In the following report, Hanover Research examines best practices in Science, Technology, Engineering, and Mathematics (STEM) education at the high school level. The report pays particular attention to the use of project-based learning (PBL) to deliver effective STEM instruction to a diverse student population.
# Table of Contents

Executive Summary and Key Findings ................................................................. 3  

Section I: STEM Education Overview .................................................................... 6  
  STEM Education: Background and Goals ................................................................. 6  
  Emergence of Specialized STEM Schools ............................................................... 8  

Section II: Designing Effective High School STEM Programs ................................ 11  
  Common Features of STEM Programs .................................................................... 11  
  Best Practices for Inclusive STEM Education .......................................................... 15  
  Strategies to Support Underrepresented Students in STEM .................................... 17  
  STEM Program Implementation: Lessons for School Leaders ................................. 19  

Section III: Using Project-Based Learning to Deliver STEM Education .................. 22  
  Project-Based Learning Overview ......................................................................... 22  
  Best Practices in Project-Based Learning ................................................................. 23  

Section IV: STEM Learning and PBL Case Studies ................................................. 28  
  Case Study: Project-Based Learning at Manor New Technology High School .......... 28  
  Case Study: Metropolitan Cleveland Consortium for STEM ................................. 32
EXECUTIVE SUMMARY AND KEY FINDINGS

INTRODUCTION

In the following report, Hanover Research examines best practices in Science, Technology, Engineering, and Mathematics (STEM) education at the high school level. The report pays particular attention to the use of project-based learning (PBL) to deliver effective STEM instruction to a diverse student population.

The report draws on the literature—scholarly publications, expert reports, case studies, interviews, and media accounts—to highlight the best practices used in the delivery of STEM and project-based learning, both for educators in the classroom and for school leaders who face the challenging task of navigating the transition to a STEM-focused curriculum.

The literature highlighting effective practices in STEM education focuses primarily on specialized STEM high schools. Historically, STEM high schools have been highly selective, attracting gifted and talented students demonstrating high academic achievement and nurturing top talent in the STEM fields. However, “the new wave appears to have a broader reach, with many of the schools aimed especially at serving groups underrepresented in the STEM fields, such as African-American, Hispanic, female, and low-income students.”

Accordingly, this report pays particular attention to the practices found to be effective in inclusive STEM environments.

The report opens with a broad introduction to STEM education, introducing the philosophy and goals behind the STEM movement and describing the basic characteristics of selective and inclusive STEM high schools. The report then describes the best practices used in STEM education, including strategies to support minority and underrepresented students, followed by a more in-depth discussion of the project-based learning approach. The report concludes with case studies of two inclusive STEM high schools: Manor New Technology High School (Texas), which features a 100 percent project-based learning instructional model, and the Metropolitan Cleveland Consortium for STEM High School (Ohio), which uses a unique pedagogical model combining project-based learning with interdisciplinary capstone units.

1 Robelen, E.W. “New STEM Schools Target Underrepresented Groups.” Education Week, September 13, 2011.
KEY FINDINGS

- Whether a district-wide STEM initiative or a single STEM high school, advancements in STEM education should reach far beyond simply the addition of more, or more difficult, math and science courses. While expanding the school’s course options in the STEM disciplines may be welcomed by students, by itself this approach represents mere curricular expansion, rather than transformation. One of the critical factors in effectively fulfilling the mission of a STEM-focused high school is the adoption of inquiry-based methods such as project-based learning, which help foster creativity, provide opportunities for teamwork, and emphasize inquiry rather than rote memorization.

- Effective STEM-focused high schools tend to share similar characteristics, with common features including the following:
  - An academic mission focused on preparing students for STEM majors and career tracks, reflected in a rigorous set of courses in the STEM subjects
  - The use of small learning communities, allowing for peer collaboration and personalized learning experiences for students
  - An integrated curriculum breaking down traditional academic silos and instead using an interdisciplinary lens to explore STEM concepts
  - An instructional model embracing inquiry-based approaches to learning, such as project-based and problem-based learning
  - The use of technology to improve instruction, facilitate lab-based learning, expand research opportunities, communicate with students and parents, and streamline assessment and feedback
  - Efforts to build relationships with community, industry, and university partners to enhance learning opportunities for students
  - Highly-qualified and well-prepared teachers with academic and professional experience in the STEM subjects

- Exemplary inclusive STEM high schools exhibit a number of other key practices, including blending formal and informal learning, offering college-level learning opportunities, designing a nimble administrative structure, and providing an expansive set of support programs. Effective inclusive STEM high schools complement the STEM curriculum with a range of student supports for diverse learners, including opportunities to work with academic tutors, advisors, and college and career counselors, as well as bridge programs to ease academic transitions.

- Many Hispanic students, in particular, perceive STEM fields as less desirable career options. Combatting these attitudes often requires additional effort on the part of the school to highlight the importance of the STEM fields, the exemplary achievements of STEM professionals, and the doors opened by STEM majors and career tracks. Successful strategies include opening channels of communication with students and parents through informational events like “Family Science Nights” and connecting students with minority mentors to provide them with visible success stories.
The transition to a STEM-focused mission and curriculum is often a stressful process for the school and its leadership, given pressures from stakeholders and the community to see results. The following practices may help school leaders navigate the implementation of STEM programs:

- Maintain a reasonable level of transparency
- Keep the focus of new initiatives on students and positive learning outcomes
- Encourage collaboration and reflective practice
- Allow time for a gradual implementation process
- Consider the long-term sustainability of the program
- Conduct program assessments to gauge success and make adjustments

The success of the project-based learning model hinges on several factors. These include the selection of real-world, authentic projects that will pique students’ interest, well-structured group work balancing team rewards and individual accountability, multi-faceted assessments, and teacher support through professional learning networks and professional development courses. Projects should be carefully calibrated to focus on a driving question aligned with course objectives and to be appropriate for students’ skill levels.
SECTION I: STEM EDUCATION OVERVIEW

STEM EDUCATION: BACKGROUND AND GOALS

American high school students rank alarmingly low among students of industrialized countries when it comes to achievement in science and mathematics. The poor performance of American students in the vital fields of science, technology, engineering, and mathematics (the STEM fields) is a fact borne out in test scores and other assessments of academic achievement. In 2013, only about one-quarter of 12th grade students performed at or above proficient in mathematics on the National Assessment of Educational Progress (NAEP), a percentage that remained unchanged from 2009. This alarming trend has led to the formation of a broad reform movement encapsulated by the acronym “STEM,” first used by the National Science Foundation (NSF) to refer to programming focused on science, technology, engineering, and mathematics.

The President’s Council of Advisors on Science and Technology (PCAST) identifies four major goals of STEM Education, examined in Figure 1.1.

