STEM
DESIGN GUIDELINES

OFFICE OF THE STATE SUPERINTENDENT OF EDUCATION
Charter School Incubator Initiative

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DESIGN GUIDELINES FOR **STEM** ENVIRONMENTS

JUNE 2015

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STEM:
WHAT IS IT?

PEDAGOGY AND TEACHING STRATEGIES

As innovation in technology and the sciences has continued to lead our economy, attention has increasingly been focused on the science and math curricula as keys to preparing the next generation of innovation leaders. STEM, an acronym for Science Technology Engineering and Mathematics, is an interdisciplinary curriculum created to reveal and utilize the connections between related disciplines, regardless of grade level. Specific learning activities may be as varied as the sciences themselves, but STEM students approach every topic from multiple points of view and are exposed to a range of informative perspectives. As the STEM curriculum has developed, it increasingly relies on inquiry and collaborative problem solving as pedagogical tools. STEM provides a model for active, student-centered learning, focused on real-world problems in a collaborative setting, engaging content from multiple disciplines.

CHARACTERISTICS OF STEM PROGRAMS

The most successful STEM programs are student-centered and project-based. They may vary in scale and ambition, but they share certain characteristics that inform their spatial organization:

CONNECTED. By their nature, interdisciplinary programs thrive on connections between activities. Effortless connections between the disciplines promote productive collaboration and cross-pollination of ideas – both student's and teacher's. Through digital communication, connections can extend beyond the individual school and engage the world of knowledge.

TRANSPARENT. As learning activities expand beyond the classroom, they become a source of information and inspiration to others, even those not directly engaged with them. Students learn by exposure to one another's work, and from the environment around them, at all times of the day. Every aspect of the learning environment can be available to instruct, demonstrate, and inspire.

ACTIVE. When learning moves off of the page and into the real space of the school, more time is allotted for trying, designing, making, and doing – leading to deeper understanding. To balance the resource and material-intensive facilities required for science and engineering, multifunctional spaces that can be readily adapted and reconfigured are essential to promote active engagement at different scales.

The design of a STEM learning environment should certainly support this broad range of features and accommodate its tendency to be messy and noisy as well. An effective STEM space will be designed for practical, experiential, and student-directed learning, and these experiences may not be as repetitive or predictable as they are in a conventional classroom. Instead, they will be more creative, interactive, and social, extending beyond "class-time" to engage informal social activity.

In the following pages we consider the basic activities and structure of a project-based STEM program at the scale of an integrated STEM suite. We describe the various spaces that best support those activities and identify precedents for these spaces. We also consider implications for the learning environment beyond the STEM suite. In subsequent sections, we illustrate a prototypical design supporting one model through a case study for Washington, DC's National Collegiate Prep Public Charter School.

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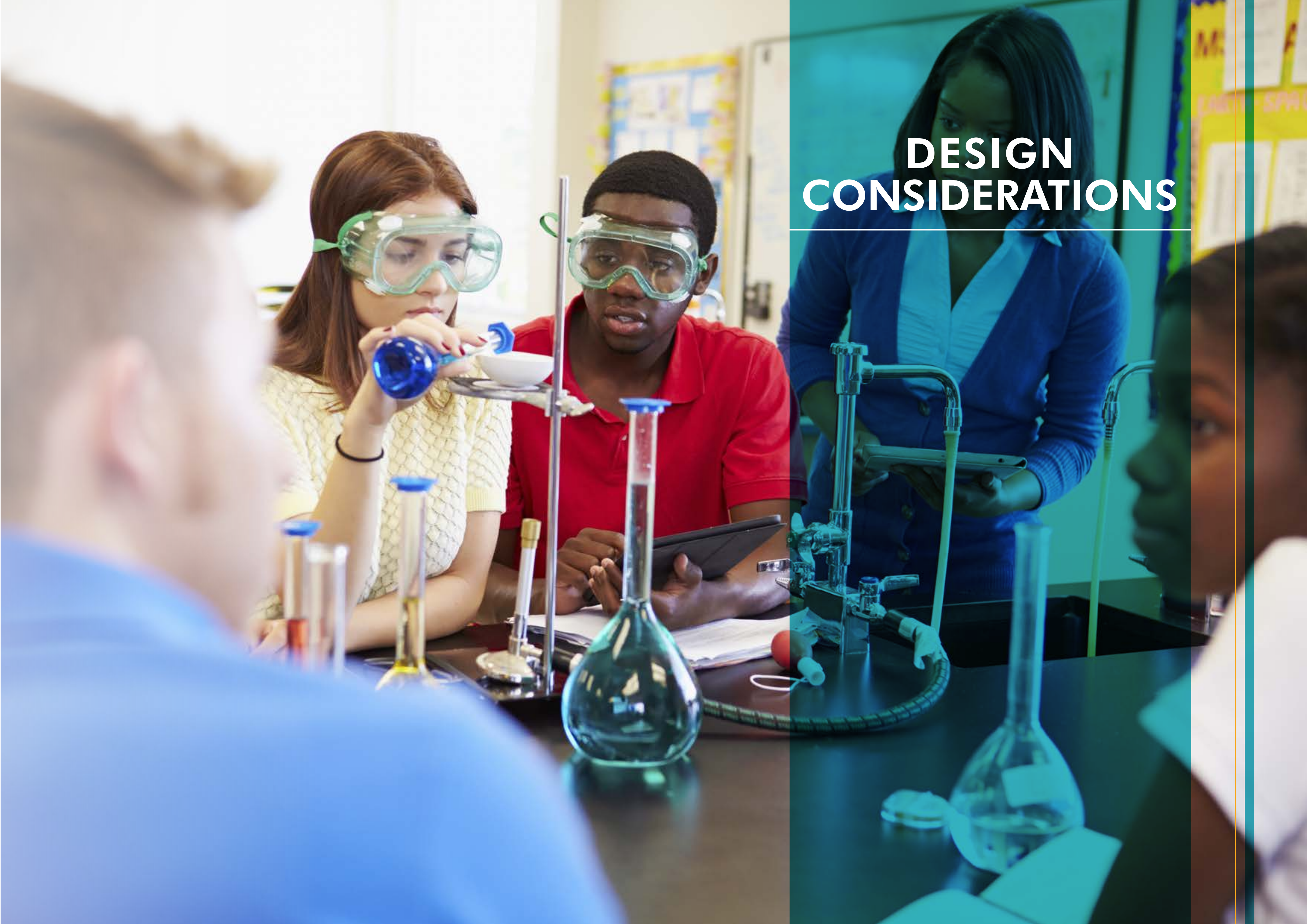
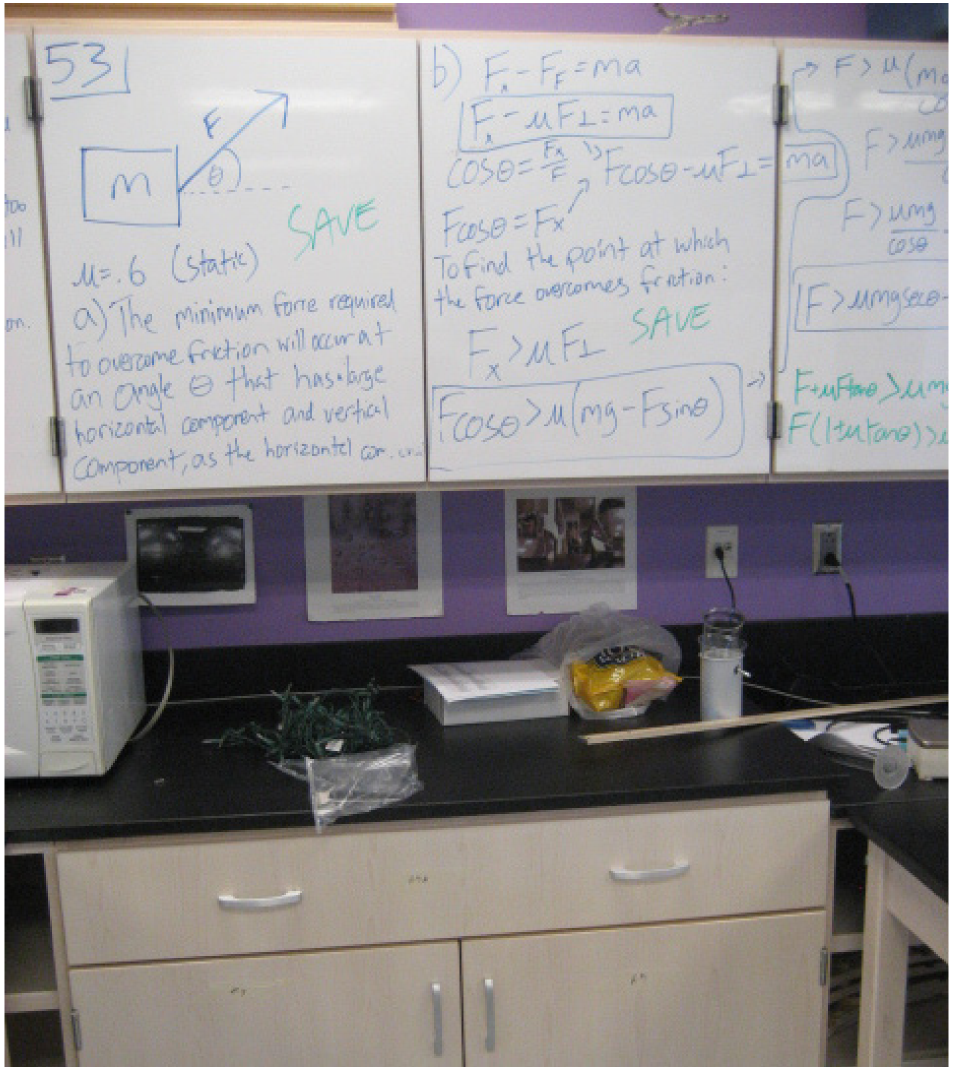


