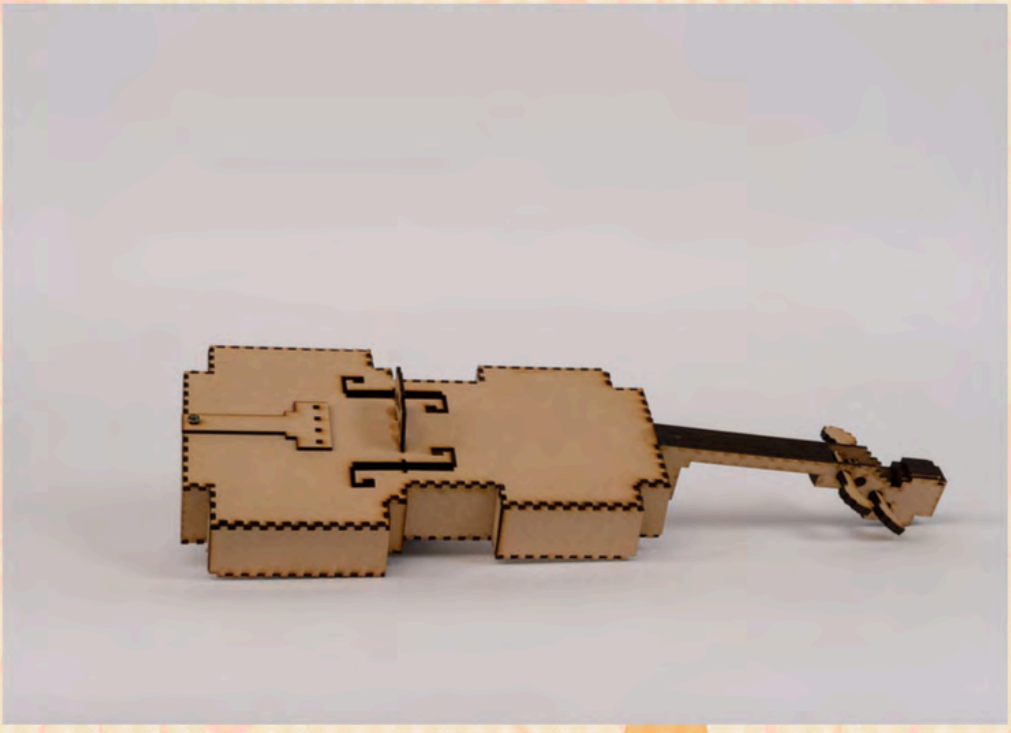
From Prototype to Pitch: New Pathways in Design, Maker and Entrepreneurship Education



Making and Learning Institute
Marymount School of New York

From Prototype to Pitch

New Pathways in Design, Maker and Entrepreneurship Education

Making and Learning Institute
Marymount School of New York

Marymount School of New York
1026 Fifth Avenue
New York, New York 10028
USA

Email: making@marymountnyc.org
Website: making.marymountnyc.org

ISBN: 978-0-9981877-0-9

Cover Design by Eric Walters
Cover Photo by Tobias Everke
Edited by Jennifer Cyranski

Table of Contents

Introduction

According to the *Harvard Education Review*, "The process of making useful objects was an everyday activity in both schools and homes throughout the twentieth century. Whether sewing a garment, building a birdhouse, or constructing a model airplane, children and youth—often with the mentorship and guidance of adults—had plentiful opportunities to learn through the process of physical creation. With ever-increasing access to digital forms of technology, the pedagogical landscape has shifted in the past two decades, with the focus on instructing young people in communicating, researching, and creating via interactive computing. While this shift offers exciting possibilities for the field of education, many educators both inside and outside of schools have revisited making as a valuable site for teaching and learning."

Entrepreneurship education is exploding in K-12 schools worldwide. As noted by author Nathan Barber, entrepreneurship courses and programs offer students "more opportunities for creativity, innovation, and collaboration" as well as how to "identify problems or needs" because "the world needs students who are looking to make a difference."

According to *Future Forwards: Exploring Frontiers in Education – Volume 5* (Re.D Studio, American School of Bombay), "In order to globally transform education and meet the needs of all students, we need more schools to move past being distinct and shining stars of innovation, to become connected constellations of innovation. More than ever, innovative schools and their leaders must connect and share school innovations and their school innovation know-how." This publication, then, celebrates the transformation of teaching and learning currently taking place in private and public schools, as well as the educational journey students take in bringing a design idea from prototype to pitch, from making to entrepreneurship.

We thank the following schools: Harpeth Hall (Nashville, TN); Scarsdale Public Schools; Little Red School House & Elisabeth Irwin High School (New York, NY); Montclair Kimberly Academy (Montclair, NJ); St. Catherine's School (Richmond, VA); Brunswick School (Greenwich, CT): Sacred Heart Greenwich (Greenwich, CT); and Marymount School (New York, NY) for sharing their stories. Special thanks to Jennifer Cyranski, Director of Communications at the Marymount School of New York, for thoughtfully reviewing the publication in advance.

Eric A. Walters
Director of STEM Education
Marymount School of New York

Don Buckley
Co-Founder
Tools at Schools

Humanities in a Makerspace

Molly Rumsey & Caitlin McLemore
Harpeth Hall School
Nashville, TN

Abstract

While STEM classes are commonly seen in school makerspaces, the humanities seem to be a less of a natural fit for design thinking, makerspace activities, and project-based learning. This chapter outlines specific project examples from humanities courses at an all-girls school. The projects all utilized the school's makerspace to enhance and extend the traditional classroom curriculum. Subjects covered include art, English, history, and reading in both middle and high school grade levels. Each highlighted project includes a detailed project description, images of the process and products, and a reflection on the design process. While the chapter provides specific examples, the focus is on the broader topic of humanities projects in a school's makerspace and can be applicable in a variety of courses and school settings.

Introduction

For years, Harpeth Hall had embraced project-based learning and "making." Teachers took innovative approaches to even the most traditional curriculum. Our students used their hands and their minds to solve complex, critical problems. However, we needed and wanted to do more. We needed a space for our 3D printers. We wanted power tools and a laser cutter. We needed a space that could get, and often stay, messy.

Harpeth Hall's makerspace, the Design Den, opened in January 2015. Guided by the technology department and a group of excited math and science teachers, Harpeth Hall transformed two under-used classrooms in its library into one bright, engaging, and flexible makerspace. Equipped with 3D printers, a laser cutter, CNC routers, power tools, hand tools, and a variety of raw materials, the

Design Den gives students of every discipline and every grade a wide array of resources to experience pure creativity.

For teachers, the Design Den is a way to try an "outside the box" approach to their curriculum or take an existing project to a new level. For students, it is an innovative space to design, create, collaborate, explore, learn new skills, and have fun in a venue that is unique from any other place on campus.

Initially, it was not surprising to see math and science teachers, especially those involved in the planning phases of the Design Den, eager to use the new space and tools. The first classes to use the Design Den included algebra, biology, engineering, and geometry. Geometry students designed and constructed soccer goals from PVC pipes and they designed and built a wooden dollhouse with furniture printed to scale on the 3D printers. Biology students recreated the stages of the cell cycle and constructed molecular models. Engineering students designed and tested wooden cars. Middle school algebra students transformed two-dimensional drawings to three-dimensional cardboard structures using the laser cutter.

While the projects in STEM classes seemed a natural fit, the humanities did not. However, faculty in the humanities department quickly expressed interest in utilizing the Design Den for class projects. Teachers were eager to explore the possibilities of using design thinking and "making" to bring the humanities to life. Harpeth Hall English, history, geography, and art teachers have embraced the possibilities that a maker space affords. They have taken innovative approaches to traditional topics.

Here are a few of the ways our humanities faculty has made the Design Den an invaluable and integral part of the Harpeth Hall experience.

A Hero's Journey

English II explores literature of the world and the journey of the hero in works ranging from classical through contemporary. In the fall of the school year, students read the short novel *Siddhartha* by Hermann Hesse and study the twelve stages of the hero's journey within the text. In the past, teachers assigned a poster representing the journey of the hero. Having the Design Den, the project took on a different slant for the culminating project.

The students were challenged to represent one particular stage of the hero's journey using the tools of the Design Den. Students used a variety of software packages, including Microsoft Paint and Publisher, to design an image that would be transferred to a 6-inch square of wood using the Epilog laser cutter. After the image was complete on their laptops, the students worked with the academic technology specialist to transfer the image to vector coordinates that were then used to etch the image onto the wood. Once the image was etched, students used the arts and crafts materials to further enhance the image to complete the overall design.

In addition, students wrote a brief description of their symbol and created a poster that depicted the complete hero's journey. The Design Den inspired many students to go even further. They chose to incorporate three-dimensional elements into their posters. The variety of the finished projects was incredible. Individual strengths and personalities of each student shone through. Students who were not always successful in writing were able to express themselves in a different way.

Distinguished Women

The sixth grade English curriculum focuses on the basics of reading, writing, and grammar along with an appreciation and respect for literature. The selected literature reflects cultural and personal diversity, and interdisciplinary projects foster unity within the curriculum. Students also experience creative writing through short stories and poems.

For several years, sixth graders researched a "distinguished woman." In order to paint a full picture of their subject, students learned the entire life of a person, not just her job or what made her famous. This is a long-standing project that has taken many turns over the years in terms of the final product.

This year, to further the exploration of symbolism in their studies, students worked in the Design Den to create an object that incorporates elements of the distinguished woman's life. The goal was to go beyond the obvious, such as creating a basketball for a famous basketball player. Students had time to brainstorm and plan in advance of their visit to the Design Den. Once they began their work, students used a variety of tools that ranged from high tech to low tech. Some chose to use arts and crafts materials, while others chose laser cutter and power tools. The project required students to use recycled/upcycled materials.

In addition to the object created in the Design Den, students used their research to write a bio poem, a simple poem written about a person. The students wrote them in autobiographical form. Dressed as their chosen distinguished woman, the students read their poems and presented their objects to parents and middle school peers.

With younger students, there is a greater need for guidance in project parameters. A specific timeline, clear planning process with due dates, and guidance on use of and conservation of materials were vital for success. As with the older English II students, the sixth graders who weren't always successful in traditional writing could express themselves in a different way and, in many cases, be able to shine.

Stargirl/The Cay

Fifth and sixth grade students at Harpeth Hall take a reading course to further develop the skills and strategies necessary to be lifelong learners. At this level, our curriculum stresses students' ability to analyze and comprehend a variety of reading material. Students learn

critical analysis and reading comprehension with a focus on preparation for future academic pursuits. In sixth grade, students read from a wide range of genres including award-winning children's fiction.

After students read *Stargirl* by Jerry Spinelli and *The Cay* by Theodore Taylor, the teacher charged them with designing and creating a visual representation of a scene from one or both books. Students visited the Design Den for a brainstorming and planning session. The meeting included a digital worksheet with sections for adding ideas, materials needed, a specific action plan/timeline, and time to sketch. Girls could work as individuals or in groups, depending on what theme or topic they chose to explore.

Because this was a new project, the teacher allowed it to be open-ended and did not set many specific parameters, other than the product needed to relate to one or both of the books. The teacher encouraged students to bring in and use recycled materials, though some raw materials like markers, paint, paper, wood scraps, and other craft materials were available.

Through the construction of a physical model, students analyzed texts at a deeper level. Many explored the connections between the two books through important characters, settings, symbolism, or thematic elements. Girls were excited to use the Design Den for the first time in reading and were eager to make something of their own. Most students naturally found a group that wanted to explore the same ideas, and those who did not were happy to work individually.

Students presented their final products to the whole class and then put them on display in the library for all students and teachers to view.

Making Bookmarks

Seniors in the AP English literature course read numerous works of literary merit throughout the class. This year, after completing the AP exam, the teacher challenged students to complete a project in the Design Den that provided a chance to reflect on the class readings. Students chose one or two quotes that they found most meaningful and designed a bookmark including the quote. In

addition to the text, students were encouraged to incorporate visual imagery and experiment with different fonts to evoke a specific mood.

The academic technology specialist gave students a brief orientation, as some of the seniors had not used the Design Den since it was still a new space. Then, the academic technology specialist helped students set up a workspace in Microsoft Paint and showed them the available materials that ranged from paper to leather. Some girls created simple, yet elegant bookmarks while others experimented with different mediums such as collage or painting over leather.

While the students enjoyed themselves, the heightened learning experience sprang from the reflective discussions students had while designing and making their projects. It was especially meaningful for the girls to have something that they created and would use even as they attend college.

Rosie the Riveter

The eighth grade social studies curriculum involves a study of the 20th century. Students hone collaboration strategies and independent research skills as they explore the global themes of this dynamic century. Alternating between international and American perspectives, teachers encourage students to construct a picture of the century that considers multiple points of view and a variety of contexts. Emphasis is placed on changes in national boundaries and alliances, the human experience within various economic systems, and debates about political systems.

During their studies of World War II, students learned about World War II cultural icon, Rosie the Riveter. The entire eighth grade took over the Design Den and had a 'Rosie the Riveter Day'. After an extensive safety lesson, each girl used a cordless power drill, hammer and nails, and a jigsaw or

handsaw. Equipped with gloves and safety goggles, they took scrap pieces of wood and explored the various tools at hand.

When not learning how to use power tools, girls researched life at Harpeth Hall during World War II using school digital archives. Students wrote important points and meaningful quotes on the IdeaPaint whiteboard walls in the Design Den. Other classes could then use these points and quotes for discussion and idea generation.

While this was a brief and basic project, for many students this was a first experience using hand or power tools. As a school for girls, this experience provided valuable, real-world lessons that enhanced the historical mission of the course.

Egyptian Artifacts

In sixth grade geography, students apply their knowledge of the geographical and cultural elements learned in the fifth grade to their study of the Eastern Hemisphere and the ancient civilizations that developed there. The study focuses on the question of "how do humans and place interact?" using the growth of the empires such as Mesopotamia, Egypt, China, India, and Greece.

After their study of Egypt, teachers tasked the students with the goal of creating a museum of artifacts. Each class was divided into "topics" related to their studies: medicine and health, education, games, agriculture and animals. Within their topic groups, girls collaborated on ideas using GoogleDocs to decide who would create what artifact and how it would incorporate into the overall display of the entire class.

Students had to choose an artifact to recreate using only found materials to 'upcycle' (students were not allowed to purchase any items). Using only a limited supply of raw materials, they created a replica of an ancient artifact to display in a classroom museum. Students took cardboard, wood, paint, styrofoam, aluminum foil, fabric, and more to recreate their artifacts.

After completing their artifact, students wrote a brief paragraph about the artifact that would be on display in the geography classroom "museum." When the project was finished, middle school peers and teachers came by for a tour with students acting as docents in the "museum."

Students were excited to use the space and enjoyed the autonomy given to them by the teachers. Using only upcycled materials made this project challenging for the students while also sparking creative and new ways of approaching a problem. This project was an incredibly messy one that required continual reminders about conservation of materials.

Self-portraits

The goal in seventh grade art is to expose students to a variety of tools in order to gain experience with different artistic media. As a student continues through the art program, she is able to use the fundamentals learned in middle school to create and design her own art projects that incorporate a variety of disciplines.

One of the major projects in seventh grade art is a gridded self-portrait pencil drawing. Students complete exercises to study different expressions of perspective and ways to represent the self through art. The teacher's goal in integrating technology and Design Den tools was to get girls comfortable with seeing their faces represented in a variety of ways, including both print and digital formats.

Each class spent several days in the Design Den working in small groups on different artistic exercises and projects. As a warm-up exercise, students completed a series of contour and continuous line drawings. Students completed the continuous line drawings electronically using the stylus and tablet mode on their laptops. Other students worked in pairs to draw each other's faces

through the clear glass partitions in the Design Den using continuous lines and dry erase markers. This exercise proved difficult for some of the students because it required concentration and stillness.

Students submitted their completed electronic files to be etched onto wood using the laser cutter. After the laser cutting step, students experimented with different media. Some students left the wood etching plain, and displayed it next to their pencil self-portrait. Others used markers or paint to experiment with different color schemes. One student ran her wood etching through the printmaker to use as an inking stamp on paper.

Students seemed more comfortable experimenting with their self-portraits and artistic techniques after time spent in the Design Den. The technology did not replace the traditional techniques and skills learned in the art classroom, rather the use of technology enhanced existing pieces and allowed for options with which to experiment.

AP Art Portfolio

Senior AP Art requires students to submit a portfolio of their work. A student's AP art portfolio must explore a specific concentration or artistic medium. A description of the collection must also be included with the portfolio.

For this project, one student individually contacted the technology specialist with a request to use the Design Den. Curious about the available tools, she was interested in utilizing technology in her mixed media collection.

For the student's concept, Extinction, she "wanted to show common objects that were used in the recent past that have gone completely out of use, such as CDs, handwritten letters, paper maps, cassette tapes, and paper dictionaries." Her goal

was to transform these “extinct,” “dinosaur” items into actual dinosaurs. The student hoped to inspire people to think about what technology and tools have gone extinct and why.

The student and technology specialist had a consultation meeting to start, and then the student designed files for the laser cutter and used power tools to create smaller pieces of the bigger “extinct” technologies. With this project, we learned a great deal about what the capabilities of the laser cutter in terms of cutting through wood. The student was very precise with her electronic drawings, and the laser cutter was able to replicate the intricate design with exact precision. Another lesson learned from this project was how to use the Design Den for individual projects. Typically, students come to the Design Den to work on a particular project within a class. This project was completely student-driven. The student made appointments with the technology specialist and worked in the Design Den to complete the project. It was open-ended and student-directed, which allowed for a greater deal of creativity than a class assignment.