Figure 1.1: Goals of STEM Education

<table>
<thead>
<tr>
<th>Ensure a STEM-capable citizenry</th>
<th>Build a STEM-proficient workforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>This goal seeks to cultivate a citizenry that has “the knowledge, conceptual understandings, and critical-thinking skills that come from studying STEM subjects.” This is important even for those who never directly enter a STEM-related career.</td>
<td>This goal seeks to adequately prepare a sufficient number of workers for job openings in STEM-related careers expected to increase in coming years. Additionally, STEM-related skills are increasingly relevant in fields not directly related to STEM subjects.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cultivate future STEM experts</th>
<th>Close the achievement and participation gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>This goal aims to educate the best STEM experts in the world because they contribute “to economic growth, to technological progress, to our understanding of ourselves and the universe, and to the reduction of hunger, disease, and poverty.”</td>
<td>This goal aims to increase women and minority participation and interest in STEM fields in order to tap into the country’s full potential.</td>
</tr>
</tbody>
</table>

Source: PCAST

Common STEM subjects include biology, chemistry, physics, computer/information systems, web/software development, engineering (e.g., chemical, civil, computer, electrical, general, and mechanical), mathematics, and statistics. However, schools may select other topics to pique students’ interest and leverage teacher expertise (e.g., environmental science, geology, biomedical research, forensic science, marine biology). Traditionally, math and science have been emphasized more than technology and engineering in practical applications of STEM. However, proponents of STEM education advocate increasing the visibility of technology and engineering in the curriculum. Engineering is critical for continued innovation, and “exposure to engineering activities (e.g., robotics and invention competitions) can spark further interest in STEM,” though such exposure is rare below the postsecondary level.

The ultimate goal for STEM education is to build a STEM-literate citizenry, referring to a person’s ability to apply his or her knowledge of “how the world works within and across four interrelated domains” (Figure 1.2).

Figure 1.2: STEM Literacy Defined Across the Four Disciplines

<table>
<thead>
<tr>
<th>Disciplines</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Literacy</td>
<td>• The ability to use scientific knowledge and processes to understand the natural world as well as the ability to participate in decisions that affect it</td>
</tr>
<tr>
<td>Technological Literacy</td>
<td>• Students should know how to use new technologies, understand how new technologies are developed, and have the skills to analyze how new technologies affect us, our nation, and the world</td>
</tr>
<tr>
<td>Engineering Literacy</td>
<td>• The understanding of how technologies are developed via the engineering design process using project-based lessons in a manner that integrates lessons across multiple subjects.</td>
</tr>
<tr>
<td>Mathematical Literacy</td>
<td>• The ability of students to analyze, reason, and communicate ideas effectively as they pose, formulate, solve, and interpret solutions to mathematical problems in a variety of situations</td>
</tr>
</tbody>
</table>

Source: National Governor’s Association Center for Best Practices

In sum, STEM education refers to “an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy.”

EMERGENCE OF SPECIALIZED STEM SCHOOLS

In 2010, the President’s Council of Advisors on Science and Technology put forth a recommendation for the establishment of 200 new STEM-focused high schools, combined with 800 STEM-focused schools at the lower (elementary and middle) grades, through the year 2020. Specialized STEM schools offer the advantage of “extended time with students to go further into the stages of expertise,” delivering educational programming that moves students from mere interest in the STEM fields to competency to expertise. Experts have praised the STEM high school movement for delivering an intervention to low-income students and students of color that does not try to remediate them, but rather offers access to rigorous science, technology, engineering, and mathematics courses and hands-on learning opportunities.

SELECTIVE VS. INCLUSIVE STEM MODELS

In 2008, Barbara Means and her colleagues at SRI International published an exhaustive report laying the conceptual foundation for specialized STEM high schools and describing the results of a survey of 315 of those schools. Means et al. distinguish between selective STEM schools, which admit applicants based on academic achievement and performance on standardized tests, and inclusive STEM schools, which predicate admissions on demonstrated interest in STEM subjects rather than academic performance. Means et al. underscore the broader student base as an essential characteristic of an inclusive STEM school, referring to inclusive schools as “the subset of STEM secondary schools seeking to serve students from groups historically under-represented in STEM fields.”

Means et al. surveyed 315 specialized STEM schools between November 2007 and May 2008, receiving 203 responses. Based on these responses, Means et al. identify several characteristics that distinguish inclusive from selective STEM schools. Inclusive STEM schools, for example, are more likely to group students and teachers for two years or more

---

13 Ibid., p. 30.
in an approach called “looping.” Twenty-seven percent of inclusive STEM schools reported looping students, compared to only 16 percent of selective STEM schools. Reinforcing the sense of community fostered at inclusive STEM schools, 65 percent of these schools provided common planning time for teachers in different subjects who teach the same students; only 44 percent of selective STEM schools did so. These organizational characteristics reflect a flexibility and sense of community not observed in the structure of selective STEM schools, which were more likely to be organized into traditional academic departments (83 percent compared to 68 percent at inclusive STEM schools).16

From an academic standpoint, inclusive and selective STEM schools differ primarily in their college-level course offerings. Selective STEM schools tend to offer more AP courses across the STEM disciplines (Figure 1.3).

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>INCLUSIVE STEM SCHOOLS</th>
<th>SELECTIVE STEM SCHOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>0.85</td>
<td>2.28</td>
</tr>
<tr>
<td>Science</td>
<td>1.20</td>
<td>3.04</td>
</tr>
<tr>
<td>Computer Science</td>
<td>0.23</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Source: SRI International17

Means et al. observe that the reason for the disparity in inclusive and selective STEM schools’ AP course offerings is not apparent from the data, hypothesizing that inclusive STEM schools are more likely to emphasize career and technical education. Overall statistics comparing graduation requirements at the two types of schools support Means et al.’s conclusion. Inclusive STEM schools are less likely than selective STEM schools to require college-level courses, 20 percent to 27 percent, but are marginally more likely to require an internship, 30 percent to 28 percent (Figure 1.4).

<table>
<thead>
<tr>
<th>TYPE OF PARTNER</th>
<th>SELECTIVE STEM SCHOOLS (N=80)</th>
<th>INCLUSIVE STEM SCHOOLS (N=71)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University or Four-Year College</td>
<td>44%</td>
<td>41%</td>
</tr>
<tr>
<td>Community College</td>
<td>30%</td>
<td>41%</td>
</tr>
<tr>
<td>Industry/business</td>
<td>33%</td>
<td>37%</td>
</tr>
<tr>
<td>Science Center or Research Lab</td>
<td>16%</td>
<td>13%</td>
</tr>
<tr>
<td>Career Technical School</td>
<td>15%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Source: SRI International18

Perhaps as a result of this focus on career and technical education, inclusive and selective STEM schools tend to partner with different types of organizations. Selective STEM schools are more likely to partner with universities, science centers, or career technical schools, while inclusive STEM schools are more likely to collaborate with community colleges or local

16 Ibid., p. 32.
17 Ibid., p. 36.
18 Ibid., p. 37.
industries. Many of these differences are slight, reinforcing Means et al.’s overall assessment of the school types’ broad similarities. Overall, Means et al. conclude inclusive and selective STEM schools employ similarly qualified teachers, implement similar instructional approaches, and maintain similar course requirements. Inclusive STEM schools, however,

show evidence of their recognition that their students may need extended instructional time and experiences that differ from those offered by traditional STEM schools. The inclusive schools are more likely to offer the level of personalization that comes from remaining in intact groups with teachers over multiple years and to provide contact with mentors in STEM fields who mirror the students in terms of background.  

Inclusive STEM schools, although structurally similar to selective STEM schools, actively create a supportive environment for their students by developing personalized learning communities and exposing students to positive role models in STEM fields. 

Although the survey focused primarily on STEM school characteristics, Means et al. also gauge implementation of instructional techniques like project-based learning and lab-based science learning. Unsurprisingly, almost all STEM schools surveyed report emphasizing lab-based science learning, but just over half of responding schools describe themselves as emphasizing workplace learning (Figure 1.5).