DESIGN CONSIDERATIONS

DESIGN CONSIDERATIONS

ACTIVITIES – PLANNING, DESIGNING, MAKING, TESTING

While some of the activities of a STEM program, such as discussion groups and seminars, fit comfortably in the traditional classroom, longer-term projects tend to displace other activities. Supporting team projects with sufficient workspace, storage, resources, and tools is critical to provide the flexibility needed to develop, test, and display long-term projects. Collaboration is an essential component of an interdisciplinary project and each phase of the project requires different resources and modes of interaction.



PLANNING

Flexible Seminar Rooms provide an adaptable space where whole classes of 25 or more can participate in seminars and demonstrations or can break into small groups for planning and research. Team Meeting Rooms can de designed more specifically for group discussions, brainstorming, or rehearsing presentations.

DESIGNING

Digital Labs contain the resources needed to design and document project ideas before fabrication or prototyping begins. Digital tools usually replace hand drafting, but when STEM is combined with an Arts program (STEAM), the design crafts are equally valuable.

MAKING

Maker Spaces with a range of tools and equipment for fabricating and refining prototypes and creating finished products are at the heart of an active STEM program. They will vary with the character of the projects and content of the curriculum, supporting anything from aerodynamics to robotics. Adequate space for storage and fabrication are critical, as is the flexibility to move large pieces and equipment.

TESTING

Galleries and Commons are ideal places for students to test their ideas, demonstrate their achievements, and interact productively with their peers. These are casual, loosely programmed spaces that create interdisciplinary connections and opportunities to host public events.

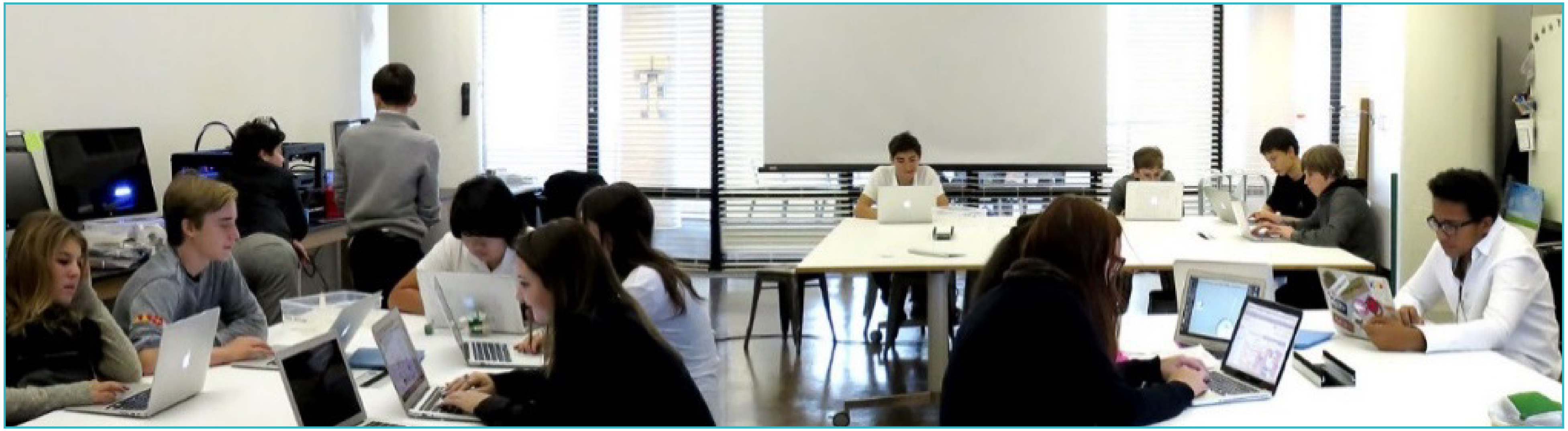
DIGITAL TECHNOLOGY

INTERACTIVE, ADAPTABLE, SHARED

Increasingly robust access to digital media and digital tools provides the opportunity for cooperative problem-solving, creation of digital content, and real-time data sharing and editing. Technology will continue to be more portable, more powerful, and easier to share.

