019). Gateway features 10 units that explore different areas of STEM through activities that build knowledge and skills in computer science, engineering, and biomedical science while also empowering students to develop essential skills such as problem solving, communication, and creative thinking (PLTW Gateway, 2019). Each unit is divided into independent, nine-weeks blocks that are built around 45-minute class periods and are designed to be taught in conjunction with a challenging academic curriculum. (PLTW Implementation, 2019). Lessons are designated for specific grade levels and some build upon one another. For example, the Design and Modeling unit that task students with applying the design process to solve problems and use Autodesk software is a foundation unit that must be completed before specialized units can be started. Each unit is accompanied with a course outline and standards guide. Examples of unit guides can be found here. PTLW offers online and in-person professional development classes that help teachers build skills and confidence around activity, project, and problem-based STEM learning (PLTW Teacher, 2019). These classes are offered a-la-cart meaning different teaches can take classes on material from specific curriculum units. Currently, PLTW is scheduled to hold multiple two-week in-person teacher training course in nearby Baltimore, Maryland this summer. It also hosts 10 to 14-week online training programs that require live meetings and collaboration with peers (PLTW, 2019).

Cost: The programs professional development classes cost $1,200 per teacher and fully stocked lesson kits cost between $1,200 and $6,000 for 20 students. These costs can be reduced. Most kits include items, such as knifes, teaching carts, and Ziploc bags, that can be taken off to reduce the total cost of each kit.

Best Practices: Project Lead The Way's (PLTW) Gateway program focuses on empowering student to lead their own discovery through hands-on PBL (PLTW Gateway, 2019). The program uses Common Core and NGSS standards.

Evidence Based: A 2012 study conducted by a researcher from Texas State University, found that 11th grade PLTW students scored significantly higher on Texas's grade 11 math assessment than matched non-PLTW students (Van Overschelde, 2013). Additionally, PLTW students attended higher education institutions at a higher rate than non-PLTW students.

Equity: The Texas study's findings held for economically disadvantaged students, meaning Henderson students should see gains from the program (Van Overschelde, 2013). PLTW should empower teachers to engage every Henderson student in the classroom, regardless of their previous educational experience. The programs professional development course would prepare teachers and administrators to implement PLTW courses effectively.

Costs	Best Practices	Evidence Based	Equity
$$$	X	XX	X

Science Education for Public Understanding Program (SEPUP) administered by Lab-Aids is a learner-centered program that enhances the role of teachers as facilitators and as educational leaders (Bayer Corporation, 2016). SEPUP focuses on three innovations to improve student engagement in science classes; making sense of phenomena and designing solutions to problems, three-dimensional learning that pushes student to connect different topics together, and equitable improvement monitored through assessment (Lab-Aids Innovations, n.d.). SEPUP for middle schools offers a full year program that is designed to replace a school's current science curriculum and a unit program that is designed to teach students about an individual topic. The full year program consists of 5-6 units that can be taught in almost any order. Units include a seven-week ecology course, a three-week biomedical engineering course, among others. Lab-Aids provides divisions with all-in-one kits that can be used for one day activities, modules that take between eight and 30 days, or for a full year long curriculum (Lab-Aids Program Overview, n.d). Kits include student books, needed equipment, and online resources along with storage containers and carts. Individual activity kits can be purchased separately. Lab-Aids also provides access to a state expert who can tailor SEPUP to work with Virginia SOL standards. Though SEPUP program are written to work off the shelf, Lab-Aids provides additional professional development services to divisions. This service is designed to be done in groups at the school level. Lab-Aids also holds additional conferences and workshops throughout the year. Importantly, this package focuses on the science portion of STEM, but could be used in conjunction with a redesigned math program to create an integrated STEM curriculum. A link to Lab-Aids middle school curriculum outline is located here.

Cost: A complete equipment package costs between $1,216 - $3,000. Each complete package serves 5 class of 32 students. Individual refill kits and additional student materials, such as physical or online textbooks, are available for an additional cost.

Best Practices: The SEPUP curriculum uses NGSS and Common Core standards to engage students in the classroom through collaborative PBL. Instructional materials utilize a research-based assessment system developed through a collaboration with the University of California Graduate School of Education.

Evidence Based: The results of 20 years of research on SEPUP finds that the program has positive effects on student's content knowledge, problem-solving, decision-making, and investigation skills (Summary of SEPUP, 2013). The program has also been shown to increase students' interest in science by highlighting its relevance outside the classroom (Summary of SEPUP, 2013).