Humanities and a Makerspace: What we have learned

For Harpeth Hall, exploring the humanities in a makerspace has been rewarding and exciting. Projects such as these enhance learning and engage students and teachers in a new way. Student who are not as strong in the humanities are given a chance to shine and to see the subjects in a new light. Most importantly, students see that this space and these tools are not just about math and science. There is something for everyone, in every grade, and every discipline. While many think it can’t be done, we’ve learned it can.

Building a Maker Culture – Before the Space

Lisa Yokana
Scarsdale Public Schools
Scarsdale, NY

Abstract

How do you ensure that your shiny new makerspace will be filled with excited teachers and students? Start now by designing curriculum and training teachers in design thinking and making so that there is a gradual and organic culture shift towards open-ended, problem-based learning with teacher as facilitator. Teacher training is the key, so that teachers begin small and learn to embrace the maker mindset in their classrooms. This chapter will walk through how to lead teacher training sessions to facilitate this shift, give examples of lessons and units happening before a makerspace is online, and examine how to support teachers throughout this shift.

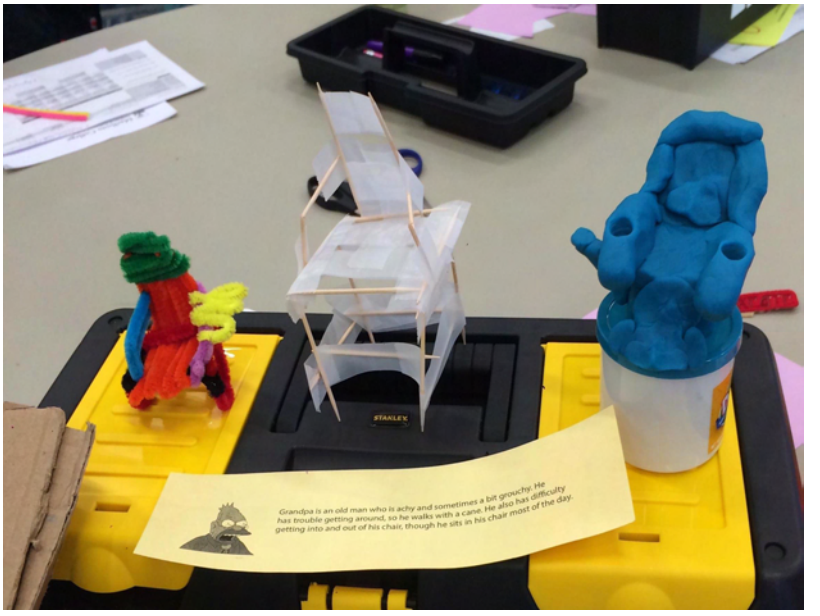
Planning for your Space

When planning a makerspace for your school community, it's best to start small and build a culture of making across all disciplines well before the space comes online. At Scarsdale Schools, we began with makerspaces at all five elementary schools. Knowing that these students would be coming to the high school eventually, we began to build a culture of making through targeted professional development and informal mentorships.

Schools can facilitate a gradual and authentic shift in both teacher practice and mindset through thoughtful professional development. Begin with the 'why' behind making and design. We can all acknowledge that the world has changed, but the traditional model of education has not. How can schools best prepare students for their future? What skills will they need to navigate their jobs -- some of which haven't yet been invented? If students can Google the answer to a question, then content is no longer a valuable commodity, while skills like imagination, problem solving, collaboration, agility, and entrepreneurship are. Traditional methods of teaching, with the teacher as "sage on the stage," only

encourage students to memorize content and regurgitate it on tests. The question becomes how might we encourage and engage our students in deeper learning experiences? Teachers can craft lessons and units in which students learn to ask questions, dive deep into problems, and struggle with the absence of easy answers. Using design thinking as a scaffold for open-ended questions, teachers can ask students to create solutions to real problems. Through making prototypes, testing their ideas and reiterating based on feedback, students learn to think like innovators and practice skills they will need to be successful in the world.

Teacher-training sessions should begin by having the facilitator ask what skills teachers feel their students need to be successful and even have them write them on post-its and put them up on the wall. Teachers may then understand the design cycle by completing the 5 Chairs Exercise[1] or The Wallet Project.[2] The session ends by asking teachers what skills they used in the process. Hopefully, they will find that they have used almost all the ones they have identified as essential.



For some teachers, making something, even something as silly as a chair for a Simpson's character out of Play Doh, is intimidating. Not everyone identifies as a maker, although humans have been making things since the beginning of time. Everyone makes something, whether it is guacamole, a beautiful home, or a lesson plan. Both the Wallet and 5 Chairs exercises have a low maker threshold. This allows teachers to complete the exercise and identify the skills used, as well

as developing empathy for their students around open-ended questions and making.

Exemplars

Once teachers have experienced the design cycle, it's important to show them some exemplars from a real classroom. I use examples from my own school, but there are many online that you can use as well. I always tell teachers that they don't have to change everything they do, just tinker with one lesson or unit. They should begin by asking: what do you want students to learn? What content do you need them to engage with? One social studies teacher, Emily Block, wanted her students to more fully understand World War I. She felt that the content was confusing, but that ultimately students did not understand the complexity and human cost of the First World War. She asked students to create a memorial to commemorate World War I and assigned teams of students to different regions. Students would have to learn about the involvement of specific countries and how they were affected. For the research and empathy phase, students learned about the involvement of their region and that region's successes and losses. Students also had to visit real memorials and record their reactions, which were processed in a class discussion. Teams brainstormed different ways to create memorials and worked on a rough prototype and were given feedback. The classroom was then turned into a temporary makerspace, with tables and desks pushed together as temporary workspaces.

Materials and unfinished projects were stored in boxes, one to a team. Students were given certain constraints: the size could not exceed twenty inches by twenty inches and recycled materials had to be used. With four class periods to build, time was tight, forcing students to be efficient. At the end, they pitched their models to an audience, justifying their decisions through historical knowledge. The lesson was assessed in three ways: process, product, and final pitch. Students completed evaluations for each team member, as well as a written explanation of their choices and intent.

Once teachers have seen some exemplars, ask them to find a lesson or unit to tinker with. What do students need to learn? What skills should they practice? An English teacher might want students to really dive into empathy with characters in a text, while a science teacher might want students to fully understand sound and resonance through making an instrument. Start with a sharing of their ideas and ask them to talk about what is still unclear to them. Teachers can offer suggestions to one another or work together if they have a similar focus. Throughout the curriculum writing workshop, it's important to regularly share progress and questions. Working collaboratively can spawn unlikely connections.

Materials and constraints are an important consideration for any maker project, and especially one that will be happening in a classroom and not a makerspace. Limiting size and types of materials can make the project manageable, as can controlling the tools available to students. Using only glue guns, exacto knives, cutting mats, cardboard, and a cart of craft materials, many things are possible. Asking students to supply other materials takes the pressure off a teacher who is new to the maker experience. Constraining the time allowed for in-class making also helps, as teachers can remember that although their room is messy right now, in three or four days it will return to what they are used to. This also pushes students to work diligently as they know that they have a set number of days to complete the task.

When it is time for the teacher to try out the lesson, helping them manage their classroom layout helps them feel in control. Teachers who are used to being totally in command of the room can be uncomfortable with the chaos and messiness of maker projects. These teachers are used to students sitting and raising their hands, rather than moving freely around the room getting materials and using tools at workstations. Safety is a concern for inexperienced teachers, so setting up cutting and gluing stations allows them to supervise potentially dangerous procedures. If possible, having a more experienced teacher in the room as a mentor during the process alleviates tension. Creating some informal mentorships helps less experienced teachers feel supported through the messy making process.

Teachers who are new to making also worry about assessing projects. I advise them to photograph groups working, as they can refer back to these when grading. If there are several photographs of a disengaged student, then it is easier to justify a lower process grade. These photos are also great evidence of team dynamics at work. This gives teachers something to do while observing students at work and documents the lesson. Grading the group's craftsmanship is also

important as a poorly constructed project is distracting and demonstrates a lack of care about the outcome. Ask students to write a statement about their intent, which justifies their decisions. Students should recognize that all aspects of a maker project are important to the outcome: decisions about materials, adhesives, and concepts, all are part of the viewer's perception of the final product.

Finally, encourage the teacher to document the project from start to finish. Looking back at photographs can help teachers assess what worked well and what didn't. It is important to process with teachers at the end and encourage them to reiterate the project, refining, adding and eliminating ideas for next time. And of course, celebrating the work, both with students in-class and more publicly through a blog, website, or evening museum-walk, spreads the positive message of making. Including thoughtful excerpts from student reflections that demonstrate their depth of understanding and enjoyment of the project helps make the learning visible. Skeptical teachers may even come on board when they see students' enthusiasm. Showcasing the work publicly encourages all members of your community to value making.

If you begin to build this culture slowly, one teacher/lesson at a time, it will be an authentic shift, not top-down. Since makerspaces are best when designed by and for the needs of the community, enlisting teacher and student voices in the design phase will increase buy-in. And when your space is finally finished, teachers will be clamoring for it.

[1] Five Chairs Exercise:
https://dschool.stanford.edu/groups/k12/wiki/17761/5_Chairs_Exercise.html

[2] Wallet Project:
https://dschool.stanford.edu/groups/designresources/wiki/4dbb2/the_wallet_project.html

Designing and Making as a Means to Understand the Past

Elaine Chu, Jessie Kirk & Mark Silberberg
Little Red School House & Elisabeth Irwin High School
New York, NY

Abstract

In this chapter, we explore how the essential practices associated with design, making, and entrepreneurship are embedded directly into the fabric of the curriculum and the classroom at the Little Red School House & Elisabeth Irwin High School (LREI). Specifically, we describe the journey our third grade students take as they explore the early history of Manhattan and its people, the interactions between the Lenape and Dutch settlers, and the implications that this history has on students' visions for the future of our city. This work was born out of an iterative process that began with the questions, "How might we design for an experience that places students on the inside of an historical narrative?" "How might we experiment with scale so that instead of making and building models that tell a story from the outside students are able to live and learn within the model itself?" And "How might students' experience with design and making lead them to discover a sense of agency and purpose in the world beyond school?" At LREI, teachers are experienced designers deeply committed to a human-centered approach to pedagogy. The emergence of design, making, and entrepreneurship has the potential to expand this crucial dimension of teaching into more classrooms and schools. It is our contention that the most important place to begin this transformation is in the classroom itself.

Introduction

For progressive schools in general and for the Little Red School House in particular, the emergence of design, making, and entrepreneurship as mindsets for learning have helped to amplify many of the core values (e.g., critical thinking, creativity, collaboration, courage) that have always been central to our practice. One has only to look beneath the surface of what many are calling essential "21st Century skills" to find the solid foundation of progressive practice on which these "new" ideas rest. That said, the current moment has provided learners, both

young and old, and the schools in which both work, with useful systems to help frame the process of experience and inquiry that is essential for learning. We see design, making, and entrepreneurship as a set of related inquiry tools that are available to learners as they set out to construct knowledge and wisdom. They allow for an investigation of experience that is grounded in empathy, iteration, the construction of personally/socially relevant products, and the agency that comes from working towards solutions to authentic and meaningful problems.

As Agnes De Lima observed in 1942 in *The Little Red School House*:

> The general education aim . . . will be achieved, not through a routine process of instruction, but through a series of experiences, which will awaken the interest in the children and develop a facility for meeting individual and social situations... We believed in the beginning as we still do that children can be happy in school, that education must be thought of in terms of growth and comes by experiencing rather than by mere learning, and that life does not begin when school ends but rather, as John Dewey says, that school is life." (pp. 3 and 5)

The ideas that are central to this chapter and this book derive their power precisely from the fact that they seek to open the place called school to the larger world in which it is situated. As we work to ensure that the activity of school is not only purposeful, but draws on the power and agency that students bring with them to school, we also understand our obligation to narrow the distance between the classroom and the wider world to which it is connected. To move schools in this direction, teachers cannot simply embrace (or be mandated to embrace) design, making, and entrepreneurship as some new program to be added to the curriculum. These ideas must come to be seen as a framework for supporting a reflective and forward-thinking practice. The best teachers have always been designers. For these teachers, the curriculum at any given moment is simply the most current iteration of a project that seeks to best meet the learning needs of a particular group of students. In essence, this chapter was born out of an iterative process that began with the questions, "How might we design for an experience that places students on the inside of an historical narrative?" "How might we experiment with scale so that instead of making and building models that tell a story from the outside, students are able to live and learn within the model itself?" And "How might students' experience with design and making lead them to discover a sense of agency and purpose in the world beyond school?"

Seen in this light, our curriculum is always in flux and being "made." We would also argue that the curriculum is something more than a scope and sequence of content and skills. In fact, we are living in a moment where what many schools have long considered the "curriculum" can be accessed more easily and reliably through resources available on the Internet. For us then, the curriculum is the activity that guides learners into an experience and serves as a roadmap for possible pathways through that experience. Some of these pathways may have been traveled before by earlier groups of learners and some will be discovered for the first time as learners bring their own prior experiences to this new context. While teachers must bring deep content knowledge and an equally deep understanding of children to their work, these are necessary, but not sufficient, dispositions for the work of teaching. Progressive schools have always seen the teacher as an experienced designer deeply committed to a human-centered approach to pedagogy. The emergence of design, making, and entrepreneurship are helping to expand this crucial dimension of teaching into more classrooms and schools. As De Lima notes,

> "We are, then, concerned in our curriculum to make sure that it affords the kind of experiences and the kinds of activities which will help children to grow normally and naturally. The old-line pedagogue was continually asking, what must a child know, what knowledge is of most worth? We ask instead, what should a child be like, what ways of acting and what habits of response are most worthwhile? But we do not consider the child alone, for naturally the individual is part of a larger group and this group part of a wider community. Our school is neither child-centered nor society-centered. Rather we take the child as he is and where he is, try to understand him, and then seek to help him understand the kind of world in which he lives and the part he is to play in it." (p. 17)

We have tried in this chapter to capture how the essential practices associated with design, making, and entrepreneurship can be embedded directly into the fabric of the curriculum and the classroom. Specifically, we describe the journey our third grade students take as they explore the early history of Manhattan and its people, the interactions between the Lenape and Dutch settlers, and the implications that this history has on students' visions for the future of our city. While we see the value that lies in creating specific named learning spaces to support this kind of work, we worry that in some schools the rush to create Maker Spaces, Fab Labs, and Design Studios may actually limit the transformation that is desperately needed in too many of our nation's classrooms. Ideally, the

boundaries between these spaces must be permeable so that opportunities for exploration and discovery can emerge in the context of student-driven interests and concepts and ideas that the community has decided are worth exploring together. Moreover, given the constraints that many schools face in attempting to create designated spaces for design, making, and entrepreneurship, we would make the argument that the most important place to begin this transformation is in the classroom itself.

"We not only study history—
we make it.
We not only live life—
we enjoy living it.
We need hope;
we need strength;
we need imagination."
—Agnes De Lima in *The Little Red School House* (p. 27)

Creating Social Scientists: Thinking like an Archaeologist

"TIME TRAVEL TO THE PAST. 1, 2, 3, LET'S MOVE FAST. SO MUCH TO LEARN, AND LOTS TO SEE. TIME TRAVEL, 1, 2, 3!"

What's the best way to study the past? Is it to read books and articles? To study photographs and artifacts? To use the Internet and do research? These tools alone failed to achieve what we really wanted: that students living in New York City in 2016 could walk right into the past and see and feel it for themselves. We found the perfect solution: time travel (see glossary). We could give our students the experience of living long ago, but once there, then what? How do you make sense of history? First, we needed to teach the specific skills for thinking about the past.

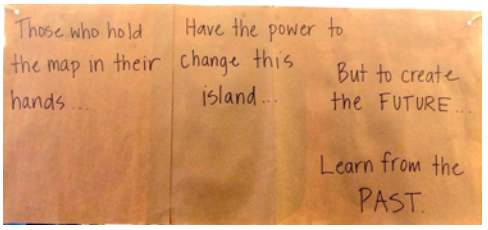
How does a social scientist think? We teach our students to assume the mindset of an archaeologist. How do we learn about the past using

Empathy at the Center

In all phases of their work, students seek to understand what it means to think, feel, see, and know from the perspective of another. Nowhere is this more important than at the start of the inquiry/design process. As students/designers seek a more empathic connection with their work, they are better able to recognize their own biases and assumptions. They are also better able to see how these dispositions can inform and also interfere with efforts to understand the other and her experiences and needs. This developing sense of self-awareness and the parallel recognition of the wants and needs of others is crucial for the young designer and maker.

primary source materials, such as artifacts, pictures, and documents? Students make careful and detailed observations and speculate using evidential reasoning. They begin making a picture of the past: Who could have used the object? For what purpose? Where? When? What does it tell us about life at that time? Once they know how to study one "Mystery Object," they are given the task of looking at a collection of artifacts that they must put together to make a picture of a "Mystery Time and Place." The emphasis is not on naming the time and place, but on understanding how people lived then and there. (See Note 1)

Figuring out the "Mystery Time and Place" from the clues provided is an exciting puzzle that mimics the authentic work of archaeologists. Once our students have practiced these skills, we provide a compelling narrative within which they can use them. Using an imaginative inquiry (see glossary) framework, the students are enlisted as archaeologists who receive a shipment of artifacts that they must analyze to create dioramas for the American Museum of Natural History. We raise the stakes even further. Succeeding at this task leads to the opportunity to apply to be on a secret team of experts who must study the history of New York City in order to save its future. As members of this "Team X" (see Note 2) students are motivated to learn about their city's history for the real purpose of making it better (see Note 3). And they must do it together.