For STEM learning environments, models of collaborative teaming, like gaming and messaging, are made practical by the convenience of technology and creative educators are embracing these models and integrating them into the curriculum.

The infrastructure to support varied activities can be as flexible as the technology itself. As a result, digital tools can be used in almost any setting without sacrificing agility. Adapting the seminar room from lecture to discussion to teaming and back to lecture provides ready flexibility if the infrastructure has been planned to accommodate multiple functions.

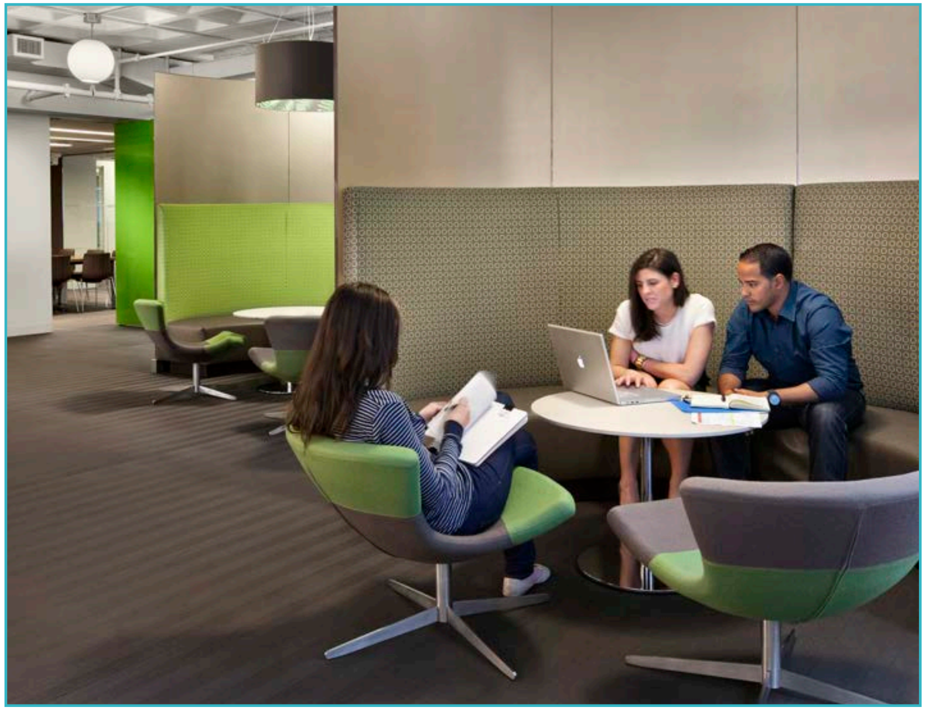


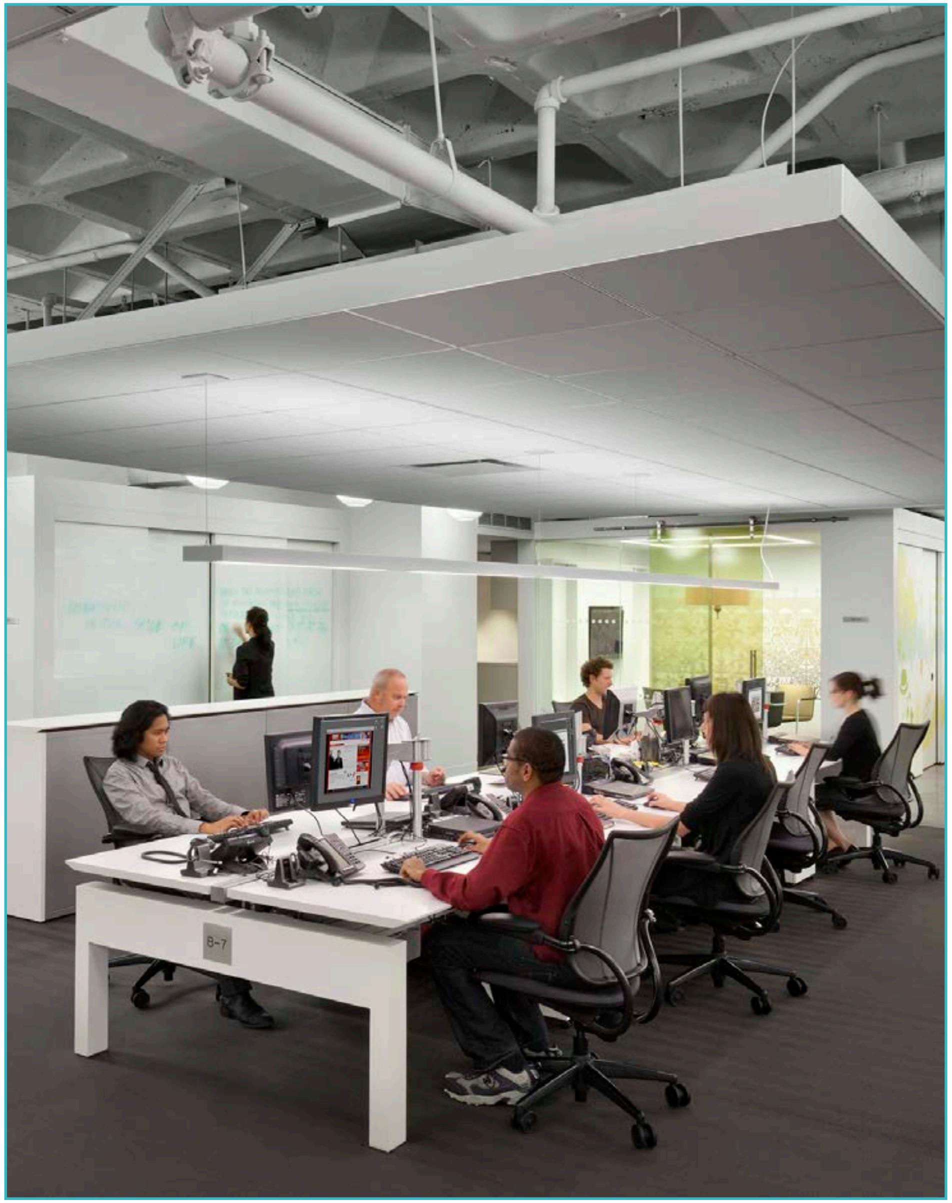
FURNITURE

VERSATILE, DURABLE, ERGONOMIC

The success of both planning studios and STEM labs will depend to some extent on the furniture and furnishings. Dedicated collaboration workspaces may be purpose-built systems with integrated display panels and data connections to allow groups to share their work, but a continuous, floor-to-ceiling white board surrounded by soft seating is a low-tech option that can work just as well.

Individual desks arranged into groups are nothing new, but efficient shapes designed for combinations that promote face-to-face interaction and continuous work surfaces make collaboration natural.

