Critical Components of Inclusive STEM-focused High Schools: A Cross Case Analysis
Curriculum and Instruction

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Author Note


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Critical Components of Inclusive STEM-focused High Schools: A Cross Case Analysis of ISHS Curriculum and Instruction

Introduction

In recent years, prominent organizations including the National Research Council (NRC, 2011, 2012), the President’s Council of Advisors on Science and Technology (PCAST, 2010), and the National Academy of Education (NAEd, 2009) have released large-scale policy reports on the state of science, technology, engineering, and mathematics (STEM) education in the United States. There has been a particular focus on matters related to STEM curricula and instructional practices, with a push for a broad re-examination of the American system of teaching the “familiar trinity of biology, chemistry, physics and, occasionally, earth science” (“Who says math has to be boring,” 2013). One recent notable effort to marshal STEM reform efforts was the NRC’s (2012) Framework for K-12 Science Education, which laid the foundation for states to lead the development of new K-12 science standards, called the Next Generation Science Standards (NGSS, 2013). These standards represent an attempt to better integrate science practices, crosscutting science concepts, and disciplinary core ideas across scientific disciplines to provide a stronger and more engaging foundation in science knowledge for students.

Recently published data in the 2012 National Survey of Science and Mathematics Education (Banilower et al., 2013) demonstrate the need for these curricular and instructional reform efforts. This large-scale survey funded by the National Science Foundation (NSF) and “designed to provide up-to-date information and to identify trends in … curriculum and instruction” (p. 1) involved a representative sample of K-12 science and mathematics teachers across the United States. These teachers provided descriptive information on the curricula and instructional practices implemented in their classrooms. Perhaps not surprisingly, data indicated that the traditional science domains of biology, chemistry, and physics remained entrenched as siloed disciplines in the majority of American high schools. Whereas 98% of high schools offered biology/life science courses, 94% offered chemistry courses, and 85% offered physics courses, only 68% of high schools offered “integrated science” courses, a number that is likely significantly inflated due to the inclusion of “general science” and “physical science” courses typically taken by students who do not intend to study science formally past high school (Banilower et al., 2013, pp. 54-55; NAEd, 2009).

Additionally, direct whole-class instruction by the teacher was the most commonly reported strategy in high schools, with 95 percent of both science and mathematics teachers using such activities at least once a week (Banilower et al., 2013, pp. 76, 81). By comparison, only 18 percent of science teachers employed project-based learning activities (p. 76). What was similarly rare for high school science and mathematics students was having the opportunity to attend presentations by guest speakers focused on science/engineering or mathematics in the real-world workplace. According to the survey, 51 percent of high school science teachers and 78 percent of high school mathematics teachers reported never using such activities in their classes (pp. 77, 82).

The desire for more interdisciplinary STEM curricula and reform-based STEM instructional practices is becoming increasingly tied to a push to increase the number of STEM-focused schools at all grade levels (NRC, 2011; PCAST, 2010). The hope is for such schools to experiment with and serve as testing grounds for innovative STEM curricula and instructional
approaches, rather than merely providing more instruction on advanced STEM concepts (PCAST, 2010). Such innovations could lead not just to increased student achievement, but also to enhanced student engagement in STEM for students from minority and high-poverty communities, leading to a broadened and more equitable participation in STEM majors and careers by student groups traditionally underrepresented in those fields (PCAST, see p. 111). This particular goal of broadening participation has stimulated the development of a particular kind of STEM-focused schools, the inclusive STEM-focused high school (NRC, 2011). These schools aim to bring the rigorous STEM curricula, increased STEM instructional time, increased resources for STEM education, and more prepared STEM teachers frequently seen in selective STEM schools to a broader student population.

**Purpose and Objectives**

This paper is part of a larger study called *Multiple Instrumental Case Studies of Inclusive STEM-Focused High Schools: Opportunity Structures for Preparation and Inspiration (OSPrI)* which explores the characteristics of a set of eight exemplary inclusive STEM-focused high schools (ISHS) across the United States. The intent of the OSPrI study is to develop rich, descriptive case studies of each ISHS under study, leading to an evidence base for identifying the critical components (described further in Table 1) of these schools (Lynch et al., 2012). The study also includes cross-case analyses to highlight the commonalities and explore the differences in these components across the ISHSs (Stake, 2006; Yin, 2003). Through this work, OSPrI aims to build an initial common theory of action for ISHSs (Chatterji, 2002), despite the many different ISHS models (Lynch et al., 2012). The study also acknowledges that the evidence may lead to multiple interpretations of school models.