Equity: Several studies have found positive effects of the SEPUP program. Compared to non-SEPUP students enrolled in the Las Angeles school district, SEPUP students chose to enroll in nonrequired science classes at a higher rate (Summary of SEPUP, 2013). Students enrolled in the LA public schools SEPUP program outperformed their peers in non-SEPUP classes on the states standardized science test. Both results held across all ethnicities and for males and females. Teachers who use SEPUP materials have shown an increase in using good teaching strategies. Combined, this evidence suggests that SEPUP would help Henderson teachers engage students in the classroom, regardless of their race or gender.

Costs	Best Practices	Evidence Based	Equity
$$	X	XX	X

RECOMMENDATION AND IMPLEMENTATION

Recommendation

Table 1: Resource Analysis Summary

Academic and Training Tools	Program Name	Evaluative Criteria			
		Costs	Best Practices	Evidence Based	Equity
1) Curriculum	FOSS	$$$	X	XX	X
2) Teacher Training	ASSET Inc.	?	X	XX	?
	Pearson	?	?	?	?
	STEM Teaching Tools	$	X	X	?
3) Activities	**NASA**	$	X	X	?
	TeachEngineering*	$	X	X	?
4) Packages	PLTW	$$$	X	XX	X
	SEPUP	$$	X	XX	X

*TeachEngineering tools and lessons can be combined to create a curriculum

Table 1 summarizes how each academic and training tool measures against the chosen criteria.

After considering the criteria, I recommend that RPS utilize a combination of teacher training tools and activities to aid in Henderson's curriculum transformation. By using a combination of resources RPS can create its own in-house portfolio of STEM tools and teaching aids. RPS should use **STEM Teaching Tools** professional development guides to introduce Henderson teachers to best practices for teaching STEM courses. By using existing SOL standards, RPS can use **TeachEngineering** to create a custom curriculum using the organizations prebuilt lessons. **NASA** activates can be used to supplement TeachEngineering activities and add variety to lessons.

As highlighted in Table 1, unlike other programs in this canvas, each of these resources is low cost and easy to implement. While none of these resources or activities have been proven to equitably empower student to succeed in the classroom, each is backed by proven universities and government agencies. These STEM institutions ensure each activity or curriculum course meets a NGSS or Common Core standards. Though none of these tools utilizes the full suite of student engagement best practices, each program emphasizes inquiry and PBL. Teachers and RPS's curriculum team can ensure that each lesson is implemented equitably and that every student can participate.

Compared to other programs in this analysis that use an outside organization to create a schoolwide curriculum and offer off the shelf professional development programs, this combination will enable RPS to create a curriculum that is tailored to the Commonwealths SOL standards and considers Henderson's students and teachers. While it may be organizationally simpler to hire an outside firm to coordinate all aspects of the STEM curriculum redesign, packages are costly and typically require a multi-year commitment to see any effects. RPS can contact these firms to receive a free sample activity kits and to receive a free consultation. Should RPS chose to look into packages, FOSS is the most promising as it has been used in Hampton, VA and has a Virginia consultant specialist.

Implementation

This section will offer suggestions for how RPS can integrate STEM Teaching Tools, TeachEngineering, and NASA activities into Henderson's curriculum transformation. Key areas to consider during the integration include:

1. Incorporating the resources into the new curriculum
2. Identifying community partners
3. Professional development for teachers
4. Tracking student outcomes

Incorporating Resources

RPS's curriculum development and Henderson redesign team should ensure that any new curriculum materials algin with Virginia's SOLs. Using the states science and math standards as a starting point, RPS can canvas TeachEngineering and NASA for lessons and activities that align with the standards. By using the Commonwealths 6th grade SOLs to guide the curriculum transformation, RPS can ensure that the 'base' of the curriculum incorporates state standards. Using the 5th grade engagement survey, RPS can add additional STEM topics to the base curriculum based on student interest.

Identifying Community Partners

In order to establish successful community partnerships RPS must; designate a staff member to be in charge of coordinating school and community relations, create a set list of expectations and meeting dates, establish clear communication channels, and develop and evaluative standard for community programs (Edutopia, 2016). RPS's community partnership team should begin reaching out to existing STEM field partners to determine their level of interest in working with Henderson students. The team should also start searching for new opportunities and establish a framework of responsibilities for the partners. To make sure that RPS maintains a good relationship with its community partners, RPS should hold engagement meetings and send out surveys after each student visit to determine how the school system can best use its partners and maintain new relationships. After the initial pilot these surveys could be administered annually and Henderson's administrators could take on the responsibility of maintaining good partner relationships.