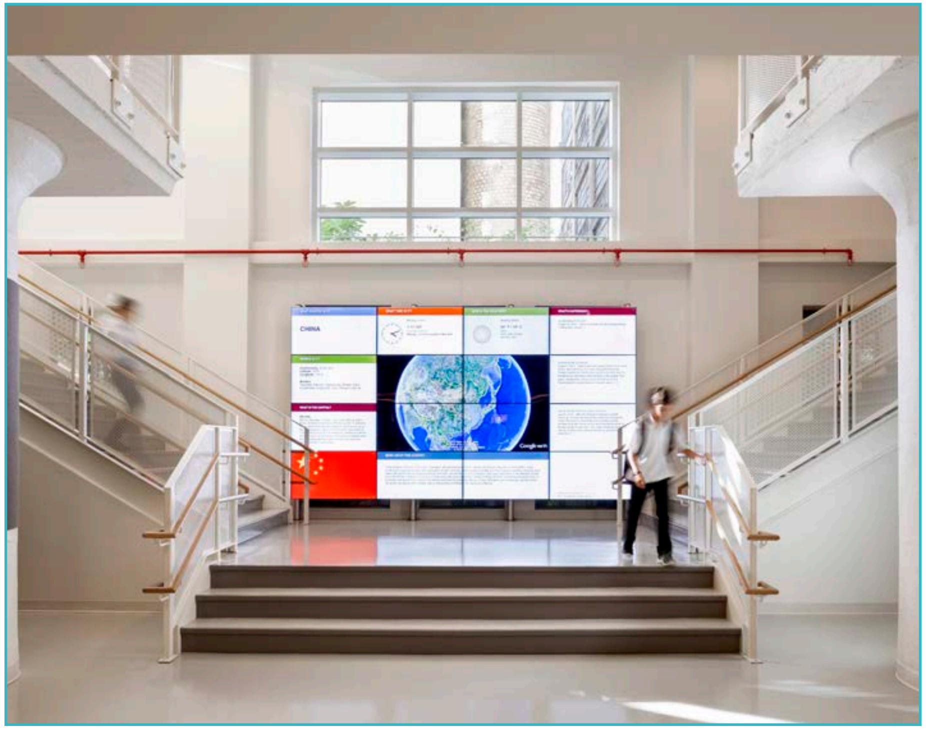


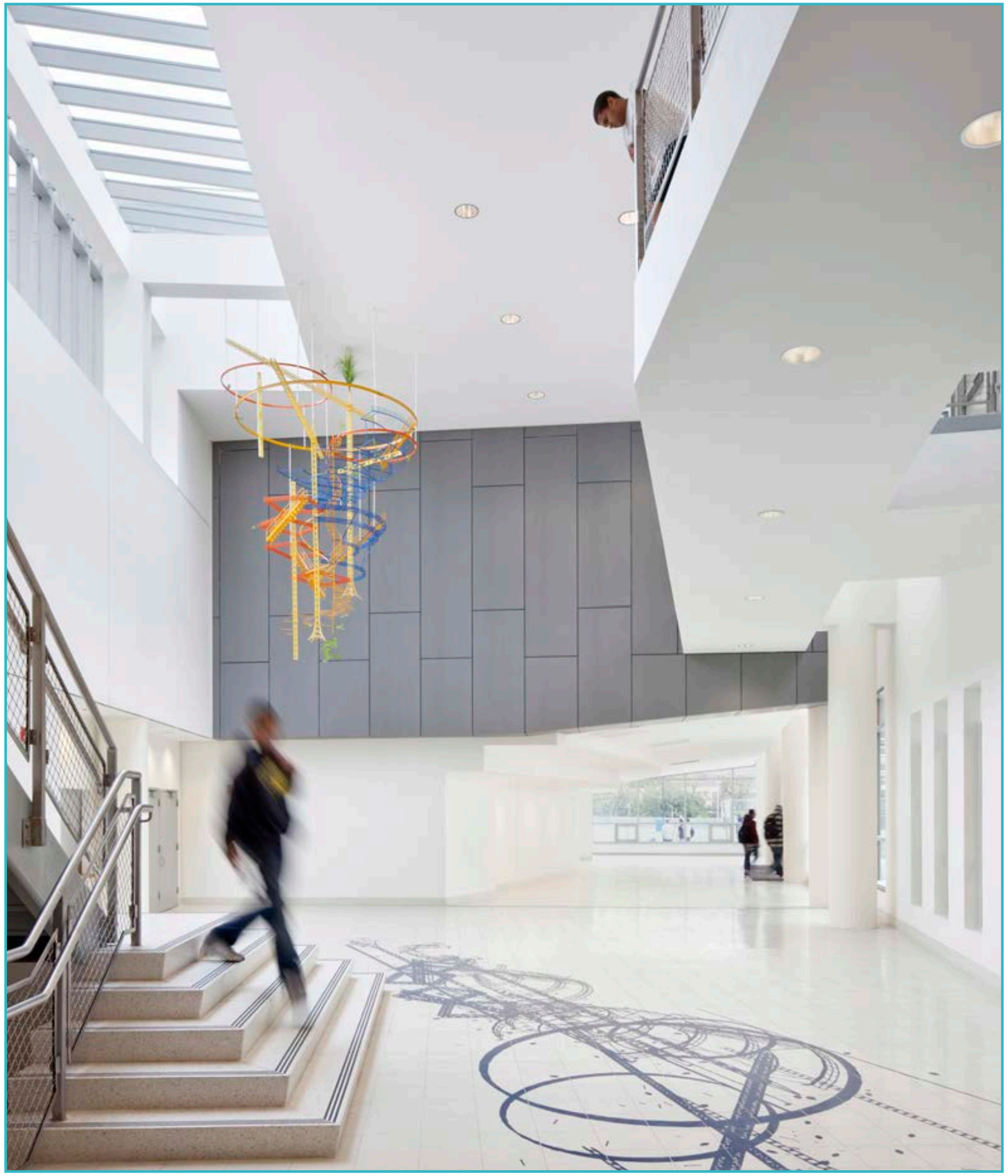


IDENTITY

CASUAL, COMFORTABLE, CREATIVE

Interdisciplinary STEM learning environments tend to acquire a distinct identity as practical, experiential spaces at the heart of a community of learners. By their nature, they are casually structured, even "messy" and appealing to students. To maximize their utilization, they should be effortlessly adaptable, with every surface an opportunity to share ideas and any moment an opportunity to see new connections. To maximize their vitality, they should expose great learning as it happens, as well as provide display spaces that inspire and exhibit the full range of creative possibilities that every learner possesses.