**Figure 1.5: STEM Schools’ Instructional Techniques**

<table>
<thead>
<tr>
<th>INSTRUCTIONAL APPROACH</th>
<th>SCHOOLS EMPHASIZING (PERCENT)</th>
<th>COURSES USING (PERCENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab-based science learning</td>
<td>97%</td>
<td>61%</td>
</tr>
<tr>
<td>Technology-supported learning tools</td>
<td>94%</td>
<td>74%</td>
</tr>
<tr>
<td>Project-based learning</td>
<td>85%</td>
<td>62%</td>
</tr>
<tr>
<td>Workplace learning</td>
<td>55%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Source: SRI International  

Fewer STEM schools claim to emphasize technology-supported learning tools than lab-based science learning, but a higher proportion of courses at those schools rely on technology. Workplace learning was least prevalent, with the lowest proportions of both schools and courses using the approach.

---

19 Ibid., p. 40.
20 Ibid., p. 30
SECTION II: DESIGNING EFFECTIVE HIGH SCHOOL STEM PROGRAMS

COMMON FEATURES OF STEM PROGRAMS

A 2010 report published by the National Science Foundation identified several key components of STEM learning, describing the approach as an “opportunity to experience inquiry-based learning, peer collaboration, open-ended, real-world problem solving, hands-on training, and interactions with practicing scientists, engineers and other experts.”21 The list at right features these components, as well as other common features of STEM programs highlighted in the literature.

STEM schools tend to be small in size, allowing students to build closer relationships with fellow students and teachers and receive more personalized learning opportunities. 22 STEM schools offer a rigorous curriculum while embracing a dual focus on both cognitive assets and non-cognitive factors, emphasizing the development of 21st century skills and providing students with valuable hands-on experiences. 23 High school STEM programs tend to gravitate toward an integrated curriculum, with inquiry-based learning—and, more specifically, project-based learning—typically embraced as the primary instructional approach. Such programs commonly integrate innovative technology into the classroom environment and place strong emphasis on hands-on, active learning opportunities, including learning that takes place in a laboratory or workplace setting. To advance the latter approach, as well as to ensure alignment with local needs and workforce demand, high school STEM programs strive to build relationships and connections with community, industry, and university partners. Finally, high school STEM programs place significant value on hiring highly qualified teachers with the capability to deliver rigorous STEM coursework guided by academic and professional experience.24

---

USING INQUIRY-BASED APPROACHES TO LEARNING

Whether a district-wide STEM initiative or a single STEM high school, advancements in STEM education should reach far beyond simply the addition of more, or more difficult, mathematics and science courses. While the addition of courses such as Advanced Calculus or Design Media may be welcomed by students, alone, these types of courses represent curricular expansion, but not transformation. Educators must modify their instructional approach to wholly transform the high school environment into a STEM-focused academy. STEM concepts are often best taught in an active, hands-on environment wherein students design solutions, create products, and present their results to fellow students. With the use of inquiry-based methods such as project-based learning, STEM environments foster creativity, provide opportunities for teamwork, and emphasize inquiry rather than rote memorization.25

Inquiry-based education, an approach combining students’ natural curiosity with the scientific method, immerses students in an educational environment wherein they must formulate difficult questions, explore problems in depth, use observations, and apply newly learned information to arrive at an appropriate solution to the problem or challenge at hand.26 The inquiry-based approach asks students to develop critical questions, investigate possible solutions, use evidence to support conclusions, connect evidence to acquired knowledge, and share their findings.27 An umbrella concept, inquiry-based learning encompasses a number of approaches, including project-based learning, problem-based learning, and learning by design.28

In project-based learning, students tackle real-world problems over a period of time, while the teacher acts as a facilitator, framing critical questions, structuring tasks, coaching students in skill development, and assessing project outcomes.29 PBL should be adopted as a central part of the curriculum and, to be effective, should present students with driving questions and engaging tasks, require “constructive investigation” leading to desired learning outcomes, and allow students to participate in designing and managing project assignments. An important component of PBL is the use of authentic tasks that students perceive as relevant to the “real world.”30

Akin to project-based learning, problem-based learning requires students to use reasoning and critical-thinking skills, combined with available resources, to investigate an identified

27 Ibid.
problem. Problem-based learning typically occurs in a small-group setting, requiring students to collaborate to generate possible solutions to the given problem.31 Some, including the Buck Institute for Education’s (BIE) Editor in Chief, John Larmer, consider problem-based learning to be a sub-category within project-based learning. Problem-based learning assignments demonstrate subtle differences from the broader PBL concept, including a tendency toward shorter, single-subject problems presented as case studies or fictitious scenarios (as opposed to the more multidisciplinary, authentic learning tasks favored in PBL).32

Finally, learning through design, another genre considered a subset of inquiry-based learning, engages students in designing an artifact to demonstrate mastery and application of a learning objective. Particularly suitable for developing “technical and subject matter knowledge,” the approach requires that students reassess, revise, and redesign the artifact as their knowledge evolves.33

**Offering an Integrated Curriculum**

Proponents of STEM education are increasingly advocating the interrelated nature of all the STEM subjects and the necessity of implementing an interdisciplinary approach rather than treating the individual subjects as “silos.”34 This interdisciplinary approach thematically links one or several courses together, allowing topics to “reinforce each other in support of the overall growth of each topic.”35

Many STEM-focused schools use an integrated curriculum, identifying themes to unite studies across different disciplines. The Wake-NC State University STEM Early College High School provides one example of an integrated, thematic curriculum. The school requires students to participate in a daily seminar, as well as integrated courses delivered in 90-minute blocks. A hybrid course might, for instance, combine earth sciences with engineering, or English with world geography. Elaborating on the school’s approach to uniting different courses with a single, thematic thread running through each, one teacher explains:36

> In August, the students in [a Humanities I class] were reading *Lord of the Flies*. As a class project, students were tasked with writing survival guides that deal with strategies for coping with life when stranded on such an island, such as how to govern themselves, how to build shelters, and how to ensure access to food and clean water.

> In the school’s science/engineering class, students were learning about fresh water issues, such as how to treat drinking water. On a recent day, they also were constructing topographical maps of an island.

31 Ibid., p. 5.
35 Ibid., p. 5.
The school further adheres to a common learning theme—the National Academy of Engineering’s 14 Grand Challenges for Engineering—which focuses learning on the STEM subjects, while also allowing for exploration of “economic, political, and ethical dimensions.”37 The Grand Challenges include broad societal goals requiring extensive work in the STEM fields (e.g., “provide access to clean water,” “advance health informatics,” “secure cyberspace”). Using these challenges to frame curricular content encourages students to “collaborate, think critically, and search for solutions to society’s most urgent problems.”38

The use of an integrated curriculum finds support in the literature, with experts highlighting the potential for “more relevant, less fragmented” learning experiences. STEM education equips students with strong problem solving, critical thinking, and technology literacy skills, leading to positive outcomes when STEM themes and experiences are embedded in the coursework of outside disciplines.39

**INTEGRATING TECHNOLOGY-ENHANCED LEARNING**

STEM high schools enhance the educational experiences of students by adopting technologies designed to improve instruction (e.g., media retrieval systems, document cameras, smart boards), facilitate lab-based learning (e.g., data collection instruments, simulation software), and expand research opportunities (e.g., internet, multimedia resources). Some STEM schools use digital portfolios for students to collect artifacts produced through inquiry-based learning, thereby infusing technology into the assessment model. Others have established academy-wide technology initiatives to advance school goals—e.g., providing students with computing devices to achieve a one-to-one technology ratio or building an online portal to communicate with students and parents regarding assignments and grades.40