Creating a Context: Thinking like a Lenape

"Come gather in the longhouse to hear the Elder's vision from last night..."

Third graders gather in a circle around the fire pit. The villagers are presented with the Elder's vision and discuss what it means: the Big Hunt is approaching. Our Lenape village must plan what to do.

Villagers share their ideas for what we need to do first, what tools are needed, what animals to hunt, and where to find them.

A Problem Worth Solving

Too often the value of a problem is only obvious and compelling to the teacher. For the student, the problem is a task relegated to that domain called schoolwork. A design and making ethos helps to create a space for students to see their own needs and interests reflected in a particular problem and helps to turn schoolwork into "life work." When the context for learning is framed in terms of a problem worth exploring, the classroom itself undergoes a transformation as students and teachers share in the possibilities for new experience and new learning.

Most students have the same response: “We’ll use bows and arrows!”

We encourage them to think through other ways to catch game and the steps involved: “Where will you get your bows and arrows? Where will you find the animals? Is that the only way to hunt? Are there other ways to catch animals in the wild?” These prompting questions push them to think beyond their initial assumptions about what hunting is.

At this point, we don’t expect students to have any knowledge about Lenape hunting, but to use their knowledge about the world and what they know so far about Manhattan in the 1500s to imagine what they would do as a Lenape in this situation. We intentionally present them with this authentic problem before they have been given any information — not to stump them or force them to guess — but to activate their innate ability to use logic and their existing experiences to problem-solve.

What students have gotten prior to this lesson is a context for thinking like a Lenape. They have learned about the environment that the Lenape lived in, what resources were available then, and how they lived together as a community. Over the past several weeks, our students have been given a name by the Name Giver, identified themselves as a member of the Turkey clan, lashed saplings together and tied on bark shingles to make a longhouse, and went through the steps of skinning, tanning, and sewing hides to make their clothing. In short, they have been living like a Lenape (see Note 4).

Prototyping to Understand

It is here that students begin to explore their questions through work with materials and making. This process helps them to distill key ideas down to their essence so that what is being made can speak to the underlying meaning of the experience. For example, through the act of making the longhouse, the student not only enters into a relationship with the materials, but also sees her relationship to the Lenape and the meaning of the longhouse in a different light. The work is also iterative, as students are not simply following a set of instructions. They are learning through the limits imposed by the materials. Most first attempts at making don’t solve the problem, but they do suggest possible next steps (i.e., “This snare design seems to work better.”). The work here is purposeful as ideas and understandings are made manifest through the act of making.

With this framework for thinking about the past as someone living back then, students are ready to learn more specific information about the various hunting methods, tools, and steps that the Lenape used. They read a detailed article and study pictures of tools and traps. By the next day, they are prepared to apply their working knowledge to making plans for their hunt. Small groups are assigned different hunting methods to work on and then come together for feedback and input from the whole class. The previous days' tasks of thinking through the various aspects of the problem (what to hunt, where, how), and research about Lenape hunting have prepared them to make detailed, informed blueprints.

Now it's time to make what we need and go on the hunt. The "men" work together to make bows, arrows, and quivers, while the "women" prepare racks for drying and smoking the meat that will be brought home. (Our students know that in drama they may be asked to take on the role of either gender.) Sticks, clay, twine, leather, and construction paper have been provided for this purpose. Our goal is to give students materials that will allow them to replicate the process of making these tools. For example, they can shape clay into arrowheads that they will lash onto sticks, whereas rocks cannot be easily shaped and paper is two-dimensional.

The Big Hunt begins in the longhouse. We pray to the Mesingw, the spirit who protects the animals of the forest. Then we begin our long trek to various habitats (forest, wetlands, etc.) where each group finds animal tracks in different parts of the room. They need to identify the animal and figure out what method would be the most suitable for hunting it. They proceed to build their traps and snares using materials they find at their site.

Teaching as an Iterative Process

This early stage prototyping work being carried out by the students also informs the teacher's thinking. We have chosen certain materials to represent what would be "found" in the field because they are easier for the students to use. And we wonder if it might make more sense to have students explore the actual materials first so that there is some understanding of the complexity and craftsmanship associated with this work. Perhaps this "empathy" for the materials themselves might then carry over into the design/making with more "modern" materials. This early encounter with materials would encourage students to ask questions like, "How might I use the materials that are available to me to communicate something of the experience/story of work with the more traditional and historically accurate materials?" In this way, when the student talks about what he has made, he can, for example, more easily refer to the clay as stone.

There is no prescribed way to do this. All that students have available to them is the working knowledge they have built over the last few days from articles, pictures, and discussions, and basic materials that we have given them to represent the logs, saplings, bark, and sinew that were available in the wild. Even after several days of talking and thinking about how to hunt an animal, students are now confronted with the reality of having to actually do it. How can you get the spring action of a snare to work? Where do you put the bait so that it will trigger the trap to fall? How can you get a group of deer to all run in the same direction towards waiting hunters? In this moment, they are forced to put their designs into action. There is trial and error, they may or may not succeed, but either way they are gaining a deeper understanding of the particular system they are working on.

To complete the full arc of the hunting process, we return to the village with our game, which is then cleaned, skinned, the hides tanned and the meat smoked and dried. We celebrate and give thanks to the spirits for our bounty. Our students have not just researched Lenape hunting, but they have experienced the many layers and complexities of it. They write in their Lenape journals about their experiences.

Designing with Others in Mind

As students continue to develop empathy for the experience of the Lenape and Dutch settlers, they now need to expand that view to include the other students, teachers and families who will visit their museum. This shift asks them to see their own learning in a different light. As the student-designer becomes curator, she must make explicit aspects of her learning that she cannot assume the visitor will share. The student asks, “How can I design this space so that it best tells the story of what I have learned?” And “How can I do this so that I do not have to step out of my character to explain things to my audience?”

Creating An Environment: Building Mannahatta

"What do we want to teach about the daily life of the Lenape and Dutch colonists?" This is the question that prompts our students to begin building a life-size model that transforms our classrooms into an interactive museum mid-year. We recreate the world of the past — this time not for students to experience the routines and struggles of long ago as they have been doing up until now, but as a platform for conveying their knowledge to others. A new element is introduced to their learning: an audience. We ask them to do this by replicating the environment of Mannahatta circa 1630: a Lenape village and longhouse in one classroom, and the streets of New Amsterdam and Dutch colonist's home in the other.

"What are the different parts that make up the Lenape or Dutch colonial community and way of life?" In answering this, our students are encouraged to think about what they know about the various aspects that make up a society: housing, food, clothing, jobs, family, education, religion, and natural environment. The goal of this project is for our students to put together the whole picture of daily life in these two communities. In small groups, students focus on one category. "What is important to teach about your topic?" They think about the big ideas, not just what they want to make, drawing from knowledge they have constructed over the past few months. They are not only using facts and information they have learned, but are also reflecting on their "direct" experiences of living like a Lenape or Dutch colonist, and thinking about what it means and why it's important. "When you were making a trap as a Lenape hunter, what did you learn about Lenape food that you think is important to teach others?" Students must think about why and how people lived as they did and how those activities functioned together to form a working society.

Work with a Purpose

The design and making process is working at a new integrative level. Earlier design/making experiences that were focused on developing the learner's understanding of the problem now need to be aligned so that they are reinforcing this new narrative that will be shared with visitors to the museum. This creates a sense of purpose and agency to the work. It is not simply work that the teacher has asked them to do. It is work that will reach a broader audience and it is work that will be viewed critically by that audience. As such, the students understand that the stakes have been raised and this amplifies their commitment to the task at hand. They are working in the service of a clear purpose even if they are not clear on how best to complete the work. And it is this tension that pushes them forward to do their best work because the outcome (i.e., the museum visitor having a positive experience) matters to them.

"How will you show your topic? What will you make?" Here, our students know what to do. At this point, they have already built parts of a longhouse, made traps and snares, made Dutch meals, dipped

candles, painted Delft tiles, etc. They have also envisioned the scenery and landscape, as well as the daily routines and interactions from "time-traveling" to the past. Students are not simply repeating what they have already done; there is a repurposing and expansion of previous ideas. Whereas they previously made tools and traps to learn about Lenape hunting, now they need to show the larger system of how Lenape hunting works, for example: the various methods, tools, habitats, prey, etc. They are designing and making with the purpose of expressing their knowledge to others.

"How will you make what you need and what materials will you use?" At this stage, the classroom becomes a maker space, as students try to bring the past to life. They have to creatively use what is available to them. "How can I build a drying rack that will stand up on a classroom floor?" "How can we make a Dutch alcove bed, when it was built into the wall?" While they have been able to imagine the world of Mannahatta right in their own classrooms, now they need to actually make it. They grapple with constructing stationary objects and backdrops to represent something dynamic and moving, i.e. a way of life. "How can we show how the gears, shafts, millstones, etc. work together to grind wheat when our windmill is painted on the wall?" "How do we teach about Lenape religion when their beliefs reached all areas of their lives and influenced everything they did?"

Unlike the making-as-problem-solving that students experienced before, they are now making the "set" for their presentation. Much of this involves painting panels that line the classroom walls and hallways to become the forest, streets, and inside of homes. The creation of these backdrops is not the project itself, but it will help others see what the students have been visualizing all along.

Making that invites Meaning

For some students, it is not until this very focused making begins that key pieces of learning start to fall into place. The encounter with the materials and the design opportunities and challenges that they present help students to see how the ideas they have been exploring are interconnected. As the student works with cardboard to build an element in the Dutch settlement, he says, "Ahh, now I see why this is important."

"Who is your character? What is your character doing and saying to teach about his or her life on Mannahatta?" This is the essence of the museum: the environment allows them to assume their character fully and put it into a greater context so that their teaching is from within. In New Amsterdam, Pheabe shows visitors why the garden behind her home is so important to her housework, while in the Lenape longhouse, Bright Moon teaches important life lessons through storytelling around the fire pit. Upon entering the museum, visitors too are immersed in the past. They move through the rooms, asking questions: not, "Can you tell me how the Lenape or Dutch lived?" but, "What are you doing? Why are you doing it like this?" Students are the experts because they have become their characters.

"What did you learn by making and doing the museum?" Our students reflect on their experience the next day. This metacognition gives them time to recognize the value of learning by making, contextualizing, and explaining:

- "Gardening is in my head now, because as I was making it [the garden and gardening tools], it was like I was doing it, except they didn't use paper and clay."
- "I felt like a Lenape. Once I became a Lenape, life was really hard."

- "I already knew about how they built longhouses, but after doing it and explaining it I learned how it's real and how it's really effective."
- "I learned about how to build snares from reading about it, but it's like I got reborn into a Lenape village and learned it all over again!"

In the museum, students are not simply presenting what they know in a static way (imparting information); they are engaged in the iterative process of recreating their understandings.

As they interact with visitors, they step out of what has become familiar territory to them, and see it from an outside perspective once again. The audience helps them see what they already know in a new way and the act of making creates a crucial context for this learning.

Creating Coexistance: Stepping into a Complex Society

"Little Fox, we have received a message from your Dutch friend, Antonius. Their Director-General, Willem Kieft, has declared that he plans to force us, Lenape, to pay a tax in exchange for the protection they claim to provide us."

Little Fox and Antonius met one day while gathering oysters by the river and became friends, and have continued to meet from time to time. The Dutch and Lenape live on different ends of the island, and even though their trading relationship allows for occasional interactions, it is unusual to have personal friendships develop between the two peoples.

The Lenape villagers (Students-in-Role - see glossary) react to this urgent news: "This is not fair. They think that we signed a contract saying they could have some of our land, and in exchange they would help protect us. But we didn't really sign a contract. We don't believe in owning land. When that trade was made, we thought we were agreeing to all live together and help each other. And now they're asking us to pay for that."

The next day, they gather with their Sachem (Teacher-in-Role - see glossary) for a Council Meeting. In his or her democratic fashion, each person is given a chance to

Why the Other Matters

Here again, we see the crucial role that empathy plays in this work. Moreover, in this phase of the work the need for empathy is also tied to the challenges posed by the relationships that drive the students' experiences. The student-as-designer seeks to understand the other, but cannot remain separate from the other. Both have a stake in the encounter and its outcome. This helps to reinforce the idea that good design, making and problem finding and solving is about understanding human needs (i.e., before you make something you really need to understand the needs of the user and it is better to make *with* the other than only *for* the other). Students begin to realize that their ideas live in a social context and often there are important tensions between ideas that must be uncovered and respected. They also begin to understand that good design seeks to turn these tensions into opportunities for positive change.

express his or her opinion about what to do about the tax. Their immediate response is to refuse to pay, but then some villagers express their concern that not paying it would ruin their trading relationship with the Dutch. As the Sachem listens to and summarizes the varying opinions, the group eventually arrives at the consensus to not pay the tax.

Meanwhile, a Dutch family in New Amsterdam is having a different conversation: "I just came from town. They're saying that the Lenape won't pay the tax! What's that going to mean for the colony?" says Papa (Teacher-in-Role), as he enters the house. Antonius, upon hearing this, thinks about his friend, Little Fox. He shares his father's fears about what will happen. He is thinking not only about how it will affect the colony, but also about how it will affect his relationship with his Lenape friend. As the conversation continues at the dinner table, he learns more about what this tax is about. His father explains how he is one of the advisors to Director-General Kieft and tells them that Kieft is considering war with the Lenape. He asks his family (Students-in-Role) what he should advise about the tax situation, even though Kieft has been known to do what he wants regardless of what his advisors or the colonists think. His family members share their concerns that war would hurt trade with the Lenape: "Isn't that what we're here for?" They also discuss how unfair it is that they, the colonists, are the ones who know what's best for the colony, but that Kieft does not listen to them. "He's going to ruin things for us!"

These two scenes are happening simultaneously in two different third grade classrooms. In this part of our study, we play out the Mannahatta story through the interactions of the Lenape and the Dutch colonists, and how these interactions are complicated by historical events that unfold. These experiences are seen through the eyes of children — a Lenape and a Dutch child — who become friends. One class is the Lenape village and the other is Dutch New Amsterdam. Their homes are the environments they created in their respective classrooms for the Mannahatta Museum. Like one's own home, the Lenape longhouse or Dutch home grounds them in one perspective, and when they meet their friend in the other room, they are learning about the other culture.

This "coexistence" framework allows students to live out the interactions and problems that arise within a dynamic and diverse society. They grapple with complex problems

Designing for Social Innovation

It is in the context of these interactions that students begin to see the design and making activities they have been engaged in as having a broader purpose. The orientation to question finding and problem solving begins to shed light on the possibilities for design and making as tools for addressing pressing social justice challenges and the value to be derived from engaging in social innovation work. This focus will move to the forefront in the final future-facing phase of the project. It also sets the stage for looking at entrepreneurship through the lens of social innovation, which focuses attention on ideas and processes that create social value as opposed to individual gain. This orientation is also well aligned with core values of the school's mission.

that have been universal human questions throughout time: How do you co-exist peacefully? How do you share space and resources? How do you work out competing interests? What do you do when you reach the limitations of your relationship? Whose fault is it? How do you deal with the other, the unfamiliar?

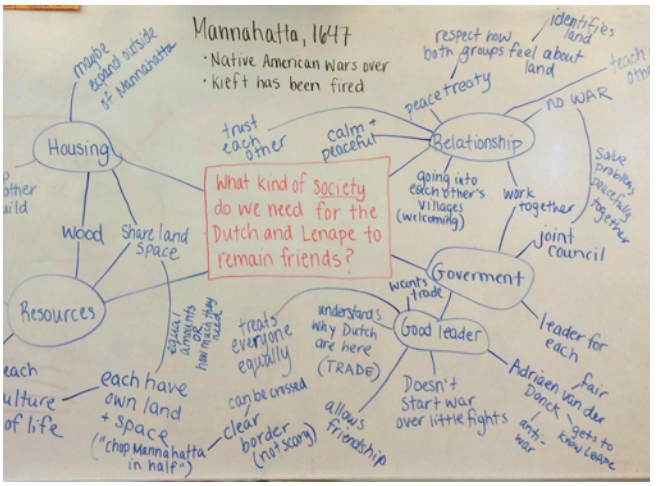
How do our students navigate these diverse views within their roles? Do they decide which view is "better"? No, they do this by being curious, by befriending.

Now that each class has experienced the fallout of Kieft's tax from their respective points of view, the friends eagerly find each other to discuss the recent events and compare their perspectives. The moments of interaction between the two friends provide opportunities for students to share the different points of view and teach each other more about Lenape or Dutch culture. For instance, in this series of lessons, the goal is for students to learn about varying perspectives on Kieft's Tax, and to gain an understanding of the decision making process (i.e. government) in Lenape and Dutch societies.

We intentionally want the students to be children — not adults — in this drama to maintain an open stance as they learn about each other, rather than having them re-enact the partisan politics of the time. However, by taking on the role of children, students are in some ways a witness to events that are driven by the adults around them. They are not the Director-Generals or Lenape chiefs solving the problems, but they have to think about how they can still have a voice within this society. They are the Lenape community members who participate in a democratic meeting or Dutch colonists petitioning against their leader. Is that enough? We don't think so. In our curriculum, we want to them to be agents of change — without having to change history.