Here, we present the findings from a cross-case analysis of the eight schools visited by the OSPrI research team: Manor New Tech High School (MNTH), Wayne School of Engineering (WSE), Denver School of Science and Technology: Stapleton High School (DSST), and Gary and Jerri-Ann Jacobs High Tech High (GJJ-HTH), Metro High School (Metro), Urban Science Academy (USA), Dozier-Libby Medical High School, (DLHS), and Chicago High School for the Agricultural Science (CHSAS). Specifically, this analysis focuses on the “STEM-Focused Curriculum” and “Reform Instructional Strategies and Project-Based Learning” critical components, which the OSPrI study (Lynch et al., 2012) defined as:

**STEM-Focused Curriculum.** Strong courses in all four STEM areas, or, engineering and technology are explicitly, intentionally integrated into STEM subjects and non-STEM subjects (Atkinson, Hugo, Lundgren, Shapiro & Thomas, 2007; Brody, 2006 as cited in Subotnik, Tai, Rickoff, & Almarode, 2010; Kaser, 2006 as cited in Means et al., 2008; Means et al., 2008; Rosenstock, 2008; Scott, 2009).

**Reform Instructional Strategies and Project-Based Learning.** STEM classes emphasize instructional practices/strategies informed by research found in Adding It Up (National Research Council [NRC], 2001), Taking Science to School, (NRC, 2007), Learning Science in Informal Environments (NRC, 2009), Restructuring Engineering Education: A Focus on Change (NSF, 1995), Fostering Learning in the Networked World (Borgman, Abelson, Dirks, Johnson, Koedinger, Linn & Szalay, 2008) for active teaching and learning (Lynch, 2008) and immersing students in STEM content, processes, habits of mind and skills (Atkinson et al., 2007; Means et al., 2008; Scott, 2009). Opportunities for project-based learning and student production are encouraged, during and beyond the school day. Students are productive and active in STEM learning, as measured by
performance-based assessment practices that have an authentic fit with STEM disciplines (Atkinson et al., 2007; Means et al., 2008; New Tech High, 2010; NRC, 2004, 2005, 2007, 2010; Rosenstock, 2008; Subotnik et al., 2010; Scott, 2009).

The objectives for this initial cross-case analysis are to synthesize the findings from eight OSPrI case studies of ISHSs with regard to their STEM curriculum and instructional strategies, in an effort to illuminate and explore similarities and differences in these schools. Specifically, the analysis examines what is taught in these schools: the range of STEM offerings, the rigors of those offerings, and the extent to which STEM permeates the school mission, informal activities, and non-STEM subjects. Furthermore, this paper describes how STEM is taught in the ISHSs: the range of instructional practices seen in these schools and the learning opportunities fostered through those strategies.

By way of examining STEM curriculum and instructional strategies, this analysis will reflect on the opportunity structures (Roberts, 1968) provided for the students of these schools, as they prepare for both for college readiness and preparation for careers beyond college. Ultimately, the aim is to identify the conditions crucial to the design and implementation of well-established inclusive STEM schools, to reveal valuable insights not just for other STEM-focused schools, but also for STEM education and pedagogy in all schools across the country.

In light of these objectives, the research questions addressed by this paper are:

1. What characteristics of STEM curriculum and instructional practices are common across eight ISHSs?
2. What distinguishing features or unique contextual characteristics of STEM curriculum and instructional practices exist across these schools?
3. What are the various contextual affordances and constraints that influence the design and implementation of STEM curriculum and instructional practices across these schools?

**Theoretical Framework**

The theoretical framework for the OSPrI study draws on the concept of *opportunity structures* first used by Kenneth Roberts (1968) in his studies of the conditions that might lead an adolescent towards criminal activity rather than a pathway to a productive career if certain positive avenues of development, such as educational opportunities, were blocked. The OSPrI study adapts this concept of opportunity structures to consider the full range of deliberate or inherent supports and guidance that ISHSs may employ to help students from groups underrepresented in STEM to move into STEM college majors, jobs, and careers, from which they might otherwise be blocked. With this theoretical framework as the foundation for the study, the OSPrI research team conducted a review of the literature on STEM schools to compile a set of candidate critical components that may work in conjunction to provide these opportunity structures for students. The ten critical components (Table 1) identified by the team represent working hypotheses for the basis of a theory of action for ISHSs, supported by the existing body of research on inclusive and selective STEM-focused high schools (Lynch, Behrend, Peters-Burton, & Means, 2012).