As described in the NSF report, “Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation’s Human Capital,”

> Emerging technologies can be instrumental in providing schools access to meaningfully enriching STEM resources. Through the Internet students can connect to formal and informal learning opportunities and STEM experts, gain interactive access to world-renowned museum collections and a vast array of digital STEM content, and participate in virtual laboratories.41

---

37 Ibid.
A 2013 report released by an international group of four organizations, including the Austin, Texas-based New Media Consortium, identified several technologies dominating conversations within the STEM education environment. The expert review pointed to four technologies entering “mainstream use” now—learning data analysis tools, mobile learning, online learning, and virtual/remote laboratories—as well as newer technologies and tools on the horizon for STEM education use (e.g., 3D printing, immersive learning, machine learning, wearable technologies, flexible displays, and virtual assistants, among others).42

**Building Industry, Community, and University Connections**

Effective STEM programs connect the local economy, the community, and college and university partners. Community integration is an essential component of the program “in conception and delivery.”43 STEM schools should build connections with the professional STEM community to enhance learning opportunities for students and to provide them with examples of real-world applications. Partnerships may range in intensity from rather casual and frequent to very formal and are typically established with the goal of offering students “more creative programs, role models, support, and continuity across school years and institutions.” 44 Examples of potential partner institutions for STEM schools include corporations, institutions of higher education, regional STEM centers, and museums.45

Public-private partnerships provide opportunities for students to connect with professional mentors and for educators to consult with industry representatives on curricular relevance and alignment with STEM careers. Such partnerships may galvanize schools to push beyond traditional boundaries to form more innovative STEM options. For example, new schools in New York and Chicago, in partnership with IBM, are serving students in the 9-14 gradespan, combining the high school curriculum with an associate’s degree.46

**Best Practices for Inclusive STEM Education**

While the inclusive STEM school movement is a relatively recent development in education, research is beginning to emerge on the efficacy of certain practices within this model. Academics at George Washington University and George Mason University are working with the non-profit research organization SRI International to cross-analyze eight exemplary STEM high schools adhering to an inclusive model of STEM education. Titled the Opportunity Structures for Preparation and Inspiration in STEM (OSPri) project, the researchers are focusing on STEM programs using open enrollment policies to attract and support underrepresented minority students.


While the research is ongoing, the team has identified 10 “critical components” for the “design, implementation, and evaluation” of such schools, based on its reviews thus far. These 10 critical components, listed at right, reflect the common features of STEM education and general best practices prominent throughout the literature, including using a project-based learning approach, integrating technology, building community and industry partnerships, and hiring and retaining qualified and well-prepared classroom educators.

In regard to curricular structure, an effective STEM school will offer rigorous course options in all four STEM disciplines, or, alternatively, intentionally integrate engineering and technology instruction into more traditional STEM and non-STEM courses. Effective STEM schools immerse students in an active, project-based learning environment, assessing mastery through performance-based assessments demonstrating an “authentic fit with STEM disciplines.”

The researchers draw attention to the need for inclusive schools to blend formal and informal learning opportunities extending beyond the traditional school day or school year. Informal learning experiences may include working as an apprentice, receiving guidance from a professional mentor, or participating in STEM projects off the school campus (e.g., in a museum, business, or STEM center). Real-world experiences (e.g., internships, work-based projects) are an integral part of STEM education, equipping students with 21st century skills to meet workforce demand, while integrating the wider community of stakeholders, including STEM professionals, into the educational mission.

Best Practices for Inclusive STEM High Schools

1. Rigorous curriculum focused on the STEM subjects
2. Adoption of project-based learning as an instructional approach
3. Technology used to flatten the typical student and teacher hierarchy
4. Blended formal/informal learning beyond the regular school day or year
5. Community and industry partnerships formed to offer real-world exposure
6. Opportunities for students to enroll in college-level courses
7. Qualified and well-prepared academic staff
8. Inclusive STEM mission
9. Use of a “flexible and nimble” school administration model
10. Effective support structure to assist underrepresented students

---

49 Ibid., p. 9.
50 Ibid., p. 11.
Inclusive STEM schools should work to elevate the educational opportunities available to students, offering high school students access to college-level learning opportunities. More rigorous course sequences and early college learning opportunities, however, should be accompanied by a comprehensive support structure, especially for minority and economically-disadvantaged students. Effective inclusive STEM high schools complement the STEM curriculum with a range of student supports for diverse learners, including opportunities to work with academic tutors, advisors, and college and career counselors. Other strategies seen in inclusive STEM schools include offering bridge programs to ease academic transitions and using looping to provide a consistent environment for students. Successful inclusive STEM high schools display a strong commitment to ensuring the success of enrolled students and creating a supportive atmosphere for students and their families, including addressing the “personal and financial challenges” they face.

Finally, the researchers highlight structural and school-wide practices critical for positioning the inclusive STEM school for success. Though an increasingly popular choice for school districts implementing STEM initiatives, there is “no umbrella philosophy or organizational structure” for this emerging model of STEM education, which targets students with demonstrated interest as opposed to demonstrated success in the classroom. A “flexible and nimble” administrative structure sets the stage for school leaders to more easily affect change. An inclusive STEM school may operate as a charter school, magnet school, or school-within-a-school, among other models. Regardless of the structural model, a focused and widely-supported mission to serve underrepresented student groups is critical, as is an academic staff with “advanced STEM content knowledge and/or practical experience in STEM careers.”

**Strategies to Support Underrepresented Students in STEM**

The advantages of STEM education and career tracks for underrepresented students are clear; indeed, women and minority students who choose to pursue a STEM career track see smaller pay gaps when compared against their white male counterparts in the job market. However, these groups continue to be underrepresented in the STEM disciplines. The reasons minority students may avoid the STEM fields are varied; while some students’ interests simply lie elsewhere, others are intrigued by one or more of the STEM subjects, but fail to pursue these challenging fields.

Past research provides insight into the obstacles deterring many Hispanic students from selecting STEM career tracks. A survey conducted by the University of Sciences in Philadelphia provides insight into the “student mindset” that sometimes interferes with students’ selection of STEM career tracks. Of 604 surveyed high school students aged 13 to 18 years, nearly half (45 percent) reported that they would not enter a science or health

---

51 Ibid., p. 11.
52 Ibid., p. 11.
care field, with common deterrents being a lack of knowledge about the field (22 percent), intimidation (21 percent), and lack of preparation in high school (19 percent).56

At-risk students often have poorly developed skills in science and mathematics, and the argument for students to persist in earning a high school diploma as one of the first steps to securing a lucrative STEM career is a tough sell for adolescents. Many Hispanic students, in particular, perceive STEM fields as career options for “geeks.” Combating this notion often requires additional effort on the part of the school to highlight the importance of the STEM fields, the exemplary achievements of STEM professionals, and the doors opened by STEM majors and career tracks. In one strategy used to promote STEM among minority students, the school hosts “Family Science Nights,” informational meetings for students and their parents focused on the advantages of STEM careers and available college scholarships.57 Promoting STEM education to family members and peers is important, as students will be reluctant to select STEM paths if the closest members of their support network fail to see the value in STEM or display negative attitudes. Teachers and counselors, then, are charged with the important duty of conducting outreach to students’ families to educate them regarding the “opportunities and possibilities” afforded by education in the STEM disciplines.58