Designing for Voice & Agency

Throughout the process, students have been asked to think about how they design for a variety of external audiences and for themselves. In addition, within the context of the drama that serves as the frame for their experience, they are able to see that every character, independent of role or status has voice. Within the context of their historical inquiry, the goal here is understanding and empathy not the fanciful creation of a "new" history. Exploration of "what might have been" is important, but at this moment connecting to a deeper understanding of how the history unfolded is important. It also helps them to understand that the history that we've inherited is not without dissenting views even though these views may not be as clearly represented in the formal historic record. At the same time, their desire to make history (the "what might be") will be addressed in the final phase of the project.



We return to our drama: (Narration - see glossary) "Willem Kieft's tax resulted in a war between the Dutch and Native Americans in the area that lasted two years (1643-1645) and resulted in extensive destruction to both Native American villages on and around Mannahatta and the Dutch colony of New Amsterdam." Dutch and Lenape parents (Teacher-in-Role) tell their child, "Even though the war is over, you can't see each other; it's too dangerous." (Narration) "The children went to bed feeling sad, but woke up knowing that they could solve the problem. They just needed to see their friend." The pairs get together to talk about what would need to happen for them to remain friends (i.e. for the Dutch and Lenape to co-exist peacefully on Mannahatta).

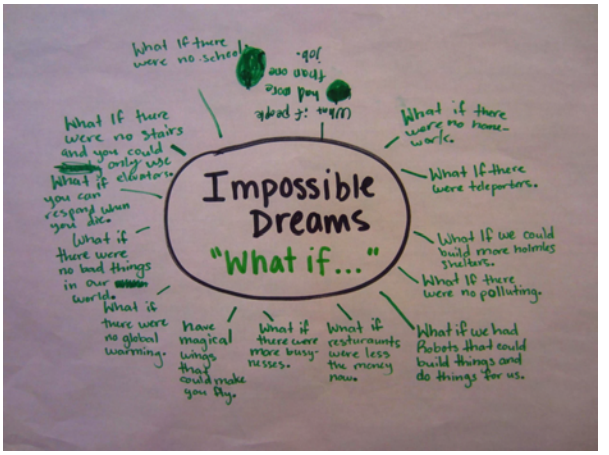
Through this "imagined-but-real" friendship, third graders are thinking about the big ideas of what makes a community work. In trying to save their friendship they identify what a complex and multicultural society needs for survival: a way to share land and resources fairly; a strong leader who allows the people to have a voice; acknowledgement of each other's differences and needs. In their design for Mannahatta, equity and respect are the essence of a successful society.

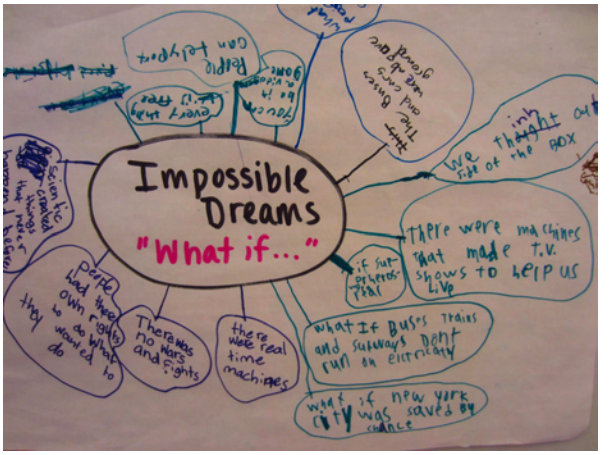
Creating the Future: Becoming Agents of Change

"New York City is in a state of emergency, and the situation is grim."

After many months of living in the past, Team X discovers their true mission: to save the future of New York City. Now the call to action they received at the beginning of the year makes sense: they must use what they have learned about the past in order to create the future.

In a way, they have been creating all along, but this time it is different. Whereas students were taking apart and putting back together existing systems, now they must come up with a whole new design. In making the City of the Future (see Note 2), students are thinking like urban planners, innovators, and entrepreneurs. They dream the impossible.





We place no limits on their creativity. The only criteria is that their inventions are purposeful, that they use past practices as a guide, and that they consider all of the parts that make up a successful society.

- "What if we could breathe underwater?"
- "What if there was no money?
- "What if everyone trusted each other so we didn't need any rules?"
- "What if there was a park next to every building?"

Students organically build on to each others' ideas and are taught to say, "Yes, and…" instead of "No, because…" They brainstorm and troubleshoot together and learn that this is a group process in which everyone has ownership in every idea that is generated. As they develop their ideas, they are invited to bring their designs back to the group for feedback: their classmates help them work through limitations that they bump up against as they turn a general idea into a complex system. "We have a food machine that distributes food to people who need it, but we're not sure where the food comes from." Their peers offer possible solutions: "What if solar panels could create energy that turned into food?" "What if everyone who has enough food gives their extra food to the machine?" "What if restaurants and farms gave some of what they made to the machine?" Students return to their plans to refine and expand them. The subsequent revisions contain ideas from the whole class.

Their project designs are blueprints for a sustainable city. Eventually each group pitches their best ideas to the class, who then votes on one project per category: housing, food, transportation, education, government, religion, community life, natural environment, jobs/work, and games/entertainment. They then begin working on their prototypes.

Their ideas are wildly utopian; they are not constrained by real world barriers. But this doesn't matter — the point at this moment is not to come up with realistic solutions to save the city, but to think like an innovator and an agent of social change. Beyond just making models for a final presentation, they are prototyping a way of thinking that could be used to solve problems in the future: Pay attention. Learn from the past. Don't give up. Make something that is different and better than what already exists. Their Team X mission to save New York City may not be real, but their sense of agency is. They know they can change the future for real.

An Entrepreneurial Mindset

The final phase of the project calls on students to work through the design thinking process and builds on their prior inquiry. In this instance, students move beyond exploring the past and are tasked with finding meaningful questions about the future and working towards solutions. This inquiry supports the development of an entrepreneurial mindset in that students are thinking and doing in a space that they have not explored before. Additionally, this work is carried out in order to achieve a desirable outcome. To do this, students working individually and then in teams must first assess the situation. This allows them to better understand the wants and needs of those for whom they are designing and the resources that are available to them. They design alternatives; some of which are wholly novel in their approach while others see new opportunity through the combination of existing solutions. Whatever the pathway, they are motivated by the idea that what they design will lead to something better that adds value. In the context of this work they learn how to advocate for their ideas and how to collaborate in the service of a shared goal.

Afterword

And so we return to the idea of the curriculum as prototype. While the design of our third grade curriculum will continue to evolve as students and teachers work and learn together, it will do so in the context of a series of scaffolded lower, middle, and high school experiences. These curricular iterations also leverage and extend the design, making and entrepreneurial skills that were essential to our third graders' experience. In so doing, our students' inquiry into the past will not only inform their present, but will inform their future as well.

Glossary

Definitions adapted from http://www.imaginative-inquiry.co.uk and https://tesoldrama.files.wordpress.com/2011/01/process-drama-conventions.pdf

Imaginative Inquiry

A teaching/learning approach that brings together three pedagogic strategies: community of inquiry, drama for learning, and mantle of the expert. Exciting and meaningful contexts for learning are used to engage students in challenging and purposeful curriculum activities.

Inquiry Learning

The curriculum is seen as something to explore rather than deliver, and children are active agents in this process. Students and teachers work together to acquire, apply, and develop new knowledge, skills, and understanding.

Drama for Learning

Using the conventions of theater (point of view, tension, and narrative), students and teachers work together to invent imaginary scenarios that give meaning and purpose to curriculum study. It is not a performance, and does not require acting. It is a role-play game where participants make up the rules and invent the moves.

Process Drama Conventions:

- Teacher/Student-in-Role: The teacher manages the learning possibilities and opportunities provided by the dramatic context from within the drama by adopting a suitable role in order to achieve such results as exciting interest, controlling the action, inviting involvement, creating tension, challenging superficial thinking, or developing narrative. Students-in-Role signifies students who are enrolled as specific characters in the narrative.
- Narration: The narrator sets the scene, signals a transition, and/or directs the characters' actions in a narrative "overlay" while

students-in-role move through the story silently (pantomime). The narration may give directions, additional information, or comment on the action of the scene or the motivations of characters.

- Rituals: Stylized enactment bound by traditional rules and codes, usually repetitious and requiring individuals to submit to a group culture. Words and actions for repeated rituals in the scene. (Example: Students use a ritualized chant or phrase to mark the beginning and ending of a "time-travel" experience.)

Mantle of the Expert

The class adopts an expert point of view within an imaginary scenario. A problem or task is established and the teacher/students use imagination to explore it. The teacher guides the drama, stepping in and out of a role as necessary, providing encouragement and motivation to the experts.

Time Travel

Using the principles of improvisation, our students "time travel" to the past. In the beginning of the year, our students design and build their own version of a time machine in their woodshop class. The creation of a physical object that they have designed gives them a sense of personal connection to their journey into the past. The physical "time machine" also helps students to bridge the divide between the concrete and the abstract by creating a developmentally meaningful symbol to help mediate their journey through time. We use a ritualized chant or phrase to mark the beginning and end of each time travel session. Rather than providing our students with a script, the time travel experience signals them to use a particular mindset to look at and interact within history. Although we ask them to envision themselves as people from the past, they are actually using their own authentic feelings, experiences, and knowledge to engage with history. Unlike performing in a play, when actors have to entirely assume roles that are not themselves, during improvisation, participants bring a sense of self-awareness while still trying to imagine how someone else would behave or respond within a given context. In this case, the context given is a problem that a group of people may have faced in a certain time and place from the past.

Notes

All quotes from Agnes De Lima are from the book, *The Little Red School House*.

Lima, Agnes De. *The Little Red School House*. New York: Macmillan, 1942. Print.

Note 1:

(1) Mystery Time & Place Artifacts (Amsterdam, 1600s)

In addition to a variety of physical objects (e.g., Dutch bonnet and spindle), students also explore a number of primary source print materials:

Additional "artifacts" like the two examples below help to frame students' inquiry around the "experience" of those who lived in the past. In this way, students come to see the narrative dimension of their journey to and investigation of the past.

Drama: Merchant Comes Home to Family

Time machine set by X (unknown time/place)

FATHER:

- "Come, children, look at what I brought home!" — show beaver skin, ask if they know what it is
- "This was brought back from a far away place across the Atlantic Ocean! Not many people from Europe have been there — only a few brave explorers — men who sail to unknown places all over the world to see what's there — have been there. Henry Hudson is one of those explorers, and his ship just got back a couple of days ago, and news has been traveling fast. They say that this place is covered with forests, with plenty of wild animals living in it—beavers, muskrats, otter, mink, raccoon, rabbit, and deer… And there are people living there too, who are very different from us."
- "Do you know what this [point to fur] means for us? The hats that I make in my shop are made from this fur. But over the years, it's been harder and more expensive to get beaver fur. The land that we have been clearing to build farms and cities over the years has destroyed the beavers' habitats, and so they have been disappearing."
- "These beaver fur hats are so popular now — if you own one of these hats, it's a sign that you are rich and important, and so, naturally, everyone wants one. My business would be booming if I had more fur to make more hats. If it's true that there are beavers all over this new world across the ocean, imagine how much business I could do! Imagine how rich our family would become…why, I could pass the business on to you, or you [pointing to students]!"
- "This is a new time — not like before, when we only had what we could make or grow here at home. Now, there are ships coming and going, bringing back goods from places all over the world — China, India, Africa… My hats could be shipped to all these places to sell!

From the Journals of Henry Hudson:

January, 1609

I have just been named captain of the ship, "The Half Moon"! I signed a contract with Dutch business merchants who want me to find a new route to China and India so that they can trade goods more easily. This will be my third voyage in search of a shorter and faster way to get to Asia. Even though my first two voyages were unsuccessful, and we had to turn back after months of sailing and searching, I am certain that this time I can find a way to Asia by sailing across the Atlantic Ocean.

If I am successful, it will bring me fame and fortune. Not only will it bring more business to the Dutch merchants, but I will be able to trade goods too. More importantly, I will be known as the explorer who found a way to Asia that no one knew about and that no one believed was possible.

September, 1609

We have reached the land that is across the ocean, and while we have not yet found the opening that will lead us to the Pacific Ocean and to Asia, we will rest here a few days, replenish our resources, and hopefully trade goods with the natives who live here.

I sailed to the shore in one of their canoes with an old man, who was the chief of the tribe consisting of 40 men and 17 women; these I saw in a well constructed house of oak bark and circular in shape.

The land is the finest for cultivation that I ever in my life set foot upon, and it also abounds in trees of every description. The natives are a very good people.

Their food is maize or Indian corn which they cook by baking and it is excellent eating. They all came round the ship, one after another, in their canoes, which are made of a single hollowed tree; their weapons are bows and arrows, pointed with sharp stones, which they fasten with hard resin. They had no houses but slept under the blue heavens.

Note 2:

Using Imaginative Inquiry to teach about the past was first introduced to Elaine by progressive educator and Imaginative Inquiry consultant, Kelli Dawn Holsopple, as part of the Phoenix Theater's In-Flight artist-in-residency program at the East Village Community School (EVCS) in New York City. The "Secret Time-Traveling Archaeologist Mantle"(see Thinking Like Social Scientists) of the entire class becoming enrolled as a secret "Team X" was first piloted in a third grade class in 2009, with subsequent iterations implemented in grades 2-4 at EVCS, and then at the Little Red School House (LREI), starting in 2012.

The concept of "becoming" the team through application letters and tests, including the "Riddle" to learn from the past to create the future was part of the mantle devised and initially implemented by Kelli, and has served as a framework to drive and give purpose to the third grade curricular study of early New York history. The "Emergency" lesson (see Creating The Future), in which the high stakes problem of the city needing a plan for the future to save the plants, animals and people, in the form of an emergency news report, was scripted and originally filmed by Kelli, thus leading to the creation of the City of the Future projects.

We are grateful for the ingenious work and ongoing inspiration Kelli has bestowed upon our craft, as teachers of history, social justice, and young, powerful minds.

For more on Kelli Dawn Holsopple's work, see: http://blog.communityworksinstitute.org/2016/04/29/ecstatic-learning-an-invitation/

Note 3:
The idea of connecting the three time periods of New York City history — 1515, 2015, and into the future — was inspired by Eric Sanderson's research and ideas in the book, *Mannahatta* (Abrams, Inc., 2009), in which Sanderson, a Senior Conservation Ecologist at the Wildlife Conservation Center in New York, explores Manhattan's geography and biodiversity in 1609, 2009, and posits a vision for the year 2409. For more information, visit the Mannahatta Project website at https://welikia.org/ .

Note 4:
We recognize there may be some question about what it means to have students "dress up like" or "act like" Native Americans. Our goal is to set up contexts and problems in which our students can imagine and learn about life as a Lenape, without them thinking they really are Lenape or acting like them in a stereotypical way. This is why we present the learning experiences within a process drama framework, where students know that they are actually themselves: we tell them that they should imagine what it would be like as Lenape in that situation, but that they are going to respond using their own feelings and experiences. This "acting like a Lenape" is really an exploration of a problem within a historical context. Our students do not try to pretend to speak like someone who doesn't speak English or use an accent; we recognize that the Lenape did not speak English, but that we are speaking it in order to understand each other. They also do not dress up in costumes, but instead rely on their imaginations to visualize the experience (for example, they can imagine they are using a spear for fishing). On occasion, we (the teachers) use a small prop to mark a shift between characters. These items are meant as a symbolic tool, not an imitative costume. Not only does the process of teaching through drama not require dressing up anyway, but we are also recognizing a cultural sensitivity.

Startup 101: An Entrepreneurship Experience for Students

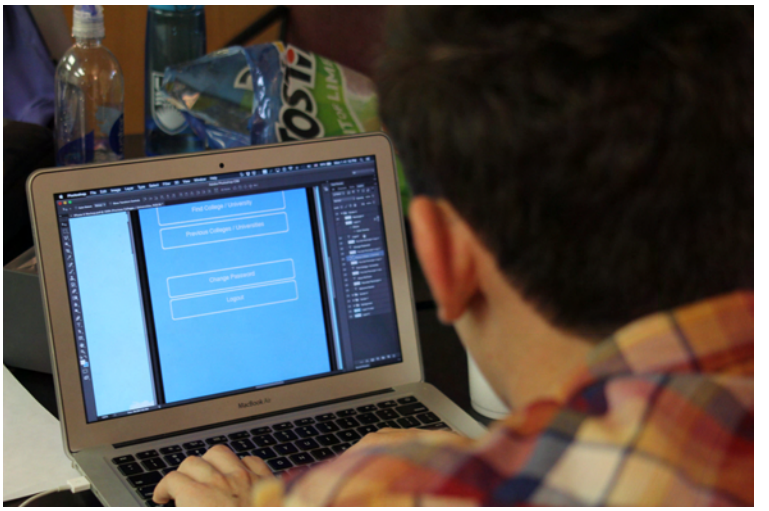
Reshan Richards
Montclair Kimberly Academy
Montclair, NJ

Abstract

Startup 101 is a one-month, intensive entrepreneurship experience for high school seniors at Montclair Kimberley Academy (MKA) in New Jersey. The experience is one of many choices that graduating seniors can apply to take part in during MKA's May Term, a flexible, passion, and interest-driven program where students can travel on school-organized trips, intern at companies, conduct independent research, writing, and art projects, partake in community service, or recently, become a member of Startup 101.