**Table 1**

<table>
<thead>
<tr>
<th>CC#</th>
<th>Title</th>
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<tbody>
<tr>
<td>1.</td>
<td>STEM-Focused Curriculum</td>
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<tr>
<td>2.</td>
<td>Reform Instructional Strategies and Project-Based Learning</td>
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<tr>
<td>3.</td>
<td>Integrated, Innovative Technology Use</td>
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</table>
4. Blended Formal/Informal Learning Beyond the Typical School Day, Week, or Year
5. Real-World STEM Partnerships
6. Early College-Level Coursework
7. Well-Prepared STEM Teaching Staff
8. Inclusive STEM Mission
9. Administrative Structure
10. Supports for Underrepresented Students

Among the ten candidate critical components, this paper focuses on the first two listed, STEM-focused curriculum and the use of reform instructional strategies and project-based learning. While the remaining components are seen as critical to effective STEM schools, the components of curriculum and instruction are most central to the goal of inclusive STEM high schools, that of preparing students for STEM related college and career preparation. Curriculum is critical since curriculum is the foundation of classroom instruction, and coherent curricula and standards are key indicators of successful K-12 STEM schools (Atkinson et al., 2007; Means et al., 2008; NRC, 2011; Rosenstock, 2008; Scott, 2009; Subotnik et al., 2010). Examining the prominence of STEM learning opportunities, then, is critical to understanding the potential impacts and distinctiveness of these STEM schools. Instruction is the second focus of this analysis, since effective STEM instruction has the ability to generate student interest in STEM and provides the gateway for authentic STEM experiences (NRC, 2011). Notably, the National Research Council (NRC, 2011) and the President’s Council of Advisors on Science and Technology (PCAST, 2010) both emphasize that effective STEM instruction aims to foster a deeper engagement with the sciences and mathematics domains by providing personal and team-oriented opportunities for students to be involved in real-world STEM practices, both within and beyond the classroom. This paper explores, then, the extent and variety of ways that STEM curriculum and instruction are present in eight case study ISHS schools.

Methods

Individual Case Studies

Schools in this study needed to meet three criteria: identify as a STEM-focused school, have open admissions that were not dependent on prior academic performance, and serve students in grades 9-12. The schools could use a random chance lottery if they had more interested students than available seats. A panel of experts in STEM education recommended 35 schools to the research team. Of these 35 schools, 18 were eliminated because they were not STEM focused or did not allow open-enrollment. Six of the schools were so new they did not yet serve 9-12 grades, and were eliminated as possibilities. Eight of the schools from the remaining 11 were selected for their geographic diversity and wide variety of educational models. The eight schools, which we have permission to identify are Manor New Tech High School in Texas (MNTH), Wayne School of Engineering in North Carolina (WSE), Denver School of Science and Technology: Stapleton High School in Colorado (DSST), Gary and Jerri-Ann Jacobs High Tech High in California (HTH), Metro Early College High School in Ohio (Metro), Urban Science Academy in Massachusetts (USA), Dozier-Libby Medical High School in Ohio (DLMHS) and Chicago High School for the Agricultural Sciences (CHSAS).

Before the visit, the research team conducted a document analysis of materials found on the internet such as admission applications, mission statements, and recruitment materials. The ISHSs chose a school-based coordinator (typically a lead teacher or vice principal) to be the main point of contact for the research team, who organized the research visit schedule and
distributed a pre-visit survey to the teachers. The school-based coordinator also participated in a three to four hour phone interview about the critical components at the ISHS. The information obtained during these interviews helped the researchers adapt the questions for the focus groups and interviews as well as support the website document analysis.

The visits to the ISHSs consisted of a four-day schedule for six researchers, who formed three teams of researcher pairs. The function of a pair of researchers attending the same event at a school was to gain two different perspectives of the interview or observation, but also for one researcher to be the observer/interviewer while the other researcher took careful notes that were as close to verbatim as possible. A sample schedule with the events for a ISHS visit can be found in Table 2.