Professional Development

After the redesign team, HR staff, and Principle London finalize Henderson's new STEM teaching team, RPS must ensure that the teachers are prepared to implement the new curriculum. RPS can use STEM Teaching Tools professional development modules as an outline for in-house STEM lessons. During training sessions, RPS can hold mock class that task STEM teachers with running a lesson or activity for their peers. At the end of each session, the presenter should receive feedback on their performance from the training staff and from their peers on ways they could have improved the lesson. These mock classes should improve teacher's self-efficacy in teaching STEM materials. During the summer, if the corona virus restrictions are lifted, RPS could attempt to hold mock classes with incoming students and new teachers; however, this may be difficult to coordinate and would have to be voluntary.

Tracking Student Outcomes

The main goal of the STEM redesign is to increase student engagement in the classroom. In order to determine if the program meets this expectation, RPS must track the long-term academic achievement of Henderson students to determine the success of the STEM program. This can be done by tracking the SOL performance of STEM students from 6th grade to 8th grade and comparing them to similar traditional students at other middle schools around the division. If the program is successful, STEM students should have higher math and science SOL scores than traditional students. Tracking STEM student's SOL scores will enable RPS to determine the impact of the redesign on student scores. Some of the principles used in the redesign can then be implemented to helps other schools improve SOL scores and meet accreditation requirements. To measure changes in student engagement, RPS should conduct yearly student self-report surveys to compare STEM students to traditional students at other middle schools within the district. RPS could also compare STEM students to non-STEM students within Henderson during the transition years.

Potential Barriers to Success

RPS should consider creating a bus route specifically for students who wish to attend Henderson from outside its existing school zone. This would enable low income students to attend the new academy and increase equity. Without a modified student transportation policy, the redesign may fail to attract students from outsides Henderson's zone.

It is unclear how COVID-19 will impact the 2020-2021 school year; however, RPS should be prepared to be flexible and to accommodate any state policy changes. For example, if Virginia adopts a rotating school day that only allows half the students to come to school on any given day, RPS will have to consider how that will impact costs. RPS should work closely with the DOE to determine its fall policy.

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APPENDIX: CASE STUDIES

Case 1: Texas T-STEM Program

In 2006, Texas launched the T-STEM program to improve math and science education statewide by transforming some traditional high schools into inclusive STEM academies (Young et al., 2011). These academies are nonselective and must have a student population that is more than 50% economically disadvantaged or more than 50% from racial minority groups (Young et al, 2011). Each academy is required to work with their local workforce development board to identify and maintain a list of high-demand occupations and to establish programs that create structured pathways for students to prepare them for high-demand STEM fields ("T-STEM Blueprint," 2019). T-STEM schools incorporate CBE, PBL, and EOtC elements into their curriculums. Teachers are required to incorporate real-world problems into their instruction. Schools are required to establish mentorship programs with outside partners and to establish enriching extra-curricular activities to encourage students to engage with STEM material outside of school hours. Students work with counselors to create a personalized education that prepares them for a desired career ("T-STEM Blueprint." 2019). Every student enrolled in a T-STEM academy is given the opportunity to take dual-enrollment classes that grant high school and college credit, setting them on a college path early in their high school career. A 2011 study conducted by a team from the University of Texas and SRI International found that T-STEM academies had small but statistically significant, positive effect in standardized math scores for ninth-graders and in standardized math and science scores for 10th graders compared to peers in non-T-STEM schools (Young et al., 2011). Though the T-STEM program serves High School students, the student population is similar to Richmond as the majority of the students enrolled in the academies are economically disadvantaged. If the Henderson redesign incorporated elements from the Texas program, results from the study would likely hold.

Case 2: The New Tech Network

The New Tech Network (NTN) works with 200 schools across the country to promote non-traditional approaches that deliver positive outcomes for student. At every school level, student-centered and inquiry-based learning are paired with PBL to deliver positive outcomes for students (DOE Press, 2013). NTN schools focus on STEM instruction and incorporate technology as a central element to teaching and learning (DOE Press, 2013). Students are assessed in traditional courses and also on their collaboration and critical thinking skills (NTN Middle School Rubrics, 2017). For example, to be considered high school ready in math, middle school students must demonstrate that they have a strong understanding of how a topic applies in practical situations, be able to logically explain solutions, and use multiple methods (diagrams, tables, etc.) to demonstrate ideas and reasoning (NTN Middle School Rubrics, 2017). In Virginia, The Gereau Center for Applied Technology and Career Exploration has coordinated with Benjamin Franklin Middle School and Franklin County High School to incorporate NTN philosophies into the school's core curriculum and to expand the variety of career elective courses (Franklin County Public Schools, 2019). The Center aims to create an integrated curriculum that incorporates handon PBL learning to ensure students are engaged with SOL material and exposed to career and high school development opportunities (Franklin County Public Schools, 2019). Like the T-STEM program, the Gereau Center partners with local business, industry leaders, and government agencies to expose the students to outside perspectives in and outside the classroom.