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SPACE TYPOLOGIES

PLANNING SPACES

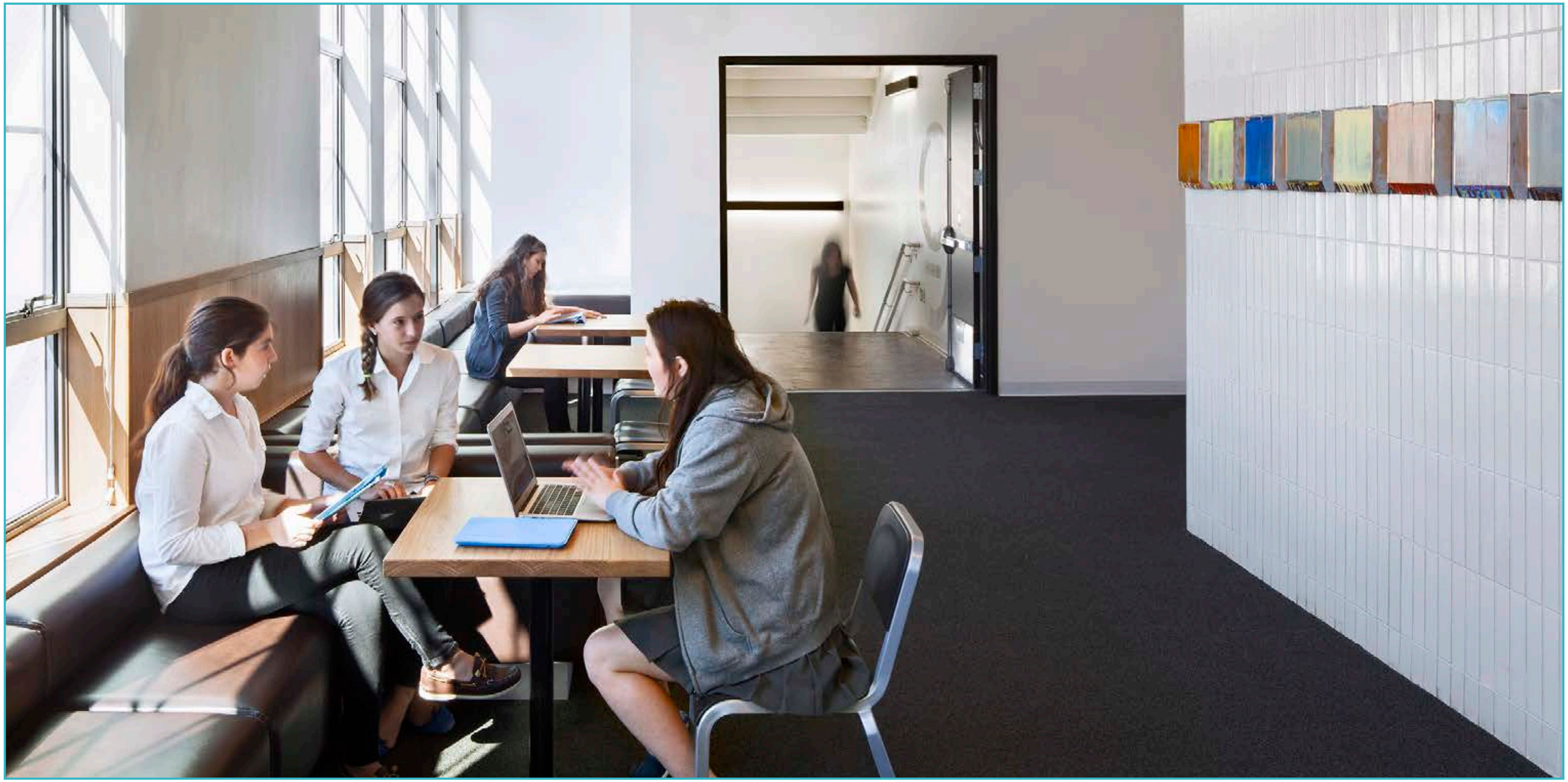
The core content of a STEM curriculum begins with planning and collaboration. At any given time, STEM planning spaces may need to accommodate several small, independent discussion groups, a handful of individual researchers, a single teacher working with one or two students, or all of these at once. Ideally, planning studios will be supplemented by a number of common collaboration spaces of various sizes. Smaller, more intimate spaces are suitable for groups that can work independently. Larger spaces should be designed so that smaller zones or sub-spaces can be formed within them without architecturally subdividing them.

SEMINAR ROOMS

Flexible Seminar Rooms provide an adaptable space where whole classes of 25 or more can participate in seminars and demonstrations or can break into small groups for planning and research. Rather than a single focal point or primary teaching wall, all surfaces can potentially be used as a tapestry of ideas and resources. Even the teacher takes on a peripheral role as a resource and guide.

BREAKOUT SPACE

Breakout spaces are hybrid, informally programmed spaces that can be used to tinker, brainstorm, consult, modify, or simply observe and learn. Located adjacent to the primary planning and designing spaces, they effectively expand the space available for project planning.



DESIGNING SPACES

STEM students actively apply content knowledge to authentic projects. In these projects, the outcome is not predetermined but will depend on the students' creativity in applying the classroom content. Design is an opportunity to collaborate with others to refine ideas and to engage creatively with the content while learning technical production skills.

DIGITAL LAB

Digital Labs contain the resources needed to design and document project ideas before physical fabrication or prototyping begins. But not all projects will have a physical product. When the final product is digital media content, digital labs provide the tools for content creation and production.

MAKER SPACES

Testing ideas with rapid prototyping and risking failure is the heart of the STEM learning experience. Hands-on fabrication is an application of knowledge and craft, and an investment in time and resources that demonstrates the value of every idea, particularly students' ideas. Fabrication engages students that might otherwise struggle with abstract ideas.

PROJECT LAB

Activities in the Project Lab can range from layout of templates and patterns to light assembly and hand finishing, each of which requires a different level of environmental cleanliness. It is important to plan for secure storage of long-term projects so that time-consuming set-up and breakdown tasks can be minimized.

WORKSHOP

Heavier machinery and high powered tools are located in the Workshop, where their use can be closely supervised and directed. Adequate ventilation, lighting, and space for maneuvering large objects is essential for safety.