In June 2016, Startup 101 successfully concluded its second year. In both iterations, nine students undertook an design challenge where they created their own companies, identified problems they felt were worth solving, researched and created prototypes of their solutions, and pitched their work to a panel of investors and industry experts. All of this took place in approximately 20 school days in both years. Both groups chronicled their work on their blog at http://startup101.mka.org .

Told from my perspective as a facilitator and with quotes and insights from students, this chapter outlines the Startup 101 program by describing the general setup, the building of the team, the four-week course period, and the culminating pitch event.



Introduction

In May 2015, for the first time at MKA, nine high school seniors were brought together to identify problems, brainstorm possible solutions, conduct research, build prototypes, and ultimately pitch their ideas to a panel of venture capitalists and industry experts. My growing interest had been in creating and supporting the structures and spaces necessary for this kind of work to take place. I also had a growing interest in getting out of the students' way: getting out of their way of learning, their independence and autonomy, their meaning-making.

I had first pitched a 'Startup 101' course idea to the high school administration at MKA, but they found that it was hard to find a place where such a course might fit. What department would it go under? What graduation requirement would it fulfill? I also proposed this course on a foundation where there would be no set schedule, no tests or traditional assessment methods, no single teacher, and no grades. This, too, did not fit with the traditional course mold at MKA. One member of the administration suggested making it a May Term offering, available just to seniors. An advantage would be that instead of a once or twice per-8-day-cycle elective course, a May Term course would allow students to work on it, and only it, from 9 a.m. to 3 p.m., Monday through Friday, for an entire month. This is what we went with. It could serve as a prototype for possible future electives or similar offerings in which more students would have the opportunity to participate.

I carried in my imagination an idea of how the course might function, but without any evidence of success or concrete ideas of how it would go, I was not sure how seniors would respond to the offering when I first pitched it to them, especially

considering that Startup 101 was competing against travel abroad, service learning projects, independent endeavors, and so on.

A student from the first cohort, Heather, said, “I became interested because, for me, the opportunity was unprecedented—creative, collaborative, and interdisciplinary. I applied to the team, hoping to be able to write and research, areas which I have always enjoyed, while also having the opportunity to further explore computer programming, a budding interest of mine. The endeavor seemed like a productive and rewarding way to spend a month.”

Heather was not the only student who felt this way. By the time applications were closed and reviewed, I had nine students willing to take a risk and work in Startup 101 for a month.

I had framed Startup 101 for the students by proposing that they would try to design and develop a product or service in one month, visit and learn from interesting companies and people, and pitch their idea(s) to investors and industry experts. I had not secured most of these elements when I pitched the offering to students, but by the time May Term rolled around, we had an outline for the design process for the month, visits scheduled to places like Google and Facebook and Techstars, and a group of five panelists confirmed to listen to the students’ ideas at the end of the month.

Building the Team

There needed to be an application process for two main reasons. First, the school had to know how many students (if any!) would be interested in participating in this venture. Second, I knew that a diverse set of interests, talents, and perspectives would be needed in order to successfully brainstorm, research, develop, and test ideas in such a constrained period of time.

The application was fairly simple. Students were required to send a simple email where in the body, they identified one or more of five designated areas in which they, the students, were genuinely interested. Interested, not experts.

These areas were: Visual and Graphic Design, Coding and Programming, Business and Finance, Research and Writing, and Social Media and Communications.

Students were asked to include evidence that they were indeed interested in the area(s) they selected. This included sharing samples of work done both in and out

of school. Some students sent links to their website or online portfolios. Others submitted papers they had written or slide decks on which they had collaborated. Some submitted snippets of code and compiled programs.

Finally, students needed to submit a 60 second (or less) video describing why they wanted to be a part of Startup 101. This was kind of like an asynchronous interview.

The area selection, the evidence, and the video all needed to be included in the email, either as attachments or as a clear breadcrumb trail of links and directions for accessing the materials. A panel of faculty and administrators who knew the students well reviewed the applications. In both years, not all students who applied were able to participate.

A student from the second cohort, Isaiah, said, "I really enjoyed my Economics Honors class and doing research, so I figured that I should apply with an interest in 'Business and Finance' and 'Research and Writing.' Other options existed for those interested in computer science, marketing, and design. I knew going in that I wanted to spend time immersing myself in the economics of starting a business and Startup 101 would provide the experience to fulfill that desire."

Day One

I planned to lead the students through a version of a design-thinking framework, as I was already using it in several other teaching endeavors. With the time, structures, and talents available for May Term, design thinking was a good fit.

On the first day, I shared the norms and expectations I had for the students and the program. They were fairly simple: I needed to know where they were from 9 a.m. to 2:30 p.m. Monday through Friday if they were not going to be in the workspace or not on a site visit. So, if they had an AP Exam, a game, or other extracurricular event, I just needed to know. If they wanted to stay home and work remotely (or go to the beach), that was fine too. I just needed to know where they were.

I also provided the students with an outline of each week and how I planned to structure the design process. The first two weeks would be focused on empathy, ideation, and research. Prototyping (and more empathy, ideation, and research) would take place during the third week. The final week would be preparing for the pitch. Sprinkled in would be visits to companies based in New York City and visits from local entrepreneurs.

I also let them know that I would not be present in the room at all times. We would have a Monday kick off meeting and a Friday wrap-up meeting. Other than that, I would drop in when I could, I would communicate online (we used Slack for this purpose), and I'd see them on the trips.

In both iterations, I made it clear that I was not sure what the outcomes would be but that I would do my best to lead students through a unique experience and give them as many chances as I could to make meaning.

A student from the first cohort said, "The first day of Startup 101 was exciting and overwhelming. I was surrounded by eight other students, all with various talents and interests, with whom I would be working for the next four weeks. Initially, the task itself seemed daunting and no one knew where to start. We all wondered if it was even possible to become a startup company at such an accelerated pace. Yet, with an introduction to creative brainstorming, we were on our feet. We felt total ownership of our company and our project. There was so much value in being given autonomy, and had Dr. Richards acted as our 'CEO' or a typical classroom teacher, the experience would have lost something."

The Workspace

After finalizing the team, the next step was finding a space for them to work at school. It would have been too expensive to rent an office space off-site. Adult presence would have been tricky at some of the school-owned facilities that were not tied to the main campus. However, we eventually found a classroom that was used only once per cycle in May—a biology laboratory. The teacher who normally used the room agreed to hold this class in a different space for the month.

My original plan was to set up the room on the Friday before the students arrived for the first meeting. However, other things came up and prevented me from being able to get to the space with enough time to unbox the small items I had purchased, such as lamps and pillows, move things around, and so on. That Monday morning, one of the students saw the boxes and was genuinely excited about the prospect of unboxing and building IKEA furniture and accessories. It was then that I decided to let the students design the space in the way they wanted. I left the room and told them I'd be back in a few hours. I was more than surprised, and more than impressed, with what they did to transform the room.

One student shared, “Our office was a dimly lit basement science classroom with rows of tables facing a whiteboard…but not for long. We pushed the tables together into the middle of the room to serve as our collaborative conference table. We made the space welcoming and comfortable, complete with a couch, chairs, lamps, pillows, a beanbag chair, snacks, and a Keurig coffee maker. One of the team members even brought in an Xbox from home, which we hooked up to the whiteboard projector. Our space quickly went from dungeon classroom to teenager’s paradise. While I initially thought such a relaxed workspace might derail productivity, that wasn’t the case. As it turned out, we looked forward to being there all day, every day.”

Visitors

Being situated at a school, there was access to many people to invite to the workspace both formally and informally: parents, teachers, local business people, alumni, friends of friends, and so on. Most of the visits happened serendipitously. For example, I had reached out to two alumni whom I was connected to via the Economics teacher. These alumni had started a local Pilates studio. I had initially reached out to see if one of them would be interested in being on the pitch panel. In our email exchange, I welcomed them to come and visit the students, and they immediately jumped on the invitation.

A student shared, “People coming from the outside helped us achieve a new level of understanding of our product as well as an eloquence and clarity with which we explained our idea. Second, it was tremendously helpful to have access to the ideas of professionals who were well-versed in entrepreneurism, business, advertising, and more. These visitors were able to give us an unbiased perspective and ask us the difficult questions we could not ask ourselves.”

Another student added, “We were lucky to have a number of people stop by our office to learn more about Startup 101. These guests were school administrators and trustees, small business owners, a marketing specialist, and curious students who wandered into our workspace. These guests were valuable for two reasons: practice and perspective. First, we needed to learn how to explain our company, product, and business plan, as well as field questions in preparation for our final pitch at the end of the four weeks.”

Another interesting serendipitous example from the first cohort was when I noticed an unfamiliar face in a photograph. I supported the posting and publishing on the students’ blog. One day, a student sent me the daily photos and text and there they were, hosting a meeting with someone whom I did not

recognize. I was wondering, “Who is this guy?” It turns out he was a seasoned marketing executive from a Fortune 500 company who had a connection with one of the Startup 101 team members. It was exciting to see the students understanding the concept and power of networking and asking questions. In my experience, people who are experts at something usually also have a passion for it and are excited about sharing that passion with others.

Visits

Being in close proximity to New York City certainly has been helpful to the program, simply because of the density of companies and entrepreneurs. For many of the connections, I used my network to schedule a tour or an office visit. For others, I just reached out to whomever I could find on a contact channel. However, proximity to a big city like New York is not critical to arranging interesting visits. There are entrepreneurs and businesses in every town, every city. And there are people who know them in every school—friends of friends, family, family of friends, and so on. It is simply a matter of reaching out to them and discovering if they are excited about the opportunity to meet with motivated learners and share their insights and experiences.

Aleezae, a student from the second cohort, said, “We took frequent field trips into the city, where we visited a number of companies beginning with 53 and concluding with Facebook. Personally, I gained the most knowledge from these field trips because they allowed me to see what working in a startup environment is really like. Aside from the pretty buildings and freeform workspaces, these field trips allowed me to hear not only the benefits of working at a startup, but also

prepared me for the challenges. We saw how different areas functioned and that while its possible to fail at a startup, there is still a chance of success. The advice we received was not only beneficial to out project, but to our lives and we will remember it as we move on from Startup 101."

Design Process

One of the biggest challenges when engaging in a design process is problem definition and articulation. Many people will focus on a product or solution without first defining and articulating the problem that is meant to be solved. An important part of this process, then, is to consider the perspectives of those whom the problem impacts most directly or most often. This empathy-oriented viewpoint is the key catalyst for brainstorming ideas.

Empathy and Ideation

I brought in a few gadgets and games during the first few days to give the students things to think about. It is one thing to think a technology, service, or activity is cool or fun, but it is a whole other thing to think about the genuine problems the technology, service, or activity might solve.

After defining the problems they were interested in solving, the students then needed to propose as many ideas towards solving the problem. A student shared, "We started off brainstorming over fifty unsolved problems, writing them on sticky-notes, and categorizing them into columns on the whiteboard (entertainment, education, organizational, news, sports). We discussed endlessly, narrowing down to our ten favorite problems. Then, we each took a problem and researched possible solutions, including the target audience, profitability, and potential competition."

In the first cohort, the nine students all focused on one problem: college admissions tours. In the second cohort, two discrete problems were worked on by different teams: street parking and dorm room supplies. In both cases, it was wise for them to settle on problems that they themselves had recently experienced or were currently experiencing. There was built-in empathy. Their peers and their family members also had some connections with them.

Research

Observing students researching for Startup 101 has been an enriching experience for me. I told the students that they needed to conduct research for two main purposes. First, they had to validate their problem. They needed to prove that it was real. While a group of nine (the team themselves) is a decent small-sample size, it was important to find out that their declarations were not just based only on their own perspectives or feelings. Fortunately, they had access to hundreds of other students in their school, and then hundreds more through their extended networks and on social media.

Second, as they settled on ideas and solutions, they had to research the validity of those solutions: practicality, usability, and demand. What else was on the market? Was there competition? Had anyone created a similar solution for a different (but parallel) problem? A student from the first cohort shared, "Target audience, product relevance, profitability, competition, cost, market strategy, business models — you name it, we researched it. Admittedly, when it came to research, we relied most heavily on our team members who had some experience or interest in business; however, what was great about having a diverse group is that each person's strengths benefitted the team. At the end of the day, research was something we all contributed to."

Another student shared, "Research for us was more than just Google searching. We set up conference calls with businesses that were using similar technology and concepts, and gained valuable knowledge from our visits to NYC and our in-office visitors. We sought information that might be relevant to us in every way we could, which ensured we were all prepared to answer any questions that could arise regarding our company and our business model, particularly during the final pitch."

Prototype

The groups made some innovative moves when creating their prototypes. They made visual proofs of concept, they made functional proofs of concept, and they made a combination of both. For all three products that have emerged from Startup 101, there was something that could be visually shown to give potential users (and investors) a very good sense of what an experience using the product or service would be like.

A student from the second cohort, David, said, “Not everything fell in to place as soon as we decided on an idea; up until the morning before our pitch, the minimal viable product that we made was still crashing and not completely working. Working on a prototype is unlike any kind of project that you are assigned in school: at any time the parameters change, from an app, to hardware, to a website, back to an app again. But as my time with Startup 101 came to a close, our app came together faster than I could have expected. Sure it is just a minimal viable prototype, and does not fully implement all that we had planned for, but in the end, it did what we needed for a successful pitch.”

Heather, from the first cohort, shared, “We could have kept improving our visual design and adding more capabilities to our proof of concept, but we were working under a compressed timeframe. Ultimately we had to ask ourselves: Does this prototype convey, on the most basic level, what we want the app to look like and what we want the app to do? While it was far from perfect, the prototype got our ideas across. We counted it as completed and moved forward.”

Iteration

Revising and refining solutions are ongoing parts of every step in a design process. Whether it is ideation, research, or prototyping, they all provide the additional information necessary for going back and making the problem clearer and the solution a better fit. When thinking about pitching, the articulation and communication of an idea require an equal amount of revision and refinement to the product itself: the problem statement, the business plan, the demo, and the language. All of these things need many eyes and many hours of practice.

A student shared, “The most difficult part of Startup 101 was the revision process of each of the three major components–business plan, prototype, and pitch. The end of May Term was quickly approaching, with many revisions still to be done. As I mentioned before, it was hard to move on from the prototype, which we wanted to keep updating as new ideas came to us. Even a few small arguments broke out among us. Those spats served as lessons in collaborating under pressure—they were quickly resolved and our team became stronger because of them.”

During the final week of the first cohort, I went into the workspace and things seemed quite tense. It was two days before the pitch, all the members were there, and all of them were passionately arguing their points and perspectives. You might think I would have been concerned, but in fact it was just the opposite. I

knew they would be prepared for their pitch because it was clear that each and everyone one of them cared about what they were doing.

The Pitch

For both cohorts, I reached out to a few people in my own network as well as some alumni from the school to find individuals who would be interested in being panelists. The panel consisted of five members: venture capitalists, industry experts, and startup founders. Each product would have about ten minutes to pitch their idea and then 10-15 minutes of questions from the panelists. I encouraged the students to invite friends and family, and the school invited faculty members, administrators, and alumni.

Sara from the second cohort, said, "After thirty days of brainstorming, researching, and developing the group's work through the month of May was finally ready to be presented. Everyone's nerves were a little high, but overall we all knew that we were prepared. We had four sections; so four people would be speaking. This was a completely democratic process and everyone simply wanted to do what was best for the group, whether that meant speaking or not. We ran the presentation as many times as we could before the pitch and finally felt ready to go. At seven o'clock we stood in front of the panel and delivered a pitch that we were all proud to be a part of."

A student from the first cohort added, "We took the pitch very seriously. Our team had decided somewhere during our month together that our idea was worth pursuing after the Startup 101 program officially ended. So, when presenting our ideas to a group of investors and entrepreneurs, we ultimately sought support and constructive feedback so that we could keep moving forward with our idea. The pitch was the end of Startup 101, but we also hoped it would be just the beginning for our company."

During the demo evening, they pitched their product and received critical but fair feedback from the panelists. From there, with both cohorts, a few students continued working on their respective projects after the conclusion of the Startup 101 course.

Next Steps

How can you bring this to your school or institution? Thinking like a designer, like an entrepreneur, has no age minimum and no single discipline that it needs to fit into. Especially in schools, young people have access to experiences — and

people with the same experience — that no older people can relate to as well as they can. Young people are the best positioned to solve problems that other young people face.

Not all entrepreneurial projects have to be intensive. For example, early childhood students can come up with new ideas for improving the home of their class pet (hamster, fish, chameleon, or whatever it might be!). Why not design and patent an idea! Middle school students can innovate solutions for reducing waste in the cafeteria. Think about how many schools there are in the region (or nation) that might benefit from that idea! High school students can design new communication systems for coaches and players. A useful solution might be applicable at the collegiate or professional level.

There are many interesting problems to be solved in schools, and who better to solve them than those students who observe and experience them the most closely?

Working the Near and Far Network

A good first step as a leader interested in bringing a Startup 101 experience to his or her community is to "work the network." This simply means talking to people, near and far, closely connected and loosely connected, about opportunities to leverage their strengths and interests in the service of student learning. Perhaps you have friends or families doing interesting entrepreneurial work. Or maybe members of the art department at your school are connected with the local design community. The parents and guardians of your students may have connections to people doing interesting work. Or how about taking a walk in your local town center and speaking with the small business owners? Your town may even have small business bureau you can contact.