Table 2
Data Collection Activities at Site Visit to MNTH (Lynch et al., 2013)

<table>
<thead>
<tr>
<th>Classroom observations</th>
<th>Non-STEM Classes</th>
</tr>
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<tbody>
<tr>
<td>Geometry</td>
<td>Spanish II A</td>
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<tr>
<td>Phylegebrics</td>
<td>ELA Humanities</td>
</tr>
<tr>
<td>Pre-Calculus/Science Research and Development</td>
<td>English/Economics</td>
</tr>
<tr>
<td>Biology</td>
<td>English 3/American History</td>
</tr>
<tr>
<td>Chemistry</td>
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<tr>
<td>Engineering class - solar cars</td>
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<tr>
<th>Focus Groups</th>
<th>Students/Parents</th>
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<tbody>
<tr>
<td>Teachers</td>
<td>12th Grade – Informal learning</td>
</tr>
<tr>
<td>Teachers of Engineering</td>
<td>11th grade – Science and Math</td>
</tr>
<tr>
<td>Teachers of Science</td>
<td>11th grade – Science and Math</td>
</tr>
<tr>
<td>Teachers of Informal learning</td>
<td>10th Grade – Technology and Engineering</td>
</tr>
<tr>
<td>Teachers of Technology</td>
<td>9th grade Parents</td>
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<table>
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<tr>
<th>Interviews</th>
<th>Non-School Personnel</th>
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<tr>
<td>School Personnel</td>
<td>Business Partners</td>
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<tr>
<td>Dean of Students</td>
<td>UTeach Representative</td>
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<tr>
<td>College Teachers</td>
<td>Samsung Representative</td>
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<tr>
<td>Principal – Partnerships</td>
<td>Alumni Interview</td>
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<tr>
<td>Teacher Mentor/Coach</td>
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<tr>
<th>Other Activities</th>
<th>During School Day</th>
<th>After School</th>
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<tbody>
<tr>
<td>School Tour</td>
<td>Key Club</td>
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<tr>
<td>Critical Friends</td>
<td>Robotics club</td>
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<tr>
<td>Circle time and Advisory</td>
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<tr>
<td>Other conversations —Technology</td>
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<tr>
<td>Student Astronomy Presentations Panel</td>
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CROSS CASE ANALYSIS OF ISHS CURRICULUM AND INSTRUCTION

Coding. The data collection activities before and during the site visit resulted in hundreds of pages of observation notes, near verbatim focus groups and interview notes, and school-related artifacts. These documents were read in their entirety for clarity and the audio recordings made during the focus groups and interviews were used to fill in the notes until they are verbatim. When all documents were cleaned and completed, the first open coding process was completed by one of the two researchers that attended each activity. Coding was both deductive, using the critical component definitions as a code book, and inductive, coding for any emerging themes that were deemed meaningful to the study. When the first researcher completed the coding process, the coded documents were passed on to the other researcher who was in attendance for that particular activity, to review the codes, adding and changing codes when necessary. The two partners discussed the codes until there was consensus with all coding for the document. The codes and documents were then placed into the software, NVivo, and reports were run for each critical component. The emerging themes were developed by placing all codes not directly referring to a critical component into an excel file. The entire research team reviewed all the emergent codes and grouped them into themes.

Each person on the six member visiting research team wrote one or two critical components into narrative form, working from the NVivo reports of all site visit data coded relevant to that code. A lead author then compiled the critical component narratives into a full case study report. The final case study report was reviewed and edited by the full site visit team, and reviewed by the school.

Cross Case Analysis

The analysis examines what is taught in these schools and how STEM is taught in the ISHSs. For the purpose of this paper, eight case studies were used for a Type 1 (Stake, 2006) cross-case analysis. In this analysis, the cases (often 75 single-spaced pages long) were treated as the data source. The cases were organized by critical components, and the relevant sections on the critical components were read in their entirety to gain a sense of the school characteristics across the eight ISHSs. The text of the critical components was open coded for any meaningful statements with no codebook used for this process. The codes were then compiled into a conjecture matrix with notations regarding the relevant ISHS extent of identification. Originally there were 35 categories in the conjecture matrix, and similar codes were collapsed into 23 broader categories that represented the major ideas of the codes. Example codes include “Increased responsibility for learning,” “Non-traditional schedule,” and “Engineering requirements.” The categories were organized into themes, and the themes were developed narratively in the paragraphs of the cross-case analysis. The narrative was member checked with the authors of the original case study and adjusted to represent consensus of understanding among all authors.