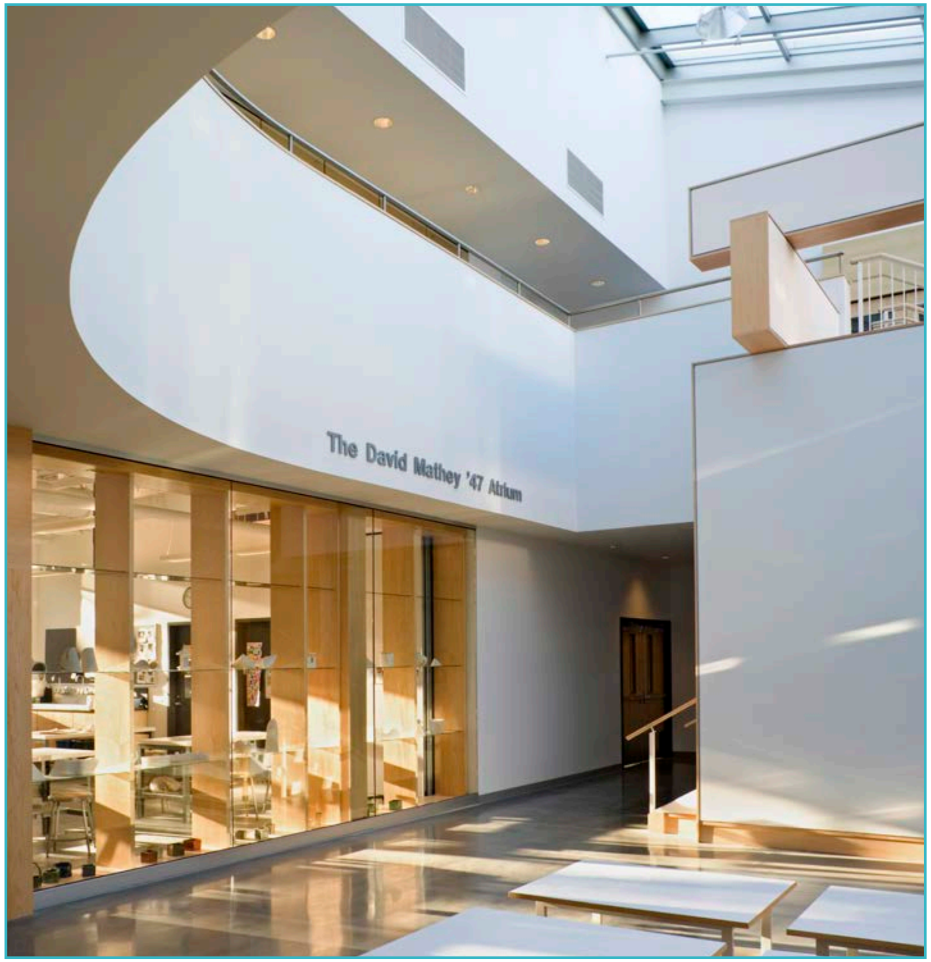
TESTING/PRESENTATION SPACES

Demonstrations or presentations by the students aren't just an optional formality. For STEM projects to rise to the level of authenticity that inspires dedication and pride, they must be tested publicly, with the prospect of risk and reward. The best presentation spaces are integrally connected to the life of the school, convenient, and visible from the major public circulation paths. This transparency and visibility fosters interest and pride in the pursuit of active, creative learning.

NuVu The Innovation School
Cambridge, Massachusetts

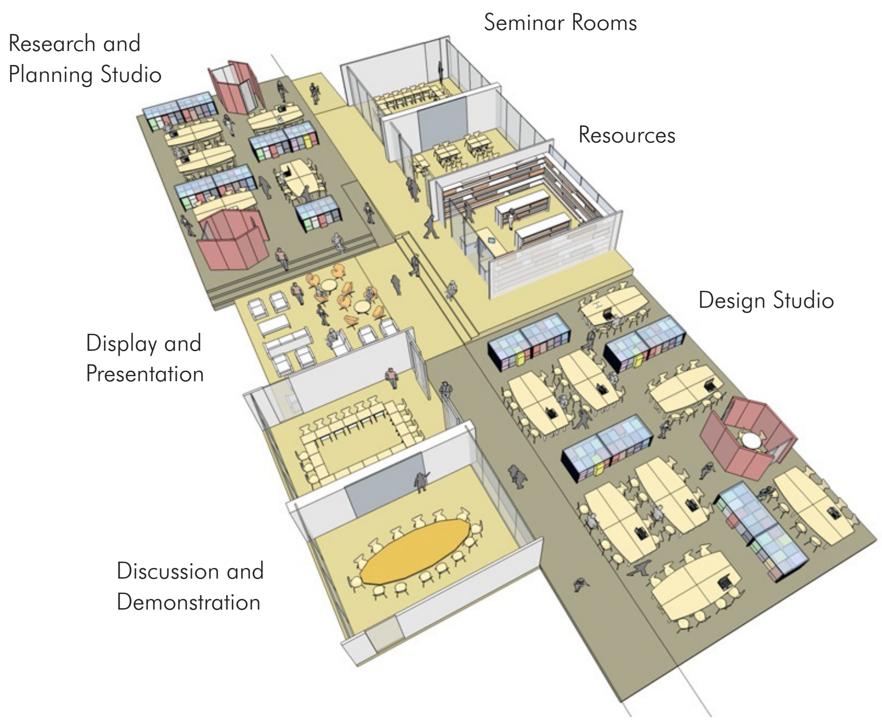
COMMONS

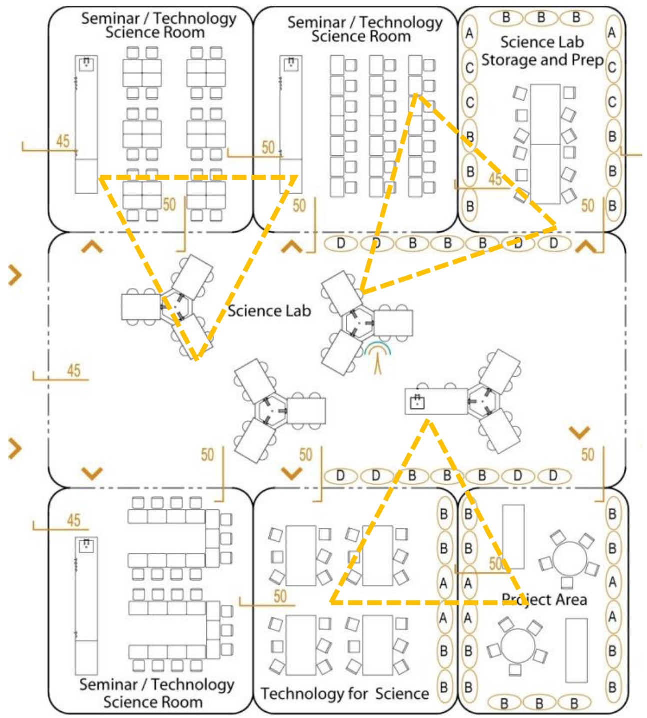
Central to the STEM suite, the Commons provides a flexible space for multiple uses throughout the year, most notably as a demonstration space and testing ground for prototypes, but also as social and communal space at all times.



STEM SUITES

The interdisciplinary character of the STEM program requires close proximity of the constituent elements. When adapting an existing space, this can be achieved simply by locating seminar rooms and design labs near the prototyping and fabrication workshops. When circumstances allow greater flexibility, intentionally designed STEM Suites with interconnected common spaces at a variety of scales offer several advantages. An environment that promotes chance interactions, transparency and opportunities for casual exchange of ideas, exposes students to a broader range of influences and inspiration. Research confirms that this exposure to variety improves problem-solving. A well-designed suite can also be more efficient. Through careful analysis of space utilization and scheduling, redundant lab or classroom spaces can be eliminated, and change-over times between activities reduced.