Establishing external partnerships, a best practice cited throughout the literature, is particularly relevant within the context of building positive STEM outcomes for minority students. Connecting these students with minority mentors provides them with visible success stories and should help build their confidence in the value of STEM careers and their ability to achieve positive outcomes in these often-challenging disciplines. Partnerships between inclusive STEM high schools and local community colleges show particular promise, not only laying the groundwork for student interest by heightening the visibility of STEM degree and certificate paths, but also connecting students with role models. Hispanic students, for instance, may be paired with Hispanic faculty or undergraduate mentors to provide guidance and answer questions regarding the STEM disciplines at the college level.59

Finally, a 2012 study published by the Association of Public and Land-grant Universities’ (APLU) Minority Male STEM Initiative (MMSI) surveyed 1,443 STEM students, 137 faculty, and 71 administrators regarding success factors at the undergraduate level, finding that high-achieving minority males enrolled in STEM majors “benefited greatly from exposure to a rigorous curriculum through their respective high schools’ Advanced Placement programs.”60 The finding highlights the importance of designing STEM schools to offer a rigorous course selection, integrating AP courses or a college preparatory or early college component.

57 Ibid.
58 Ibid.
59 Ibid.
STEM Program Implementation: Lessons for School Leaders

The literature on STEM initiatives and specialized schools yields insight into implementation from the perspective of school leaders. The following profile of Cleveland High School, based on the work of researchers at the University of Washington, highlights several of the key lessons administrators have learned while navigating the complex process of transforming a high school into a specialized STEM academy.

Lessons Learned at Cleveland High School

For years, Cleveland High School has been one of the state’s poorest performing high schools, but the introduction of a “project-based, interdisciplinary” STEM initiative has helped the urban high school begin to make progress in improving student outcomes. While the school has adopted a number of changes over the years, the most comprehensive transformation took place in the 2010-2011 school year, when the school, previously considered a “neighborhood school,” began to pull in students from across the district. The school split into two smaller STEM academies—the School of Life Sciences and the School of Engineering and Design—and adopted a new approach to education, using project-based and interdisciplinary instruction and integrating one-to-one technology into the learning environment. The School of Life Sciences now focuses on biology, biochemistry, and global health issues, providing opportunities for students to investigate body systems and disease, while the School of Engineering and Design focuses on the physical sciences and technology, featuring “a computer game design program and a pre-engineering program that [exposes] students to leading edge technologies in robotics, aeronautics, rocket design, and alternative energy.” Over the 2010-2011 school year, the high school saw an approximately 5 percent increase in the attendance rate, as well as improvements on the Measure of Academic Progress (MAP)—a 7 percent increase in 9th grade reading and an 11 percent increase in 9th grade math.

Leading change in a school community is a stressful and difficult task. At Cleveland High School, leaders’ stress levels were heightened by “pressure to rapidly restructure, responsibility for defining uncharted territory regarding STEM implementation in this particular district and school, accountability for providing evidence of effectiveness […] and the] need for reliable and predictable resources to support ongoing professional growth and development.” A published case study based on an interview with one of the school’s assistant principals yields the following recommendations for school leaders launching inclusive high school STEM initiatives:


64 Ibid., p. 23.
- **Maintain a reasonable level of transparency:** It is vital for school leaders in charge of transformational STEM initiatives to clearly communicate expectations and listen to stakeholders. Successful communication efforts “combine expectations with discussions about resources and support” and stress previously agreed upon priorities and strategies. At Cleveland High School, school leaders clearly communicated how the school’s new project-based approach to learning could be united with the school’s existing pedagogical philosophy based on the “4R’s” (relationships, relevance, rigor, results). School leaders also acknowledged the challenges anticipated with the shift to a STEM environment, engaging teachers in discussions regarding program implementation and listening to teachers’ concerns.

- **Keep the focus of new initiatives on students:** It is important for school districts to keep the focus of new STEM initiatives on students and positive academic outcomes. At Cleveland High School, leaders asked teachers to establish professional goals to advance the achievement of four different types of learners. At the outset of each year, teachers, guided by school leaders, “select two low-performing students, as well as a middle- and a high-performing student” to “serve as a touchstone for strengthening instructional practice.” In the words of the school’s assistant principal, the model produced “intentional planning:” “When teachers were asked to pick four students, it forced people to build relationships. Teachers had to look at reasons for struggle [...] and for success to help plan lessons that would help students succeed.”

- **Encourage collaboration and reflective practice:** Finally, it is important for educators to collaborate and reflect on the learning process, practices which allow teachers to “access shared knowledge, reassess assumptions, and ask better questions about improving instruction.” At Cleveland High School, teachers worked together in professional learning communities to advance adoption of the project-based learning approach, a structure allowing teachers to “share and vet projects” and to announce student presentations to “create authentic experiences” for the adolescents to present their work.

**Recommendations from the Literature**

Other recommendations for school leaders include the following:

- **Allow time for a gradual implementation process, budgeting time for extensive planning and research.** The Carol Martin Gatton Academy of Mathematics and Science in Kentucky is ranked among the top five high schools in the United States, according to *Newsweek’s* “America’s Best High Schools 2011” report. Tim Gott, Director of the Academy, describes his experience in starting this successful STEM
school in a 2011 article in the *NCSSSMST Journal*. The interview emphasizes that a slow implementation process allowed for careful research and planning and that visiting other similar STEM schools played an integral part in the formation of the specialized high school.71

- **Consider the long-term sustainability of the program.** Sustaining a STEM program involves several factors, including building and maintaining local capacity for continuous improvement to STEM structures. Districts must also ensure the availability of funds for the program beyond the implementation phase. Additionally, ongoing feedback and evaluation is necessary to track, measure, and implement changes to the system, including instructional models and professional development for teachers.72

- **Conduct program assessments using quantitative and qualitative measures to gauge success and facilitate continued improvement.** STEM schools may wish to assess the success of their programs according to quantitative and qualitative measurements. Standardized tests do not adequately serve this function since the goals of STEM education go beyond preparing students academically. Thus, measurements such as the percentage of students who continue on to pursue STEM-related majors at the postsecondary level or the application of STEM knowledge to non-STEM related careers may also be relevant metrics.73 In addition to student outcomes, the Ohio STEM Learning Network (OSLN) suggests that teacher attitudes, content knowledge, and instructional practices are useful measures of program effectiveness.74 These measures can be used to inform professional development planning—also an important factor in sustaining a cutting-edge STEM program.

---


http://sites.nationalacademies.org/dbasse/bose/index.htm

74 “Statewide Forum.” October 7, 2010. Ohio STEM. 
http://f6c9c2d06bec2b445164f540d13c4cf288be03ec.gripelements.com/pdf/Public_Private_Collab_/final_forum_powerpoint.pdf
SECTION III: USING PROJECT-BASED LEARNING TO DELIVER STEM EDUCATION

PROJECT-BASED LEARNING OVERVIEW

The Texas Science, Technology, Engineering and Mathematics (T-STEM) Initiative defines project-based learning as an:  
- *Inquiry-based* instructional approach,
- in a *real-world* context,
- where *students generate the pathways and products*,
- that meet defined, *standards-based outcomes*.