You can also do one of the things that I did to get my foot in the door of some businesses. Look up interesting companies with offices nearby and simply send them an email describing the entrepreneurship project. 100% of my emails got responses, and many of them lead to visits. If there is no one nearby, you can always set up a videoconference or interview. Students in Startup 101 communicated with members of companies located all over the world. They did not let distance or time keep them from learning.

The Startup 101 experience is evidence that students can succeed when there are clearly defined norms and boundaries, when they are given access to people, places, and ideas, and when the teacher gets out of the way of their learning as much as possible.

Moving Beyond the Drive-By Model for Professional Development

Don Buckley, Tools at Schools
Eric A. Walters
Marymount School of New York
New York, NY

Abstract

According to makered.org, maker education will allow for "building a new body of practice in teaching making—and a corps of practitioners to follow it." In this chapter, we will review Marymount's Making and Learning Institute, an innovative immersion experience in maker education, global education, and transformative teaching and learning practices, as well as discuss the highlights and challenges of a new form of professional development.

Making as a Disruptive Force in K-12 Education

Technology has disrupted teaching and learning as we know it. Instant and universal access to information has dramatically changed the role of the teacher. As a result, teachers cannot merely follow a set curriculum for each discipline if the students are what Alan November calls, "owners of their own learning." New curriculum goals should target the true transfer of understanding and require learning to be interdisciplinary with a focus on critical thinking, collaboration, and effective communication.

According to *How People Learn*, "Transfer requires learners to actively choose and evaluate strategies, consider resources, and receive feedback." In contrast to a traditional classroom, the quick prototyping that happens in a "maker space" allows students to consider all resources and materials, evaluate strategies, and receive feedback if the prototype does not serve the intended function. Learning becomes meaningful to children as they define a problem, imagine a solution, and use diverse materials to build their solution to quickly determine whether or

not their idea "works." In his recent book, *Invent to Learn*, Gary Stager wrote, "Making things provides a powerful context for learning." Further, Piaget suggested that it is not the role of the teacher to "correct a child from the outside," but to create conditions in which the student corrects herself.

In order to create a broader ecosystem for "making" in schools, we must first consider refashioning, from the ground up, the role that teachers play in helping students imagine multiple solutions to problems. The goal is to encourage teachers to plan environments where students can "make things" in order to satisfy their own natural curiosity and discover the interaction of systems in the world. This innovative mindshift can only take place if teachers are provided time and space to tinker, ask questions, work with others, and develop the skills necessary to foster a culture of making. Although teachers and educational leaders are beginning to recognize the benefits of making in schools, so few educators actually know how to use digital fabrication tools in concert with rapidly changing technologies. It is critical to give teachers a guided yet exploratory professional development experience in the use of making as a mode of transforming teaching and learning. The use of digital design and fabrication tools will play a large part in redefining teaching and learning in classrooms.

Making and Learning at Marymount

Marymount School of New York, an all-girls, N-XII Catholic day school, was founded by the Religious of the Sacred Heart of Mary (RSHM) in 1926. Known for its commitment to science, technology, engineering, math, and design thinking, Marymount values tradition while simultaneously encouraging innovation and experimentation.

In 2011, Marymount opened its first makerspace, the Fab Lab (Fabrication Lab) at our 97th Street Campus. This Fab Lab was the first of its kind in a K-12 school in the country. Opportunities grew for students to tinker, experiment, play, take risks, strategize, and design solutions to real life situations and challenges. In 2013, the IDEA Lab opened at the School's Fifth Avenue Campus, advancing the culture of making across the curriculum and across divisions. In 2014, Marymount opened the TinkerSpace at our Fifth Avenue Campus for students in Pre-K through Class II and the STEAM Lab at our 82nd Street Campus for students in Classes III through V.

Making and Learning Institute (MLI): Year One

Immersion Experiences

The traditional model for professional development often features a speaker, followed by a question and answer session. We consciously decided to reimagine the professional development opportunities offered through the MLI to be opportunities for immersion in the culture of making at Marymount, as well as conversations with student and faculty makers.

Over the course of 2014-2015, we offered five such experiences that followed the general schedule below. Five different experiences were offered in 2015-2016.

8:30 a.m.	Arrival
9:00 - 9:15 a.m.	Overview of Making and Learning at Marymount
9:15 - 10:00 a.m.	Low Resolution Design Activity
10:00 - 10:45 a.m.	Conversations with Marymount Makers
10:45 a.m. to noon	Tour of Marymount Maker Facilities

A MLI participant works on her low-resolution design that will "make my students better learners."

In order to facilitate meaningful conversations with Marymount makers, we moved away from the traditional Powerpoint presentation approach to an exhibition model. Faculty and students were stationed at tables around the lobby. A variety of projects and disciplines were featured, including the Class II Invention Convention, the Class III Cardboard Challenge, the Class IX Curator's Gallery, and the Class XI Physics, Design, and Social Justice Project. In addition, divisional projects in design and writing and technology infusion in the world languages were on display. MLI participants could visit one or more exhibits, and engage in deep, meaningful conversations about the making and learning process in the classroom.

After tours of our maker facilities, both at our Fifth Avenue Campus and at our 97th Street Campus, participants had the opportunity to engage in conversations about maker education in their own school. Each cohort of participants left the immersion experience with a deeper understanding of the potential impact of maker on teaching and learning, with a toolbox of ideas for implementing making activities into their curriculum and with an overview of how other schools have made this paradigm shift.

Maker Day @ Marymount

Each year, Marymount hosts Maker Day @ Marymount, a small-scale version of the popular Maker Faire held annually at the New York Hall of Science. This free, day long event is for educators, students, parents, designers, and makers to present projects, attend workshops, and explore how digital fabrication and making are reviving and inspiring our classrooms.

In 2016, keynote speaker Fred Kahl challenged the participants to consider how making is not only changing the way we think, but also the way we learn, as he wove the concept of making through New York City's history as a innovation and creativity center.

Mr. Kahls's keynote was followed by a series of student-led and teacher-led workshops, including workshops on Scratch programming, using student-built sensors in the science classroom, littleBits technology, and innovative strategies for maker education in the K-12 classroom. Maker Day @ Marymount 2016 was attended by over three hundred participants. Maker Faire @ Marymount, co-sponsored by Maker Faire, will be held on Saturday, April 8, 2017, in collaboration with the annual RoboExpo, an event for students of all ages, with a shared interest in robotics, to come together to pursue similar goals or to express themselves uniquely.

Two Maker Day participants enjoy a workshop on stop motion animation.

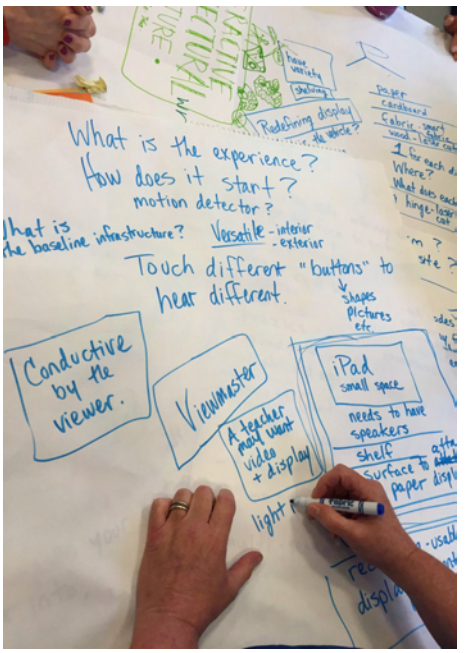
Additional Workshops

The MLI also supported additional workshops that fostered a deeper understanding of the transformative nature of making and learning in K-12 education. These included:

1. Making, Tinkering, and Engineering in the Classroom in a Reggio Emilia Context with Gary Stager and Sylvia Martinez. This all day workshop focused on "project-based learning, making, tinkering, and engineering." Moreover, "powerful ideas from the Reggio Emilia Approach, breakthroughs in science education, and the global maker movement [are] combine[d] to create rich learning experiences for the participants." (Source: inventtolearn.com)

2. Make Making Happen Workshop for STEMTeachersNYC. This local organization is dedicated to the interchange and interaction among teachers of various STEM disciplines. Their general purpose is to cultivate excellence in STEM teaching and to promote learning, self-confidence, and success for all students. In this half-day workshop, educators visited the 97th Street Fab Lab to not only explore the various tools available for maker educators, but also to collaborate on both low-resolution and high-resolution projects to enhance or extend the curriculum.

Design, Do, Discover



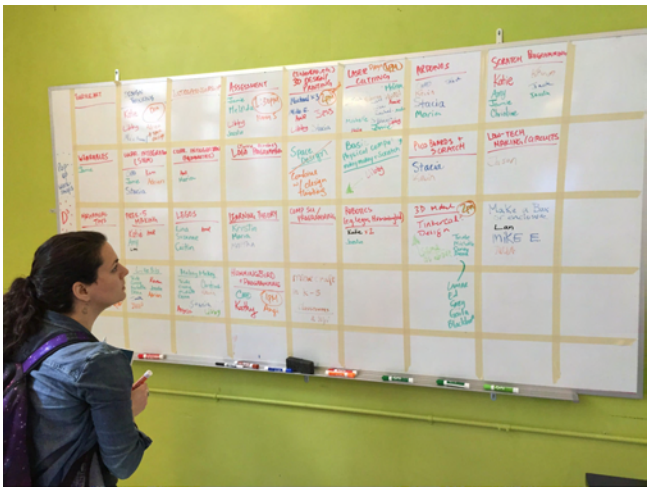
A Design, Do, Discover team plans their project.

This two-day workshop, co-coordinated with the Castilleja School in Palo Alto, California, served as the capstone event for the Making and Learning Institute. The workshops brought together educators who are passionate about hands-on learning, as well as the practical implementation of these experiences in the classroom. In particular, the focus is on the infusion of digital fabrication, making, and physical computing projects into the daily life of the K-12 school.

The objectives of the workshop were:

1. Provide an overview of digital fabrication labs and makerspaces and the types of projects that can be done in these spaces.
2. Learn about the different models adopted by schools to integrate these learning spaces into the curriculum.
3. Collaborate in teams to identify, ideate, and prototype hands-on projects relevant to their teaching.
4. Gain hands-on experience with major tools found in a digital fabrication lab, such as the laser cutter, 3D printer, and programmable microcomputers.
5. Meet like-minded educators and become part of a community of fabbers and makers working in education.

Participants worked either individually or in teams on a project of their own choosing. Instead of providing a formal slate of workshops, we opted for a modified "unconference" model, in which workshops of interest to participants were proposed and developed "on the fly" as needed.



A participant reviews the schedule of "pop-up" workshops at D3.

The projects were as varied as the participant population and featured the effective use of the NXT Brick, Arduino, Makey Makey, and Raspberry Pi, with project construction facilitated by the use of the 3D Printer, CNC Milling Machine, and Epilog Laser Cutter.

D3 was attended by over eighty participants worldwide. They had the opportunity to work with an internationally recognized team of makers and designers who served as mentors for the workshop. To quote one participant, "I have never been so challenged in my teaching career but I've also never been so inspired to collaborate. D3 has truly changed the way I look at my British Literature curriculum."

MLI: Year Two

In 2015-2016, the scope of the MLI was expanded to include an additional focus on both global education and the interdisciplinary relationship of STEM and the humanities.

Students pose next to a poster advertising #edcampgloabled @ Marymount

EdCamps are free, inspirational, participant-driven collaborative professional growth experiences. Edcamps are conversations. The schedule for the day is generated at EdCamp. Participants can lead any session, as long as they have an idea, question, or conversation related to the EdCamp theme. EdCamp sessions can be whatever participants want it to be!

On October 24, 2015, the MLI hosted #edcampglobaled, a global conversation that celebrated the global community. At Marymount, students and faculty are equipped with the lenses of empathy and respect, and they develop cross-cultural understanding by imagining possibilities through multiple perspectives. Marymount is part of an international Religious of the Sacred Heart of Mary (RSHM) network of schools, a borderless community that shares common goals, criteria, values, and vision. The RSHM Network spans nine countries and three continents. Regular exchanges occur throughout the international network, and Marymount students and faculty identify themselves as global citizens.

The objective for #edcampglobaled was simple: "Do you want to make global connections, promote global literacy, or engage in a conversation about global programs? You will connect with your peers locally and have the opportunity to interact with students and teachers virtually from across the globe."

The main theme that emerged at #edcampglobaled was developing a definition for global education.

Model 1: As a learner, I am stationary but information comes to me and raises my awareness of key global events and issues.
Model 2: Building perspective through peace.
Model 3: Sharing resources but moving away from a patronage and philanthropic model and towards an integration and companionship model.

The conversation at #edcampglobal revolved around how the following concepts and ideas may be used to either support the three models above or how those three models may be used to transform the above concepts and ideas.

- Virtual Field Trips
- Educational Technology Professional Development
- Conferences and Events
- Maker Movement
- Power of Images

Hacking the Essay Workshop

In order to expand the definition of making and learning and to ensure that the humanities are not excluded from the conversation, the MLI hosted a workshop entitled "Hacking the Essay" with a team of educators from the Convent of the Sacred Heart in Greenwich, CT on Wednesday, November 11, 2015. The interactive workshop focused on the humanities and STEAM learning, with a specific focus on project develop and assessment, as well as researching, archiving, and blogging about maker space projects.

Hacking the Essay participants work on deconstructing a text

This workshop had the following goals:

- Hacking traditional methods of research, writing, documentation, and presentation.
- Exploring a new mindset and process in teaching and learning that connects making with the humanities.

Participants worked on a variety of learning activities, including:

- Using visual notetaking as well as info- and sketch-doodling in deconstructing Annie Dilliard's *An American Childhood* and Virginia Woolf's *To the Lighthouse*.
- Using Universal Methods of Design as a basis, reimagining the standard city bus stop through bodystorming, interviewing, critical incident techniques, surveys, personas, and measurements.
- Using curated, interest-driven research in tandem with the creation of graphic representations in a makerspace for middle school English/arts.

<u>Explore the Mobile Makerspace and littleBits</u>
Marymount was already using littleBits, a modular electronics kit, as a tool in our Lower School and Lower Middle School curriculum. As part of the Class II Invention Convention, Lower School students used littleBits and other materials to design their own products and create commercials to market their unique inventions. In order to take their students' technology literacy to the next level, the faculty and administrators decided they wanted each student to have their own "mobile makerspace" to be able to invent with littleBits across classes and subjects, both inside and outside of school. As result, Marymount and littleBits co-sponsored a 1:1 littleBits program for students in Classes III to V.

Because we believe our students are our best teachers, Class IV students facilitated the workshop that focused on tinkering, playing, collaborating, and inventing through the mobile makerspace and modular electronics.

Conclusion

The Making and Learning Institute, an institute within Marymount for professional learning, seeks to explore a new paradigm in professional development by immersing participants in a maker culture. In the first year, the Institute ran thirteen events, attended by 220 faculty and administrators from seventy-five schools in eleven states. These programs were facilitated by twenty Marymount faculty, thirty Marymount students, and five guest speakers. We have sought to offer a wide variety of learning experiences for attendees that broaden their understanding of maker education.

There are still challenges ahead. While we have been successful in attracting early adopters in maker education to the program, we struggle to address the needs of emerging leaders in this area. Furthermore, as we continue to expand our definition of making, we risk the possibility of diluting the program further.

To that end, we are seeking innovative strategies to continue to evolve the program. These include:

1. Developing a cohesive brand strategy
2. Implementing regular communication with Institute members
3. Supporting additional maker education and STEM programs outside the Institute
4. Publishing a monthly email newsletter that focuses on upcoming events and latest initiatives in maker education
5. Connecting key maker education, STEM education, and global education programs in the United States and beyond
6. Developing a library of exemplar projects.

As such, the primary goal of the Institute will be to provide educators with the time and space to tinker, ask questions, explore, collaborate, and develop the skills necessary to foster a culture of transformative teaching and learning.

Physics, Design, and Social Justice

Allison Hupper, Sofia Cabrera, Caroline Lin & Julia Ranocchia
Marymount School of New York
New York, NY

Abstract

The science curriculum provides a unique opportunity for teachers to infuse teaching and learning with the broader topics of social justice and design thinking. In this chapter, we will review our benchmark project in our Honors Physics class, Physics, Design, and Social Justice, in which we develop a physics-based solution to a local or personal social justice issue.

Introduction

Marymount School of New York is an independent, all girls, N-XII school in Manhattan. With a long tradition of innovative approaches to education, the school's curriculum has recently undergone a paradigm shift in teaching and learning. With the addition of four separate maker and design spaces, all students have the opportunity to imagine and build, engineer and design, prototype and make. Moreover, Marymount's mission asks us educate young women who "question, risk, and grow; care, serve, and lead; and who are prepared to challenge, shape, and change the world."

This project originated over ten years ago as students in Honors Physics identified a local, regional, or international social justice issue; proposed a physics-based solution to that problem; and then produced a one- to two-minute video outlining their solution. As the project evolved over time, students started constructing their solutions using low-resolution materials. As with all projects, this project eventually ran its course and was retired.