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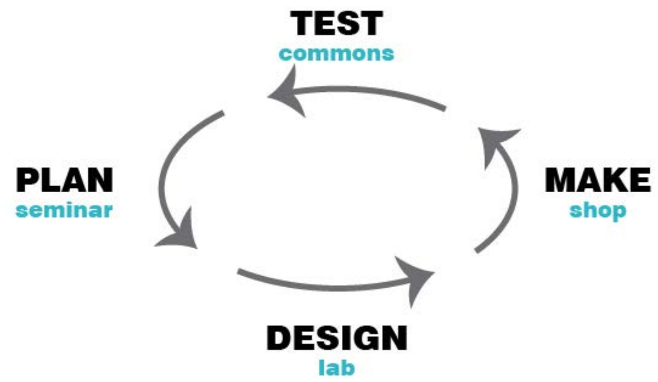
CASE STUDY


The American Embassy School
MS/HS Library Resource
FALSE PRINCE

CASE STUDY:
NATIONAL COLLEGIATE PREP PUBLIC CHARTER SCHOOL

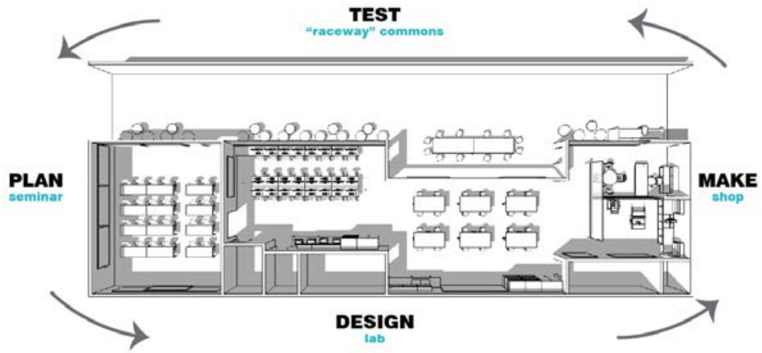


Currently serving students in the 9th through 12th grades, National Collegiate Prep Public Charter School is located in the Charter School Incubator at the PR Harris Education Center in Southeast Washington, DC. Its mission is threefold:

- To provide a rigorous 9th-12th grade, standards-based college preparatory curriculum to maximize students' academic achievement.
- To provide an interdisciplinary curriculum which integrates international studies themes across the academic curriculum leading to an International Baccalaureate (IB) Diploma.
- To prepare students to be self-directed, life-long learners equipped to be engaged citizens of their school, community, country, and world.

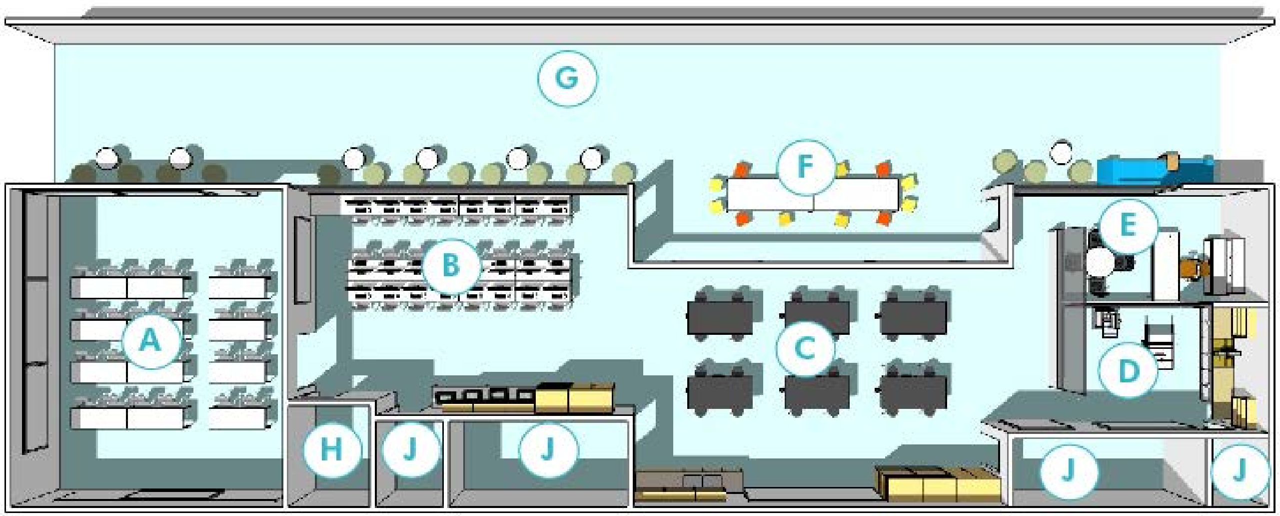
The philosophy of National Prep is to create opportunities for, and mold the capabilities of, young men and women to achieve new academic experiences and accomplishments; not simply repeating what other generations have done, but learning from those previous generations to become young men and women who are critical thinkers and discoverers. National Prep provides students with an excellent high school educational experience that includes broadening their life experiences and understanding the global community in which they belong.

To support their mission and goals, National Collegiate Prep has initiated a STEM program focused on the physical sciences, robotics, and engineering. All students participate in at least one project-based interdisciplinary learning activity per quarter. In addition, two to three STEM specific classes are engaged throughout the school term with hands-on content application and project development. An active after-school program extends the potential reach of their STEM-based curriculum.



Consistent with the process of testing ideas based on applied content knowledge, the NCP learning model features a continuous loop of planning, design, making and testing – each iteration building upon the last. This model is reflected directly in the layout of the proposed suite. In addition to accommodating the programmatic and functional needs of the space, the overall organization facilitates natural relationships between the fundamental project activities.

STEM SUITE



A Seminar Rooms

B Digital Lab

C Project Lab

D Workshop

E Faculty Office
Office for faculty, large enough for small group meetings and transparency for maximum supervision at all time

F Breakout Space "The Sidelines"
Zone for small project groups & spectators during racing competitions

G Commons "The Raceway"
Corridor wide enough for a variety of activities & display opportunities

H STEM Suite toilet
Corridor wide enough for a variety of activities & display opportunities

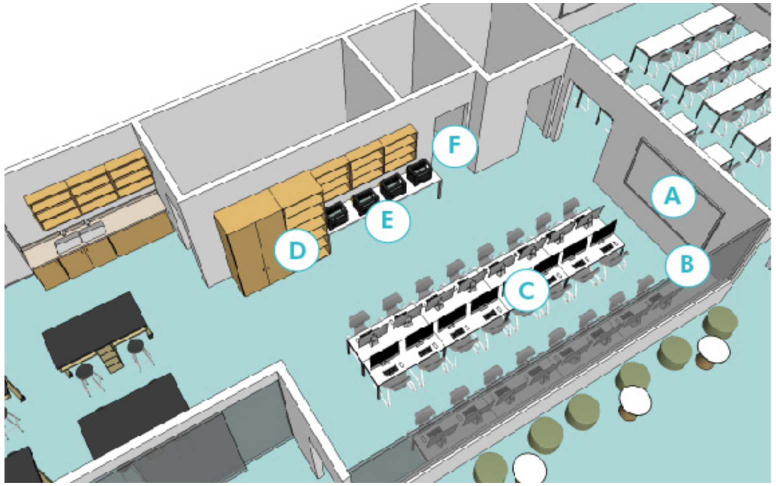
I Storage Closets
Large closets provided to accommodate large scale project storage

At any given time, a class may have four or more projects underway. The suite is designed to provide for collaboration at various scales – from two or three students, up to full classes meeting together – and in various phases. Although the lab spaces are interconnected, they offer the possibility of several teams working independently on different projects, in different phases, all within one space. The potential for peer-to-peer learning is amplified.