STEM-PBL is less an instructional philosophy than a “curricular framework” supported by inquiry-based learning experiences that encourage students to ask challenging questions and work to solve complex problems. STEM-PBL “has as its goal the actualization of learning around a project that includes describing ill-defined tasks, hypothesizing, modeling, testing, and refining.” The model shifts instruction away from “short, discontinuous, teacher-centric lessons,” instead asking students to “investigate interdisciplinary, rigorous real-world topics usually originating from a driving question.”

STEM-PBL is most successful when the project leads toward a “well-defined outcome” (i.e., a measurable goal) through an “ill-defined task.” In *STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach*, the authors elaborate on this concept:

Too often, hands-on activities are verification of known—or at least taught—concepts. The ill-defined nature of STEM PBL requires higher order thinking skills, problem-solving, and increased content learning. One misconception about PBL in general is that it is chaotic or haphazard. Nothing could be further from the truth. Ill-defined is not ill-designed. The teacher must design tasks that allow for student investigation, multiple solutions, and engaging contexts all of which converge in a common understanding of the ill-defined outcome.

---

76 Ibid.
78 Ibid.
80 Ibid.
STEM projects should be “strategically designed,” engaging for students, and linked to critical content and skills. Teachers and students commonly employ “engineering, literary research, writing, artistic and scientific” design processes in planning and carrying out STEM projects. Demonstrating mastery within a PBL learning environment requires students to exhibit the learned content or skill through a presentation, performance, competition, or similar route. Another important stage at the conclusion of a project is reflection. During this stage, teachers should guide students in considering what they learned and how it applies to other scenarios.

Educators should approach STEM-PBL lessons by clearly “identifying the objectives, content and standards for the lesson,” determining realistic goals for the project, and evaluating students’ abilities to successfully complete the project, given the outlined standards and timeframe. In preparing STEM-PBL lessons, teachers should also work with their peers to develop interdisciplinary connections, as well as collaborate with business partners to connect students with real-world examples of the types of projects assigned, thereby building the authenticity of the tasks.

**BEST PRACTICES IN PROJECT-BASED LEARNING**

According to a literature review conducted by the Washington Informal Science Education (WISE) Consortium, a group dedicated to STEM education in Washington State, the success of the PBL model often hinges on project selection and design (i.e., reflective of real-world problems and aligned with defined content and skills), the small group structure, multiple learning outcomes and means of assessment, and teacher participation in professional learning communities and development. These key practices allow educators to boost project-based learning “from a fun and engaging exercise to a rigorous and powerful real-world learning experience.”

---

82 Ibid.
83 Ibid.
85 See the following sources, cited in: “Pre-K-12 STEM Project-Based Learning.” WISE Consortium. http://experiencewise.org/pre-k-12-stem-project-based-learning/
**Figure 3.1: Keys to Project-Based Learning Success**

1. **A realistic, real-world problem or project**
   - aligns with students’ skills and interests
   - requires learning clearly defined content and skills (e.g., using rubrics, or exemplars from local professionals and students)
   - increased student control over his or her learning
   - teachers serving as coaches and facilitators of inquiry and reflection

2. **Structured groupwork**
   - groups of three to four students, with diverse skill levels and interdependent roles
   - team rewards
   - individual accountability, based on student growth

3. **Multi-faceted assessment**
   - multiple opportunities for students to receive feedback and revise their work
   - multiple learning outcomes (e.g., problem-solving, content, collaboration)
   - presentations that encourage participation and signal social value (e.g., exhibitions, portfolios, performances, reports)

4. **Participation in a professional learning network**
   - collaborating and reflecting upon PBL experiences in the classroom with colleagues
   - courses in inquiry-based teaching methods

Source: WISE Consortium (“Pre-K-12 STEM Project-Based Learning”)\(^{87}\)

**DESIGNING AND CALIBRATING REAL-WORLD PROJECTS**

Central to project-based learning success is a “carefully calibrated project design.”\(^{88}\) Educators must identify a driving question for the project to revolve around, with PBL being most effective when the critical question aligns well with the course’s objectives in terms of key learning outcomes and accurately matches students’ skill levels. Scholar Woei Hung puts forth the following process for designing effective problem-based projects (Figure 3.2).\(^{89}\)

---

\(^{87}\) “Pre-K-12 STEM Project-Based Learning,” Op. cit.


Figure 3.2: Key Steps for the Design of Successful Problem-Based Projects

1. Define the content or skills students will master through project-based learning

2. Discuss the real-world context, brainstorming relevant scenarios and activities

3. Identify potential projects, selecting the one with the highest relevance to the content objective

4. Determine both the most viable solution and alternative outcomes, identifying the “realistic path of reasoning and the knowledge (concepts, principles, procedures, and facts)” related to each path and using these to pinpoint necessary research and problem-solving skills

5. Calibrate the project, ensuring the knowledge and skills student acquire when arriving at the most viable solution align with curricular objectives and standards

6. Create a description of the project, incorporating information on higher-level research or reasoning skills necessary for students to solve the problem when above the students’ skill level

7. Build opportunities for students to reflect on their learning into the project design (e.g., journal-keeping or meeting weekly with a project supervisor) and the final assessment

In: Vega, V. 2012. “Project-Based Learning Research Review: Evidence-Based Components of Success.”

---

90 Ibid.
**Structuring Opportunities for Student Collaboration**

The opportunity for students to work collaboratively with their peers is a central component of STEM learning and an equally critical factor in project-based learning. Experts point to two critical ingredients for achieving success in this area: team goals and individual accountability. Educators should tie team goals or rewards to each individual group member’s growth, encouraging students to relate their personal success to the success of their peers and to assist struggling team members. Educators should further measure each individual’s success against past performance to give each student an “equal chance of success.” Potential strategies and tools educators may use to help facilitate successful group work include regular meetings, planning sheets, and group contracts.91

**Using Assessments to Support Student Success**

Criteria for successful project outcomes should be explicitly defined at the beginning of the lesson when students first launch their projects. The assessment model should integrate “multiple opportunities for feedback, reflection, and time for students to revise their work.” Furthermore, the end-goal of project assignments should reflect real-world professional practices (e.g., portfolios, presentations, or public exhibitions). Finally, the literature suggests seeking input directly from students when defining criteria for final assessments, a practice which builds a sense of ownership for project outcomes among students.