Findings

Curriculum

The eight ISHSs in this study were found to have more rigorous requirements for graduation than those designated by the state in which they were located. Typically the ISHSs expected students to take at least one more science and one more mathematics class, and as a result, students at ISHSs took more academically challenging courses than their peers at comprehensive schools. Five of the eight ISHSs have at least one required engineering courses, MNTH and WSE require two. Also, typical to the ISHSs in this study was the curricular strategy that all students took the same classes and were expected to master the material before moving on to another course. The ISHSs had educational models where students could re-learn material
until they mastered it, for example, at a 70% achievement level. This structure was purposeful; the schools deliberately set up these requirements so that all students experienced the same rigorous coursework in preparation for either college or some form of post-secondary education for a career path.

Although most all students in each grade took the same courses as a cohort throughout their high school careers, the ISHSs were able to individualize instruction by offering honors credit within a course if a student requested the higher academic level and worked to meet those higher goals. An example of extra work done to complete an honors level course was to pursue, with teacher support, the preparation for the Advanced Placement (AP) exam for the subject area. GJJ-HTH’s honor classes were so rigorous, they were recognized by the state as being equivalent to the AP level. Five of the eight schools in this cross case analysis did not offer AP courses for a variety of reasons. MNTH, GJJ-HTH, Metro and CHSAS did not offer AP classes because the type of learning required in the courses to prepare for the AP tests were not compatible with their educational models (mastery learning and problem-based learning). WSE did not offer AP courses because a nearby early college school offered them, and the district felt that both schools should have different missions to serve the needs of all students. DSST, USA and MHS did offer AP courses in approximately seven subjects per year. Certainly, the fact that the ISHSs were small schools, averaging 100 students per grade level, also fit with the approach of these schools to offer a smaller set of courses than typically offered at comprehensive schools.

Textbooks were not widely used in most of the ISHSs. Rather the teachers taught students to be consumers of reliable digital resources. This had the potential to create challenges for students who had problem-based learning experiences in high school and then experienced traditional lecture and recitation in college, where success is dependent on note taking skills from lecture and textbooks. However, alumni of ISHSs reported that the lessons they learned in high school allowed them to adapt to more traditional settings in college because the high level of student responsibility for learning taught them to seek help and learn independently.

**Non-traditional school schedules.** The ISHSs were able to accommodate opportunities not commonly found in high schools, such as supporting community college coursework, integrating subjects across content, providing systematic faculty-wide professional development, facilitating team teaching, offering internships and project based learning experiences, by developing flexible school schedules. For example, MNTH students did not attend classes on Mondays until the afternoon, giving teachers times to plan together and evaluate each other’s work. Students were to pursue internships or work on culminating projects during this time out of class. Similarly, WSE moved to a semester schedule with double-blocked classes, so that students could take advantage of courses at the local community college that were offered in compatible time blocks as their high school classes. Students at WSE would take a mixture of college-based courses and high-school based courses each semester, checking in and out of the building as necessary. At GJJ-HTH, teachers who worked together to integrate their courses sometimes team-taught and sometimes taught separately, depending on the needs of the students. At six of the ISHSs, college professors from 2-year or 4-year colleges came to teach at least one class for dual credit. This process gave students a scaffolded college experience, which later led to increased self-efficacy for passing a college-level course.

**Content integration.** Six of the eight schools offered more traditional class structures at the 9th and 10th grades, which led to successful integration across subjects in 11th and 12th grades, and several of these schools integrated through a themed approach, such as agriculture or medicine. The other two schools, HTH and MNTH, utilized problem-based learning through the
year and the curriculum and integration of topics could change from year to year, given the inclinations of the teachers. Often, STEM and humanities classes were integrated at these schools, and STEM disciplines were often integrated as well. An example project from HTH involved the integration of 9th grade physics and humanities, resulting in students creating a social theory about the rise and fall of civilizations, and then designing a literal representation of this theory as a gear-driven moving model using principles learned in their physics class.