The opening of the IDEA Lab at Marymount's Fifth Avenue Campus afforded students and faculty the opportunity to infuse making into their curriculum. The IDEA Lab is outfitted with three 3D printers, an Epilogue Laser Cutter, and a CNC milling machine, as well as a sewing machine and embroidery machine to support physical computing and soft computing. According to our teacher, Mr. Eric A. Walters, Director of STEM Education at Marymount, "this new space gave me an idea. I could bring back the physics and social justice project," as this new equipment would "allow students to actually design and build their solutions in a way they had not been able to before." The project gained a new name: Physics, Design, and Social Justice and was reintroduced into the curriculum. Table 1 shows the specific focus of the project by year.

Table 1. Physics, Design and Social Justice Topic by Year

Year	Project Focus
1	International Social Justice Issue
2	Regional Social Justice Issue
3	Local or Personal Social Justice Issue
4	Engineering for Social Good

The project has the following learning objectives:

1. Connect design thinking methodology with physics concepts
2. Connect physics concepts with social justice issues
3. Connect physics concepts with authentic learning experiences

Before we even started thinking about what issue we would like to address, we had to understand the design process. We first learned Tinkercad, (tinkercad.com) an easy-to-use 3D CAD design program. Our challenge: design an object that will move an object either horizontally or vertically (but not both) in a non-traditional way. Image 1 below shows one such design.

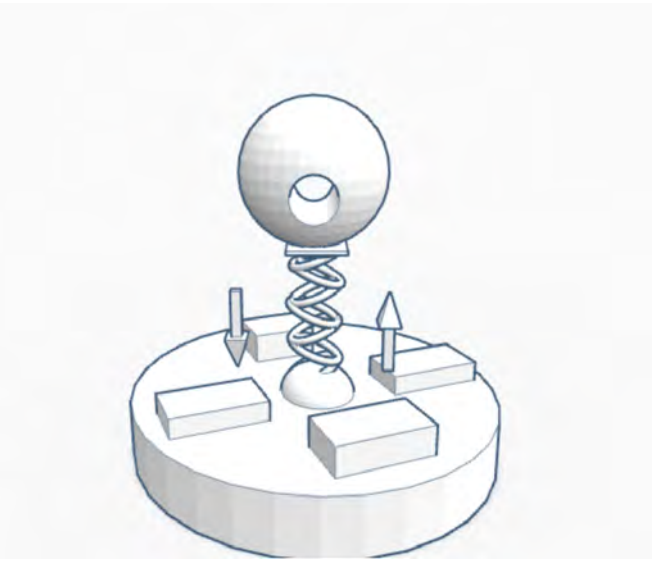


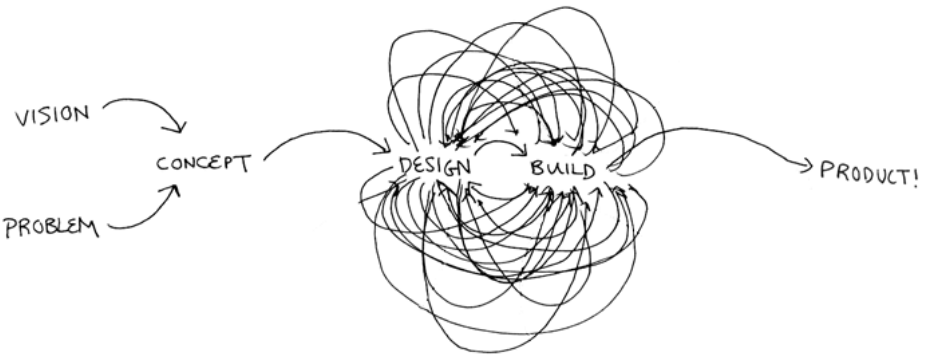
Image 1. A innovative vertical transport device, designed in Tinkercad

As previously mentioned, our challenge was to design a product that solves a local or personal social justice project that incorporates important physics concepts. We first split into teams of two or three, and were given a copy of *The Designing for Growth Field Book* (published by Columbia Business School) to document our work.

We took the following steps to move from prototype to pitch.

1. Brainstorming various social justice issues. We needed to consider which problem we wanted to solve. This step required us to answer the following questions: What issues were we passionate about? Does the issue affect us directly or does it affect another constituency? What is the root cause of the issue and were there any existing solutions to the problem? Before we could begin to develop a solution, we had to truly understand what our problems.

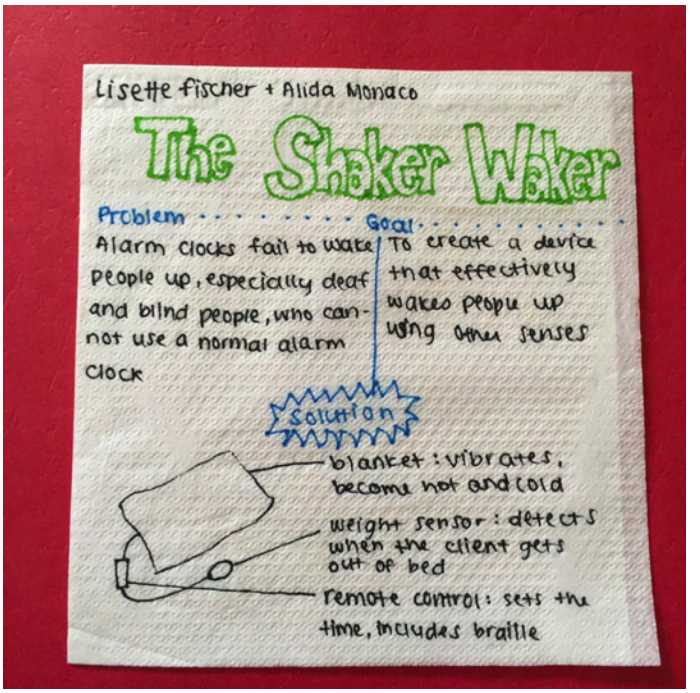
2. Understanding the design process.



We had to be careful not to immediately jump from problem and concept to product by skipping over the iterative process in between. Once we had determined our problem, we needed to develop empathy for our audience and for their needs. Our audiences ranged our own student body to skiers to the hearing and vision impaired. We surveyed our appropriate constituencies, using that information to finalize our product concept.

3. Feedback from our peers. Once we had our first concept finalized, we pitched our preliminary ideas to our classmates and to our teacher. Our classmates gave us valuable feedback and we used that feedback to support the iteration process. From this step, we had our final concept and idea.

4. Creating a napkin pitch. Once we finalized our design, we created a napkin pitch, both on video and on an actual napkin.



The napkin pitch included the problem we sought to solve, our solution, as well as our competitors and partners we would need to have.

5. Constructing Our Prototype. We then had the option of using the IDEA Lab to construct a high-resolution design or using common materials to construct a low-resolution design. Most of the groups used the IDEA Lab to build their prototype. Our prototypes and their design requirements are shown in Table 2 below.

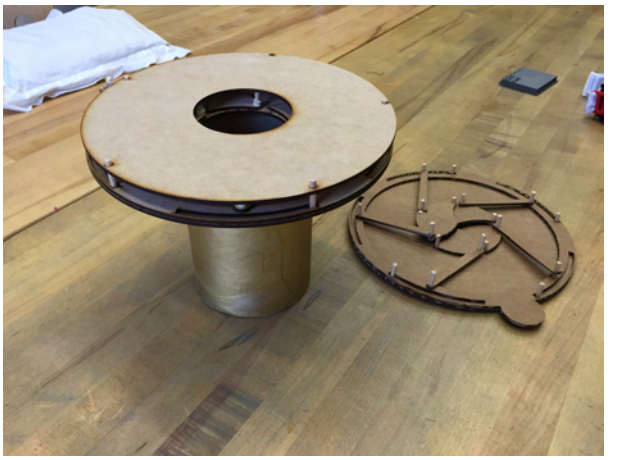
Table 2. Prototype design requirements

Project	Physics Concept	Materials Needed
Shaker Waker	Pressure, oscillations	Blanket, remote control, pressure sensor, vibration mechanism
B Fit	Thermodynamics	Ace bandage, temperature sensor, Arduino Flora
Smudge-Be-Gone	Pressure, magnetism	Neodymium magnets, pen
Teddy Text	Force, GPS	Teddy bear, Arduino, WiFi shield, GPS sensor
Where R U Now?	Geolocation	GPS sensor
Mac Mat	Conduction	Conductive material
See + Goggles	Thermodynamics	GPS sensor,
Litter Bug	Mass, weight	Low resolution materials, thin plywood on laser cutter

Three of our prototypes are shown below.

The Shaker Waker

See + Goggles



Litter Bug

6. The Pitch, Part 1. After creating our prototype, we were required to present our work to a panel of judges: Ms. Kate Godwin, Creative Technologist in Residence at Marymount; Ms. Kelly Hoey, author, investor, and one of the one hundred most influential women on Twitter; and to our peers. Our presentations had to meet the following guidelines:

- Three minutes in length
- Includes a description of the social justice issue
- Discussion of how our solution solved our specific social justice issue
- Discussion of how physics is inherently involved in the solution
- Discussion of the design process
- Demonstration of our working prototype

After our presentation, we were given two minutes for follow-up questions from both the panel of judges and from our peers. The questions we were asked ranged from strategies on how to improve the design of our product; identification of potential flaws of the design and suggestions for ways to fix and ameliorate these flaws; and suggestions for ways to broaden our audience.

7. The Pitch, Part 2. We also produced a short commercial to promote the most important features of our designs in an engaging and informative way. The commercial was to be thirty to sixty seconds in length, and we were to film and edit our commercials on our iPhones. Even though we did not use professional cameras, cinematography was critically important. Shots needed to be clear with good lighting, an appropriate background, and high quality audio. Once our commercial was completed, we then needed to show our commercial to the outside world.

Limitations were placed on who could evaluate our commercials. Students, faculty, administration, and staff from Marymount were precluded from viewing our commercials, so we needed to rely on friends, family, neighbors, and students from other schools. Moreover, at least one of the people had to be a "person on the street," presumably since that person would have an unbiased opinion about our design. As our evaluators watched our commercials, we asked them several questions, including whether or not they would buy the product. We recorded their responses as they offered constructive criticism about our design and our commercial that could help us further develop our product.

The student commercials and napkin pitches are on YouTube at: https://www.youtube.com/user/MrWaltersScience

8. The Final Decision. As we came to the end of the school year and the end of our project, we needed to make a decision about whether or not to continue with our project. Moving forward, we would have the opportunity to find funding to support our project with the long-term goal of bringing our "product" to market.

Impact on Our Learning

After our class was introduced to this project, we were all excited by the challenge of developing a product that used a physics concept to solve either an everyday problem or a social injustice. However, we were also nervous. How would we be graded? How much work would this entail? What if we failed? In the end, though, for each of us, the project had personal meaning because we could relate it to a specific aspect in our own lives. Throughout the research and design process, we learned how physics is an important factor in improving society and in addressing world issues. We developed an understanding of the connections between science and social justice and how our designs could have a significant impact on the lives of people around us.

In addition to developing an appreciation for what "physics can do," we were able to experience some of the processes required to develop a product. Although this process was occasionally frustrating, the final presentation, along with our prototype, was rewarding, exciting, and empowering for each group.

A Daring Design Process: STEM for Sale

Ann Hamilton-Dixon, Christina Irving & Ana Cristina Kapetanis
S's School
Richmond, Virginia

Abstract

The Fourth Grade Design Project was piloted during the 2015-2016 school year. This seven-month project focused specifically on emphasizing STEM skills that are crucial components to business development. It was an authentic learning experience that was cross-curricular and, to a degree, monetarily self-sustaining. In this project, students were active participants in entrepreneurship, self-directed learning, research, computer coding and 3D design and printing. The Project was inspired by students, designed for students and molded by the contributions and efforts of students.

Introduction

St. Catherine's Lower School is committed to the development of each student as a whole child, ready to take on the challenges of the modern world in which they will be leaders. Starting in the classroom and moving to larger venues, girls have opportunities to take risks, work collaboratively and make choices essential to learning self-reliance. As one of our core values states, we "strive to cultivate intellectual habits in which we take joy in learning through energetic inquiry, analytical and creative thinking, and continual striving to reach new levels."

In a world in which technology plays an ever-increasing role, we believe it is important that our students learn how to effectively and responsibly utilize the many tools at their disposal. We introduce engineering and physics to our youngest girls through building activities and provide them with early exposure

and a solid foundation in coding (also known as programming) through software and apps. For example, our youngest students are exposed to Cubelets, which are blocks that provide them with an introduction to building robots. Because the girls are never explicitly taught what the blocks do, they get to freely explore and create, developing problem-solving skills along the way. Other programs used in the Lower School include Lego WeDo, Lego Mindstorms Robotics and Scratch 2.0. The STEM program in the Lower School is designed to provide girls with opportunities to use technological tools so they can collaborate, communicate, share and be productive as they learn to be conscientious and socially responsible citizens.

Inspiration

The inspiration for this project came from a fourth grade student who shared her design for a "flying scooter" with the Lower School technology teacher. Her Google Slides document included a top view, a bottom view and a front view of the scooter. The technology teacher realized that this student was attempting to do 3D CAD work in a 2D medium, a task not easily done. To support this student she searched possible apps, programs and websites for a 3D design/drawing medium that would be attractive and easy to use for a ten-year-old student. The search eventually led to Tinkercad, a web-based 3D design tool. The site's interface is colorful, making it attractive for elementary school children, and the library of 3D shapes makes it simple and easy to use. A link to the site was sent to the student's parents with a suggestion that it might help their daughter with her design work.

Additionally, while serving as a judge for a FIRST Tech Challenge robotics competition in the winter of that year, the technology teacher met many teams that were using 3D printing to manufacture parts for their robots. There was one team of sixth graders who used 3D printing to create team medallions to pass out to judges. During the design interview, the team revealed that they had learned to do 3D printing the year before as fifth graders. A fledgling idea took form: "If these students could do 3D printing, then there was no reason why St. Catherine's fourth grade students couldn't do it with instruction, support and guidance. Maybe a design unit could be added to the fourth grade technology curriculum."

From past experience with upper elementary students and 3D design, the technology teacher was aware that not all fourth grade students were developmentally ready to create 3D drawings on a 2D computer screen. If this unit was to succeed, there needed to be another activity of equal importance for

students to pursue if they were not quite ready for 3D work. The desire to expose all lower school students to more opportunities to learn coding had existed for several years. Computer coding was selected as the second design activity using the Scratch website (scratch.mit.edu) as the medium. At this point, the concept for a design unit for all fourth grade students morphed into a bigger Design Project, and the process to make it a reality began.

The Design Project

Finding time for a project of this scale was a challenge. At St. Catherine's School, a one-hour combined Library/Tech class was scheduled weekly for each fourth grade class. The fourth grade Library/Tech time was originally created to allow the lower school librarian, technology teacher and the fourth grade teacher to work together to plan projects that would blend library and tech skills with classroom curricular content. For the past several years, the fourth grade teachers had been transitioning towards seamless integration of technology into daily classroom lessons and activities. This transition freed the Library/Tech time to be used for the Fourth Grade Design Project.

The librarian and the technology teacher worked together to flesh out the Project. Through many conversations three main threads, that would ultimately be intertwined, emerged: Research, Entrepreneurship and Design. The librarian and technology teacher knew they wanted the Project to be an authentic experience, not just an "isn't-this-cool?" add-on. They also envisioned the Project as being, at least in part, monetarily self-sustaining. The students could sell the objects they produced and the proceeds would be used to purchase replacement filament for the 3D printer.

The two teachers envisioned the Project running from the beginning of school until mid-March. Through initial work with TinkerCad and Scratch, they realized that the Project required students to have an understanding of concepts and skills from a variety of subject areas—art, science and mathematics among them. Thus, the Project needed to be cross-curricular and required the involvement of the art, science and fourth grade teachers. When approached with the idea of the Design Project, all agreed to adjust their units and projects enough to include the concepts and skills needed to support it.

At this point, administrative input and support was sought and the technology teacher shared the Project idea with the Director of Lower School and the school's Director of Technology. Their support was crucial, since curricular changes needed approval and funds were required to purchase a 3D printer. Both

administrators were intrigued and gave full support to moving forward with the Design Project. After researching different makes and models of 3D printers, The FlashForge Creator 3D printer (an entry-level unit) was selected. The Creator had a low price tag and two extruders, making it ideal for use by the students.

As stated previously, the Project organically split into three main threads or themes: Research, Entrepreneurship and Design. While the design thread was the most time consuming and intensive, the research and entrepreneurship threads were vital for providing purpose and direction for the overall project. A closer look at these three threads provides specific details as to how skills were taught, concepts were introduced, and technology was managed. A full schedule of the Project, broken down by month, is provided at the end of this chapter.

Research and Entrepreneurship Threads

While initially conceived as a vehicle to introduce coding and 3D design to students, it became almost immediately evident that the Project could also serve as a basis for an authentic research experience. Students had been introduced to 3D printing and were excited to try their hands at creating designs using the school's printer. However, the students were informed that they would need to find a way to replace the plastic filament used in printing (so that future fourth graders would have materials with which to work). The students' natural conclusion was to sell their work to make money. However, there were challenges. Could they just sell anywhere? To whom would they sell? What could they create that people would buy? It became evident that they would need to research the particulars of starting a business.

The librarian created a research organizer based on the Big 6 research model (big6.com). Developed by educators Mike Eisenberg and Robert Berkowitz, Big6 is an information inquiry model used by schools worldwide. It helps students break down the research process into manageable stages, while also developing critical thinking skills throughout the process.