**Offering Professional Development Opportunities**

Professional development for teachers is one of the most critical factors for successful outcomes with project-based learning, as classroom educators are the ones “on the ground,” designing and managing projects, monitoring students’ progress, and assessing outcomes. Ideally, teachers should be able to participate in professional development courses on inquiry-based education and the PBL approach, as well as connect with their peers to share strategies, reflect on their experiences, and identify potential opportunities for collaboration. For teachers to successfully facilitate inquiry-based learning, they should have numerous opportunities to observe, collaborate, practice, and reflect.92

Manor New Technology High School, profiled in further detail in the final section of this report, provides an example of the types of professional development initiatives used by inclusive STEM schools adopting project-based learning as the primary instructional approach. MNTHS has used the following professional development strategies:93

- Weekly professional development meetings lasting one to two hours (resulting in a truncated school day for students), which include faculty-wide meetings and leadership committees

---

92 [1] Ibid.
- Peer-evaluation protocols providing a “supportive meeting space” for teachers to receive feedback on how to improve or adapt their approaches as students’ projects progress
- The implementation of a “Teaching Advancement Program,” which offers teachers additional time and compensation in exchange for new responsibilities regarding mentorship of their peers
- Tutorials on STEM curriculum, teacher training, professional learning communities, and business partnerships to deepen teachers’ familiarity with PBL-based learning
- Summertime professional development opportunities at a summer training institute
- Team-teaching and individual development by senior educators to improve new teachers’ understanding of the theories they will be applying to curriculum with their students94

SECTION IV: STEM LEARNING AND PBL CASE STUDIES

CASE STUDY: PROJECT-BASED LEARNING AT MANOR NEW TECHNOLOGY HIGH SCHOOL

Recognized widely in the literature on STEM education, Manor New Technology High School is an inclusive STEM high school option within the Manor Independent School District in Texas, approximately 12 miles outside Austin. Established in 2007, the school serves students in grades 9-12 in a specialized STEM-focused environment. The school is one of three high schools within Manor ISD, the others being a comprehensive high school and a small alternative high school for students with discipline referrals. In the 2011-2012 school year, MNTHS reported a total enrollment of 333 students and employed nearly 27 FTE teachers, for a ratio of approximately 12 students per one classroom teacher. The school’s student population is 46 percent Hispanic, 29 percent White, and 20 percent Black, with more than 50 percent economically disadvantaged.

The school has received abundant praise for its model of inclusive STEM education. In May 2014, the International Association for STEM Leaders awarded Principal Steven Zipkes the STEM Visionary Award. The school hosts more than 1,000 visitors each year interested in replicating its model and has gained recognition from President Obama and U.S. Secretary of Education Arne Duncan. The school has achieved its success largely by adopting project-based learning, infusing 21st century skills into the curriculum, and building a robust student support structure.

CLEARLY-DEFINED INCLUSIVE MISSION

MNTHS strives to equip students with the skills and knowledge necessary to succeed in an “information-based and technologically-advanced society,” immersing learners in a “student-centered, collaborative, project-based community” focused on the STEM disciplines. The school has adopted five core values—“Respect, Integrity, Responsibility, Perseverance, Trust”—and promotes five learning outcomes for students—

“Communication, Collaboration, Work Ethic, Critical Thinking, Research.” 100 MNTHS maintains an inclusive admissions process, using a lottery system to select the incoming class, while balancing the ratio of male and female students and awarding a “slight advantage” to current students’ siblings.101

**STEM-FOCUSED CURRICULUM**

MNTHS is part of the New Tech Network and demonstrates fidelity to the organization’s STEM model, which involves three primary components: applying project-based learning, using technology in the classroom and across the school site, and building a positive school culture valuing responsibility and respect for others.102 Curricular requirements for graduation include completion of five credits in science, five credits in mathematics, two credits in engineering, and two credits in technology, as elected by the student, over the course of the 9-12 gradespan. Students must also complete a Capstone Project Senior Year Internship for at least one semester.103 The school uses a “flexible trimester system,” allowing students to earn more than the typical number of credits required in the State of Texas (i.e., four credits in science and mathematics).

A case study completed as part of the OSPri’s research on inclusive STEM high schools provides the following information on the school’s typical course sequences in the STEM subjects: 104

- **Science:** The typical course sequence in science begins with completion of Biology and Chemistry, followed by cross-disciplinary courses pairing science and math skills—e.g., Physics (with Algebra II), Scientific Research and Design (with Statistics), and Environmental Science (with Pre-Calculus).

- **Technology:** The curriculum requires completion of two years of technology courses, though students have the freedom to choose these courses from a list of pre-approved electives (e.g., Digital Animation, Programming).

- **Engineering:** The engineering sequence consists of two courses—Introduction to Engineering and Principles of Engineering—accompanied by electives (e.g., Digital Electronics) and extracurricular opportunities (e.g., Robotics Club) for students with particular interest in the subject.

- **Mathematics:** The typical course sequence in math takes students from either Algebra I or Geometry in the 9th grade through either Pre-Calculus or Calculus in the 12th grade. The school has designed a Mathematics Enrichment course to assist struggling students.

---


102 Ibid., pp. 48-50.

104 Ibid., pp. 14-16.
Despite the STEM focus, the school maintains a “strong and popular humanities program,” offering cross-disciplinary courses integrating technology and project-based learning. Higher level humanities courses offer college credit through a community college partnership. However, the school does not offer AP courses. Due to fears that the new STEM school would attract all of the district’s most academically talented students upon its launch, the district decided to leave AP course offerings at the comprehensive high school as a strategy for “retaining academic variation” at both.  

100% Project-Based Learning

While MNTHS is a STEM school, insights from students, teachers, and administrators suggest that the school’s identity is equally, if not better, defined by project-based learning. Instruction at MNTHS follows a 100 percent PBL model. Of the project design process, the OSPrl case study explains:

Teachers plan their curriculum by analyzing the relevant Texas content standards for a course, and then identify relevant project-based challenges that align to the standards. This allows students to learn the material intended by the standard in a contextualized and interdisciplinary way. This is more than a curricular gimmick at [MNTHS], it is the dominant curricular and instruction model employed by all teachers, STEM and humanities teachers alike.

In fact, the majority of 11th and 12th grade courses take a cross-disciplinary approach, integrating two disciplines in an expanded time slot (double the length of a traditional, single-subject course) and pairing teachers to work as a team.

Math achievement is the primary driver of the school’s instructional approach and curriculum, and teachers use “systematic test data analyses” from the state’s math assessment to inform PBL lesson design in science and engineering. PBL lessons are designed to cultivate 21st century skills, including critical thinking, collaboration, communication, and creativity, among others. PBL units further help hone productivity skills necessary for the workplace, including work ethic and time management. Student input suggests a positive response, with students expressing appreciation for the “contextualized approach” of project-based learning. Those who do begin to struggle with the more difficult concepts tackled through project-based learning benefit from teacher tutoring and mini-workshops.

On the following page, Figure 4.1 illustrates a sample PBL lesson at Manor New Technology High School.

---

105 Ibid., p. 17.  
106 Ibid., p. 17.  
107 Ibid., p. 15.  
108 Ibid., p. 15.  
109 Ibid., p. 15.  
110 Ibid., pp.22-23.  
111 Ibid., p. 15.
Figure 4.1: Sample Project-Based Learning Activity

**Setting**

80-minute Trigonometry/Geometry class

**Goal**

Students will work in groups to formulate a building design within given parameters for the building’s size, transitioning from rough sketches to floor plans on graph paper to electronic drafts using Geometer’s Sketchpad

**Challenge**

Accounting for wall widths within the design

**Strategy**

Incorporating a trigonometry workshop, facilitating group activities (more than 60 percent of class time), and involving students in hands-on activities (more than 90 percent of class time)

Source: Lynch, S.J. et al.112

**Technology and Student Support**

At MNTHS, teachers use the ECHO learning management system to deliver feedback on projects, track grades, and complete rubrics. Students use the same system to email teachers with their questions regarding project assignments and to follow their academic progress. However, the school also uses less formal technologies. YouTube, for example, serves as a “repository for student work projects.”113

Student support is a significant priority for the school given its inclusive mission. Among its support programs, the school offers a summer bridge program for rising 9th graders in a one-week orientation format. The school also requires students to participate in weekly advisory periods beginning in the 9th grade. Discussions carried out in advisory periods center on topics such as adjustment for younger students and college selection for older students. For struggling students, the school offers remedial, or “catch-up,” courses, as well as tutoring options.114

**Teacher Selection and Support**

Among the teacher characteristics desirable for the STEM environment, MNTHS favors a strong academic background, a flexible and open-minded approach to instruction, dedication to continued professional learning, and the ability to work collaboratively with

112 Ibid., pp. 19-20.
113 Ibid., pp. 24-25.
114 Ibid., pp. 41-43.
peers and to seek assistance and support when necessary. Many teachers at MNTHS have held careers outside education, in areas such as medical technology, computer programming, and military service.  