A wide corridor that links the STEM Suite to the rest of the school doubles as the common space and public face of the curriculum. Large enough for robust displays and transparent enough to give visitors a view to the maker spaces, the Commons is the place where ideas can be tested. Whether in public demonstrations or team conversations, ideas are ventured and proven in the Commons. A subspace to the side of the corridor is a particularly useful addition. During demonstrations, it can be a place for spectators; during planning and design, a place for collaboration; and during busy production times, it can provide overflow space for fabrication and finishing.

Throughout the suite, ample storage close to the active centers is a necessity, so that the production of projects is not interrupted or damaged by constant relocation.

DIGITAL LAB



A Display Wall
Magnetic whiteboard to be used for lessons & communicating project information

B Printer
Designed area for digital printer(s)

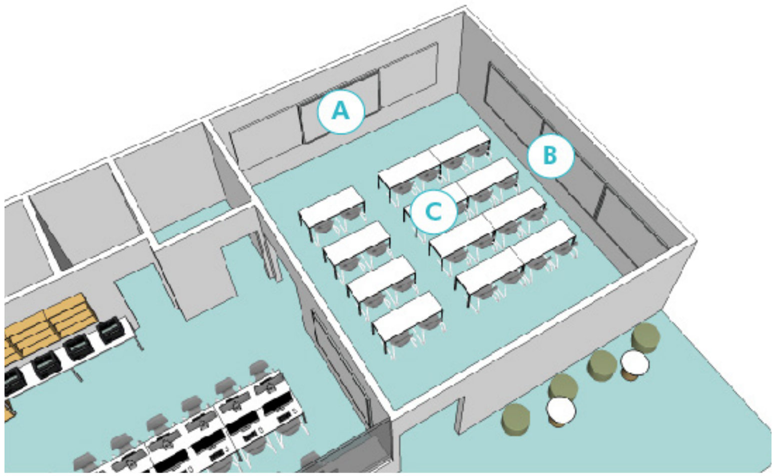
C Computer Station
A mixture of desktops & laptops allow for flexibility within design lab

D Storage
Lockable cabinets for laptops & device storage

E 3D Printer
Designated area for small 3D printers

F Storage Closet
Storage closet for large projects, such as computer building projects.

SEMINAR ROOMS



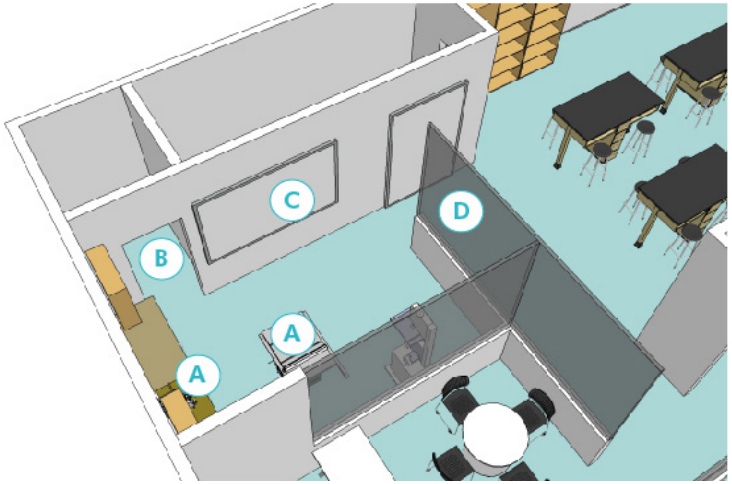
A Teaching wall
Smartboard Technology

B Whiteboard
Along perimeter of seminar rooms to allow for personalization and display within the room

C Furniture
Flexible furniture to enable small group discussions within project groups

"Clean" areas for planning and design are much like more conventional teaching spaces, but reimagined for flexibility and student-centered learning activities. A mix of fixed station computers and mobile devises can be employed to make the most of the available space without limiting the bandwidth available for technology applications.

WORKSHOP



A Machinery & Work Bench
A variety of workshop machinery

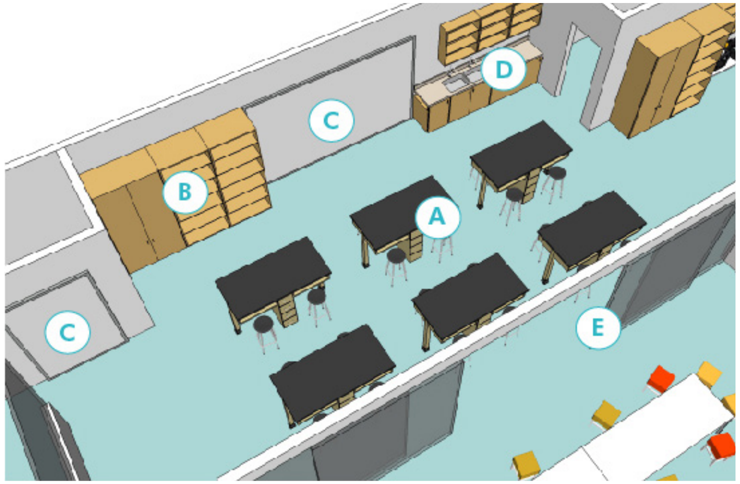
B Storage Closet
Storage closet to store a variety of tools for different project types

C Display Wall
Magnetic whiteboard to be used for lessons & communicating project information

D Windows
Woodshop machinery is very dangerous and requires maximum supervision while in use. Providing windows allows the teacher to keep an eye on students in order to prevent accidents.

Production Areas are zoned to keep the "dirty" production activities separate from those that require a cleaner environment. As it so happens, these activities also tend to be the loudest and most dangerous, so locating large equipment in the workshop and hand tools in the Project Lab effectively keeps the heavier activities from disturbing the more intensive work.

PROJECT LAB



A Furniture
Tables with built-in storage & on casters allow for flexibility & a variety of room configurations

B Storage
Storage cabinets & shelves provide space for supplies & facilitates organization

C Display Wall
Magnetic whiteboard to be used for lessons & communicating project information

D Wet Area
Providing sinks within the project lab helps maintain a healthy hygienic environment

E Sliding Doors
Sliding doors that open up into common areas allows for direct connectivity between the Project Lab and the adjacent common areas & essentially makes the lab larger

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