The curriculum was developed by the teachers in all of the ISHSs in this study, and the teachers began with the standards required by each of their states. Teachers reported that there were no difficulties addressing all state standards through project-based learning during a school year. At GJJ-HTH and MNTH, the curriculum and integration of topics could change from year to year, given the inclinations of the teachers. Often, STEM and humanities classes were integrated at these schools, and STEM disciplines were often integrated as well. In classes, using a project-based approach was combined with multiple disciplines; for example, biology and engineering students at GJJ-HTH produced prototypes of museum displays for biological processes, such as the distribution of mold spores, which were selected by museum professionals for scale-up and display at the local science museum. Another example at GJJ-HTH involved the integration of 9th grade physics and humanities, resulting in students creating a social theory about the rise and fall of civilizations, and then designing a literal representation of this theory as a gear-driven moving model using principles learned in their physics class.

One notable exception to the integration of subject matter at ISHSs was mathematics. At GJJ-HTH, mathematics was at one time integrated into other subjects, but the administrators and teachers felt that by fully integrating mathematics, they were not challenging students with the rigor that mathematics could offer separately. Therefore, GJJ-HTH taught mathematics separately, while all other courses remain integrated. It was reported at DLMHS that chemistry and mathematics was most difficult to integrate into the other subjects. At MNTH, WSE, and DSST, mathematics was the subject for which students were the least prepared as 9th graders. School administrators and teachers worked together to support students in their mathematics classes, often by scheduling two mathematics classes at a time, to help students gain the knowledge they needed. Schools all reported that all other levels of academic coursework were determined by the mathematics level of the students. By the time students graduated, the highest level of mathematics students took for graduation included: MNTH, AHS, DSST, MHS and USA – Pre-calculus; HTH and Metro – Calculus; WSE – Calculus or Statistics (depending on the community college course choice). Two of the schools, WSE and DSST, opened feeder middle schools as a strategy to raise this level of math achievement, so students were better prepared to enter the ISHS at a higher mathematics level and to gain some experience with taking on the responsibilities of long-term projects and working collaboratively on teams.

**Engineering and Technology classes.** Five of the eight of the ISHSs in this study required that students take engineering to graduate. At GJJ-HTH, the idea of design was woven into all of the projects throughout the classes, and students were required to take one Engineering Design course. At DSST, students took a required course freshman year in Creative Design and an optional senior course in Advanced Engineering. At MNTH, there was a required sequence of engineering classes beginning with Introduction to Engineering, followed by Principles of Engineering, and an elective course in Digital Electronics or participation in a robust Robotics Club. At WSE, students were taught at the high school by community college instructors in AutoCAD I, II, III and Hydraulics. The purpose behind the college instructors at the high school level was to forge relationships so that students continue to pursue engineering at the community
Technology was a large piece of school life at ISHSs, and it was typically used as an information resource, communication tool, or presentation instrument. Technology courses were offered at all eight ISHSs. For example, GJJ-HTH – two years of Multimedia Production; MNTH – two years of electives chosen from Theatre/Digital Media Literacy, Digital Animation, Applied Video Game Design, Programing, Web Serial, and Marketing/PIT/DML/Basic Programming; WSE - a variety of technology classes were offered through the partnership with the local community college; DSST – one year computer science elective.

**Instruction**

Collaborative group projects were a hallmark of instruction at all eight ISHSs, supported through teacher training and selection. At GJJ-HTH, all instructional time was devoted to project-based learning, except for mathematics which had short-term projects that punctuated the direct instruction and problem solving lessons. GJJ-HTH was affiliated with a graduate-level teacher preparation program where many of the teachers were also teacher educators in project-based learning. The teachers at GJJ-HTH were mainly hired from the pool of graduates of this teacher preparation program. At MNTH, problem-based learning was the pervasive educational model, and all teachers were trained systematically to be adept that this type of instruction. At WSE, students had some instructional time devoted to short-term projects where teachers organized students to work in groups at least four times per year. DSST had a unique way of teaching about learning through collaborative group projects where freshmen and sophomore classes were taught through mainly direct instruction and problem solving. However, teachers gradually introduced students to working collaboratively in groups during their junior and senior years. Metro designed authentic collaborative experiential learning in their medical-themed instruction, such as participating in making rounds with doctors, interns, and residents. Although about half of the schools visited employed problem-based learning consistently throughout the year, surprisingly the other half maintained traditional instructional methods for their younger students and then gradually moved them to more student-centered learning techniques.