Teachers receive a considerable level of support at MNTHS. A Teacher Coach “supervises, mentors, and assists” teachers, while two Master Teachers provide further guidance and three Mentor Teachers “provide day-to-day contact and support in a more detailed course-specific, student-specific” manner. Professional development opportunities include weekly teacher meetings, summer experiences through the New Tech Network, and Project Lead The Way (PLTW) instruction for engineering teachers.  

**CASE STUDY: METROPOLITAN CLEVELAND CONSORTIUM FOR STEM**

The Metropolitan Cleveland Consortium for STEM High School (MC² STEM High School) is an inclusive STEM school serving one of the nation’s most economically disadvantaged school districts. Established in 2008, the school surpassed the district’s and state’s achievement levels in 2011, based on the percentage of high school students meeting or exceeding the state standards. The school achieved a 95 percent graduation rate that year, compared to 84 percent across the state and just 63 percent within the district. The school adheres to an inclusive STEM school model, using a lottery system to determine student acceptance. In the 2011-2012 school year, MC² STEM reported an enrollment of 299 students, more than three-quarters of whom were Black.

The school uses a unique “embedded campus model,” which “allows students and staff to benefit from the onsite resources” provided by corporate and campus locations. As students progress through the high school years, they change locations: the Great Lakes Science Center for 9th grade, General Electric’s Nela Park for 10th grade, and the Key Bank Classrooms for STEM Education, located at Cleveland State University’s downtown campus, for 11th and 12th grade. The school lists more than 20 community partners, including the NASA Glenn Research Center, Cuyahoga County Community College, and the Cleveland Clinic, among others. These partnerships expand internship and apprenticeship opportunities for students and help facilitate extended learning opportunities, such as a

---

115 Ibid., pp. 28-29.
116 Ibid., pp. 30-32.
118 “Search for Public Schools – School Detail for MC² STEM High School.” National Center for Education Statistics, Common Core of Data, 2012. http://nces.ed.gov/ccd/schoolsearch/school_detail.asp?Search=1&InstName=stem&State=39&SchoolType=1&SchoolType=2&SchoolType=3&SchoolType=4&SpecificSchTypes=all&IncGrade=1&LoGrade=1&HiGrade=1&ID=390437805476
121 Ibid.
summer learning session at Case Western Reserve University or the option to work with tutors from NASA or GE.

The school uses a pedagogical model embracing four key concepts—“Transdisciplinary Project-Based Learning, STEM Education, Community Partnerships, and Mastery Learning.”122 The school’s graduation requirements stipulate that each student must achieve mastery for all state standards, as well as satisfactorily complete two major projects, one in the sophomore year and one in the senior year. Students must complete 60 hours of either community service or STEM service to graduate. The school uses capstone projects to assess mastery of approximately 40 percent of the state standards, while “more traditional in-class methods such as quizzes and presentations” cover assessment for the remaining standards.123

**Transdisciplinary Capstone Projects**

The school’s instructional approach unites two of the best practices highlighted throughout this report—using project-based learning and making interdisciplinary connections—in a single pedagogical model: transdisciplinary capstone projects. Instructional delivery and assessment follow a unique year-round calendar, with 10-week sessions followed by three-week breaks. Traditional courses are integrated into project-based capstone units, which follow an overarching theme uniting multiple disciplines.

One example is the school’s “Bridges” capstone, in which “students learn about the mathematical and engineering concepts necessary to construct bridges, as well as the symbolic meaning of bridges in literature, history, and social studies.”124 Figure 4.2 demonstrates the contributions of each of the six participating disciplines to the Bridges capstone project.125 Other capstone topics include: Sustainability, Light, Communications, Health and Wellness, Community Action Plan, and DNA, Diversity, and Design.126

---

124 “Search for Public Schools – School Detail for MC² STEM High School.” National Center for Education Statistics, Common Core of Data, 2012. http://nces.ed.gov/ccd/schoolsearch/school_detail.asp?Search=1&InstName=stem&State=39&SchoolType=1&SchoolType=2&SchoolType=3&SchoolType=4&SpecificSchTypes=all&IncGrade=-1&LoGrade=-1&HiGrade=-1&ID=390437805476
MC² STEM High School uses the Understanding by Design approach to develop the interdisciplinary capstone projects, hosting weekly planning meetings and offering a weeklong Professional Development Institute (PDI) each year to bring teachers, school administrators, external partners, and students together to brainstorm, select, and plan the capstone options. In developing the capstone projects, the school not only considers the Common Core State Standards, but also engineering and technology career readiness standards. Industry partners help brainstorm potential projects and provide insight into how the state standards tie into their work, thereby assisting teachers in creating more authentic capstone units. Designing the Sophomore General Electric Project, for example, required input from GE Lighting representatives.

**Mastering-Based Assessment**

Mastery-based assessment tools include rubrics and grade cards jointly designed by teachers. These instruments gauge students’ mastery of the desired outcomes of the course.

---


128 Ibid.
in terms of specific knowledge and skills (i.e., “benchmarks”), with teachers assigning one of three grades for each of the identified benchmarks—an “M” to indicate mastery (i.e., competency at 90 percent or higher for grades 9-10 and 70 percent or higher for grades 11-12), an “I” to indicate the need for instructional support to achieve mastery, or a “0” to indicate failure to turn in an assignment. Students receive credit for the capstone only when they have mastered 100 percent of the identified benchmarks. Figure 4.3 presents one example of the assessment process, based on a single benchmark.129

---

**Figure 4.3: Mastery-Based Learning: Sample Assessment Rubric**

![Mastery-Based Learning: Sample Assessment Rubric](image)

Source: Metropolitan Cleveland Consortium for STEM High School

**PROJECT EVALUATION FORM**

Hanover Research is committed to providing a work product that meets or exceeds partner expectations. In keeping with that goal, we would like to hear your opinions regarding our reports. Feedback is critically important and serves as the strongest mechanism by which we tailor our research to your organization. When you have had a chance to evaluate this report, please take a moment to fill out the following questionnaire.


**CAVEAT**

The publisher and authors have used their best efforts in preparing this brief. The publisher and authors make no representations or warranties with respect to the accuracy or completeness of the contents of this brief and specifically disclaim any implied warranties of fitness for a particular purpose. There are no warranties which extend beyond the descriptions contained in this paragraph. No warranty may be created or extended by representatives of Hanover Research or its marketing materials. The accuracy and completeness of the information provided herein and the opinions stated herein are not guaranteed or warranted to produce any particular results, and the advice and strategies contained herein may not be suitable for every partner. Neither the publisher nor the authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages. Moreover, Hanover Research is not engaged in rendering legal, accounting, or other professional services. Partners requiring such services are advised to consult an appropriate professional.