**Culminating experiences for students.** All eight ISHSs had culminating experiences at the end, some with culminating experiences across all four years. GJJ-HTH and DLMHS students produced a cumulative digital portfolio, which was presented at a year-end celebration including parents, teachers, school partners, and the community at large. At MNTH, students moved from project-based learning in their freshman and sophomore years to challenge-based learning in their junior and senior years, which was more cognitively challenging. At WSE, USA, Metro, DLMHS, and CHSAS students completed community-service and career exploration projects each year outside of class. DSST students were required to do a month-long internship during their junior year and an applied research project during their senior year. The culminating projects at all schools were presented to a wider audience than
the teachers, which was both motivating and providing authentic feedback to the students about STEM careers and 21st Century Skills. With each new project, additional challenge and depth was required, building in increased student responsibility for learning.

**Data-driven decision making.** Student performance data was used by all eight schools to inform instruction. As an example, MNTH staff regularly met and discussed the achievements and challenges of individual students. MNTH also frequently implemented math achievement tests, moving students among math classes fluidly among math classes depending on their learning needs for that week or month. At WSE, the school leader regularly reviews every student’s report card each semester, and students report both the school leader and the school counselor know about their performance at any given time. Using multiple sources of information such as test scores, project outcomes, and teacher feedback to inform what was working well and what needed to change, the four ISHSs used data to personalize classroom instruction, identify students for additional supports, and establish classes or support structures as needed.

**Implications**

Across the eight school case studies considered in this analysis, the STEM curriculum and instruction were examined. Four common themes arise regarding these components from the case study schools designed to provide rigorous STEM related college and career preparation for students underrepresented in STEM fields. While each school is unique in design, culture and its own constellation of resources, there were similar approaches to the shared goal of STEM success for students.

First, the mission of preparing students for STEM college majors and careers requires rigorous preparation. At the eight ISHSs under study, this resulted in unique and additional challenges for students. The schools had graduation requirements higher than those specified by the state, students were often expected to work toward mastery of STEM concepts (rather than simply a completion of assignments), and culminating experiences were used to help students ritualistically capstone their experiences as they move to the next grade or level.

Second, all eight schools faced challenges with mathematics. Not only did students enter with low levels of math readiness, but the ISHSs shared the goal of graduating students prepared for demanding studies of mathematics and STEM subjects in higher education or post-secondary training – beyond levels to which typical comprehensive high schools aspire. The four schools addressed this challenge in different ways, including double-block classes, innovative instructional methods, and connecting math to engineering and robotics experiences. What they held in common was using creative approaches as they worked to help students reach these high goals.

Third, the schools in this study used innovative instructional approaches. By encouraging and supporting teachers to use project-based learning, collaborative student groupings, and relying on more information gathering than textbooks, these schools provided learning environments where students were expected to play an active role in their learning. The schools also found ways to combine classes and support students as they explored the STEM disciplines as integrated, rather than siloed, sets of constructs and skills.

Finally, the eight ISHS schools in this study were small and nimble. They used flexible scheduling strategies to find the most effective ways of presenting material. They used multiple sources of data to frequently check on student progress, and they used this data to hone in on student and school needs. The schools took adaptive and inventive points of view, since their
guiding goal was not to preserve standard high school structures and practices, but to do as much as possible to provide rigorous STEM-related college and career preparation for all students.

As discussed in Subotnik and Tai (2011), students in selective STEM high schools who had research experiences, an internship and whose teachers integrated STEM were more likely to complete a STEM major. ISHSs are likely to provide STEM experiences through curriculum and instruction that position students for success in college. ISHSs offered rigorous STEM experiences that build social capital leading to citizens that are STEM-literate and have 21\textsuperscript{st} Century skills even if their graduates do not pursue STEM fields as much as selective STEM high schools.

Several national organizations including PCAST (2010) and the National Research Council (2011) have called for more research on all types of STEM schools: selective, inclusive, and CTE. The results of this cross case analysis contribute to the much needed literature on the critical components of inclusive STEM high schools. The analysis and synthesis of the types of cohesive curriculum in STEM schools done in this work provides researchers a baseline from which to develop further study, and delivers information to policy makers to streamline efforts for future STEM efforts.
References


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