It was decided that the research component of the Project would be done as a whole class, so that the librarian could model the Big6 process (as well as demonstrate the use of different electronic resources). In keeping with the Big6 model, students first defined their task (start a business that could make enough money to replace the printer filament) and thought of questions they would need answered to successfully complete their task. They brainstormed a variety of information resources that could provide information on their proposed task (books, websites, electronic databases, experts in the field, etc.). They also

established how they would access these resources (for example, using a search engine to find a website or the library's online catalog to find a book).

In addition to introducing an information inquiry model, the librarian also wanted to focus on a few specific skills related to online research. First, students generated a list of possible keywords based on their defined task and the questions they needed answered to complete their task. Students used KidRex (www.kidrex.org), a child-friendly search engine, to conduct a search for websites. As a group, students practiced looking at the results page of a search engine query and making educated guesses on the best websites to select based on the summary, URL and website title. Students were successful in finding websites related to business creation, but it became evident that most of these sites were too advanced to be useful, which led to a discussion on website evaluation.

The librarian then introduced the students to the periodicals database Explora by EBSCO (https://www.ebscohost.com/us-elementary-schools). Using their keywords, students searched for magazine articles about starting a business. Students located and downloaded an article on their topic (which was at a much more appropriate reading level than the websites they had found using a search engine). This experience led to a discussion of the benefits of using library databases versus general web searching.

The article they found not only gave structure to the remainder of the Project, it served to tie the three threads of the Project together and became the overarching theme of the Project. It suggested to "decide what you want to sell," which opened a discussion on market research; this led students to reach out to the larger school community to establish what types of designs and objects would be most appealing to their target audience. The article also warned entrepreneurs to "manage your time," which led to a lesson on the division of labor. Students wanted to be involved in all steps of the business process, but when they reviewed all of the tasks, it became apparent that they would have to divide and conquer.

Representatives from all of the classes were selected to serve on different committees. The representatives reported back to the whole class, so everyone was informed of decisions affecting the business. Groups included a Permissions Committee that met with appropriate school administrators to determine the criteria for selling at school functions. There was an Advertising Committee that, with the help of teachers, established ways to communicate the sale to the target audience. There was also an Organization Committee that met with the school

facilities manager and business office staff to plan a space for selling and determine acceptable methods of payment.

The article also stated that business owners must "raise money." Although the students already had the materials needed to use the 3D printer, the Upper School economics teacher visited each fourth grade class. Using the combination of a short video (bizkids.com/clip/profile-student-painters) and class discussion, he taught the students about revenue, expenses and profit. Armed with this knowledge, the students were able to set a price for their product based on the cost of production, the number of objects created to sell, and the price of a new spool of filament.

Design Thread

The goal of the design thread was for each student to complete a culminating personal project. Students could choose to create a 3D object in TinkerCad or they could choose to code a short animation sequence about 3D printing in Scratch. They could choose to work on their designs alone or in pairs. 3D objects would be printed and sold while the coded animations would be shown to the entire Lower School.

The Design Project timeline devised by the librarian and technology teacher split the Project into four stages: training, designing/coding, manufacturing/presenting and selling. Working backwards from a proposed April date for the sale, each stage was loosely assigned a set amount of time. The training stage (which included research, market research, and working through the tutorials) was scheduled from the end of September to mid-November. The designing/coding stage (when the students designed their objects and coded their animations) was scheduled for mid-November through early February. The manufacturing/presenting stage (when the 3D objects were printed and the animations were shown to the entire Lower School) was scheduled for mid-February to April. The selling stage (the sale of the student-designed objects) was scheduled to be in mid- to late April.

Training

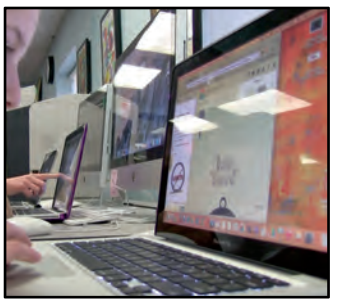
The technology teacher realized the traditional method of teacher-led, step-by-step instruction was not an efficient way to train the fourth grade students in the use of TinkerCad and Scratch. Instead, she opted to have the fourth grade students teach themselves to use TinkerCad and Scratch through online tutorials (which also helped promote the concept of teaching students to be lifelong, independent learners).

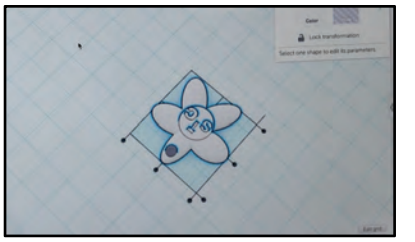
She prepared an introduction to the new learning paradigm of self-directed, independent learning, emphasizing that the student would be in control of her own education. The students would work through the tutorials at their own pace, although they would need to complete them within a given amount of time. To ensure students understood the concepts of 3D design and coding, they would be required to complete a set of both TinkerCad and Scratch tutorials. The librarian, technology teacher and classroom teacher would be available to give support to any student that ran into difficulties or needed additional help.

A six-step engineering design process was introduced to the students: Ask, Imagine, Plan, Create, Test and Improve, Share. Similarities between the design process and the Big6 research process were emphasized. Students worked their way through the first three steps before any design or coding work was attempted.

Designing

The website TinkerCad was selected as the medium for 3D designing, but its use was dependent upon individual accounts with usernames based on email addresses. The technology teacher struggled with how to use the site with many students. Luckily, within the past year AutoDesk acquired TinkerCad and added it to its inventory of apps and websites available for 3D design work. AutoDesk saw the educational potential for the use of TinkerCad and some other beginning-level software, so they created Project Ignite: a website that acts as a dashboard for educators. (https://projectignite.autodesk.com/). AutoDesk made sure Project Ignite was compliant with the Children's Online Privacy Protection Act (COPPA). In the dashboard, teachers could set up different classes and populate them with students, assign TinkerCad tutorials and 3D projects to students, and monitor their progress. Project Ignite was chosen as the method for allowing students access to TinkerCad.





The fourth grade students learned to use TinkerCad through the online tutorials “Let’s Learn TinkerCad” provided through Project Ignite. These tutorials were presented via text and images, thereby requiring a great deal of reading and translating words into actions. Some students did not relish these activities, and those with comprehension issues found them to be challenging. Teacher support was always available to those who needed it, and ultimately, every student was successful in completing the assigned tutorials.
Students who chose to create a 3D object for their personal project went through a two-step planning stage. They were first tasked with doodling, with paper and pencil, quick sketches of as many design ideas as they could generate. (See Fig. 1)

After choosing one design idea to pursue, they were tasked with drawing a to-scale drawing on graph paper ruled in centimeters and millimeters. (See Fig. 2) They were given a range of size for different shapes. Round shapes needed to have a diameter of between 2 to 4 centimeters and rectangular shapes needed to be between 2 to 3 centimeters in width and between 4 to 6 centimeters in length; however, these size ranges were not rigid. Adjustments were made to accommodate a given design, although shapes smaller or larger than these measurements tended not to print well.

To move to the Create stage of the design process, students were required to have a teacher review first the doodles and then their to-scale drawing. During these reviews, students explained their thinking and teachers made suggestions for improvements. Keeping in mind their earlier market research, student designs included mostly small charms and keychain fobs.

Final agreement on the design was noted by the teacher writing her initials on the to-scale drawing. The student was then given access to the Design Freestyle project in Project Ignite where she could begin creating her 3D design. (See Fig. 3 and 4)

-

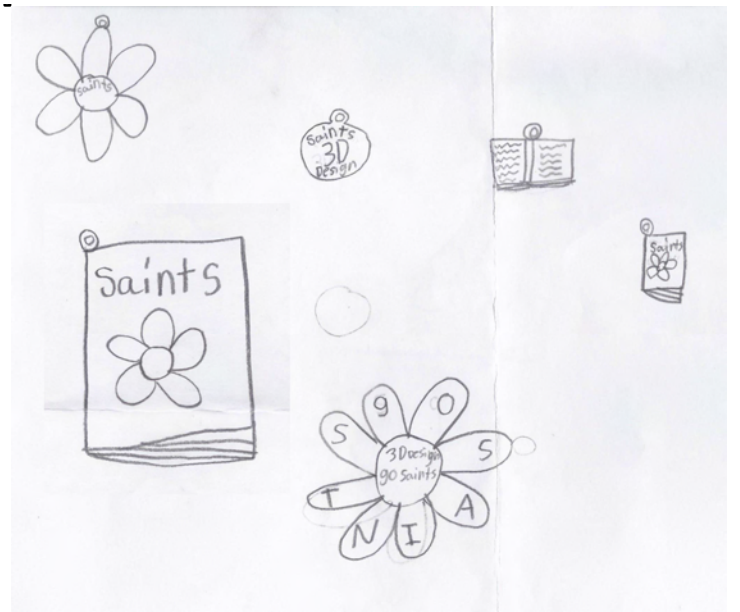


Fig. 1 3D Design Planning Stage 1, Doodles

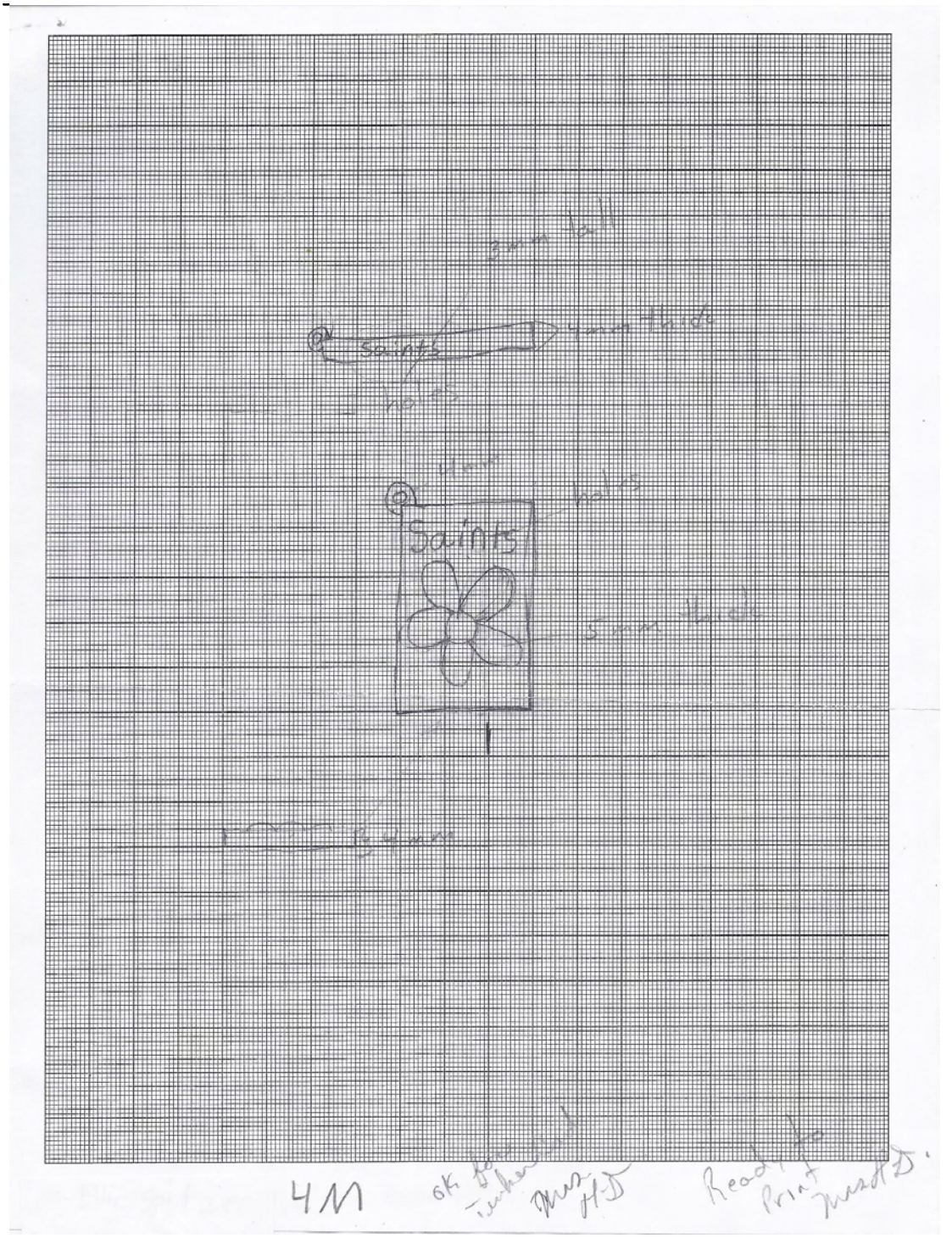


Fig. 2 3D Design Planning Stage 2, To-Scale Drawing

Fig. 3 3D Design Creating Stage, Drawing in TinkerCad via Project Ignite

Fig. 4 3D Design, Final Product

Coding

Scratch, a COPPA-compliant website, was designed by Massachusetts Institute of Technology for people of all ages to learn computer coding. There are three choices for handling student work: download an offline version of Scratch 2.0 to each student computer (which allows a student to code in Scratch without an Internet connection), create an online account for each student (which allows her to work on her project on any computer at school or at home), or use the Create area of the website without an online account (which requires a student to download her work to the computer each time she stops work and upload it to the website the next time she wishes to work on it). The last method was chosen for saving Scratch files with the additional step of having students drag/drop their file into their Google Drive accounts. At St. Catherine's, Google Drive accounts are activated for fourth grade students. Access to Google Drive is achieved through a link on the "Fourthies" website (a website created and maintained by the fourth grade teachers). This method meant there was no need to create individual accounts for each student, yet the project files would be available to the students any time they wished to work on them.

The students learned to use Scratch through the online video tutorials (scratch.mit.edu/help/videos) provided on the Scratch website. The students were purposefully taught to start the video, watch for a bit, stop the video and try the skills for themselves. It took some practice and some encouragement, but all students eventually completed the tutorials. It often took more direct instruction to teach the students to go back to a video tutorial and replay it to help them work through a coding problem they were having.

Students who chose to code an animation sequence for their personal project were taught to create a storyboard for their Planning stage in the design process (See Fig. 5). They were asked to include sketches of what they envisioned for scenes and to include text they thought would be displayed. If they planned to make an audio recording, they were asked to write a script of what would be said in the recording. Final agreement on the plan was signified with one of the teachers writing her initials on the storyboard, after which the student began creating code in Scratch (See Fig. 6).

Fig. 5 Animation Planning Stage, Storyboard

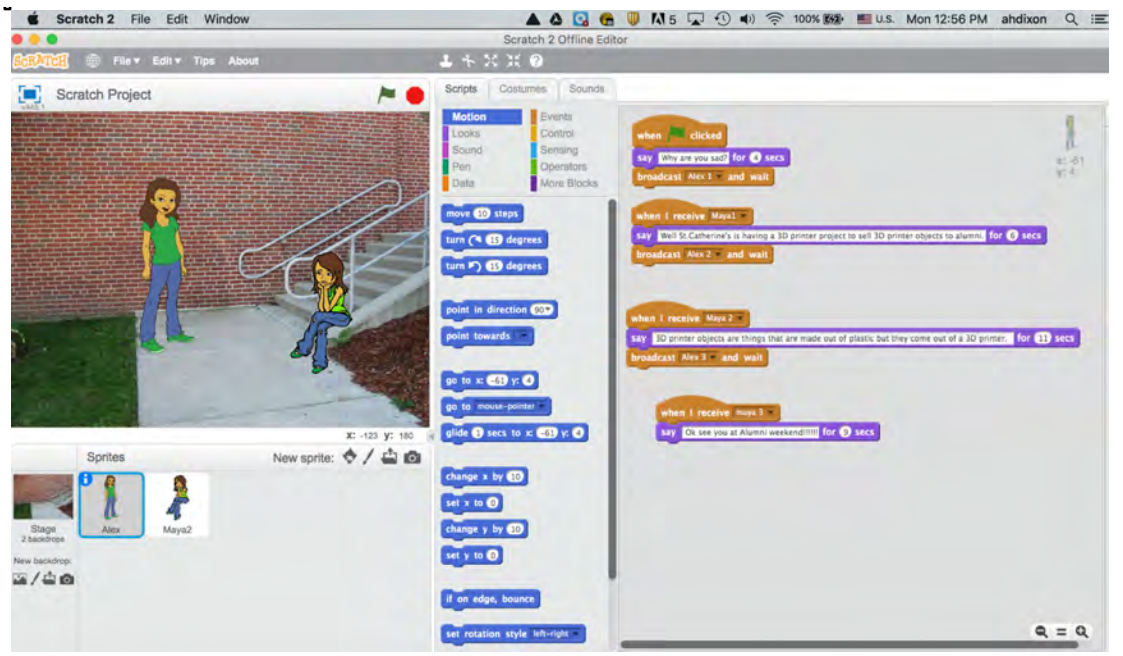


Fig. 6 Animation Creating Stage, Coding in Scratch

Manufacturing/Presenting

Once students completed the design process, it was time to manufacture or present their work. Students who created a 3D design worked closely with the librarian to print their designs. Works created in Tinkercad had to be downloaded and converted to a file readable by the 3D printer. ReplicatorG software, provided with the Flashforge printer, was only installed on teacher laptops. Although this step was completed by the librarian, she talked the students through the process so that the students had an understanding of all the steps involved in making a 3D print.

Once a compatible file was downloaded to an SD card, the students printed their design. Under supervision of the librarian, students were allowed to key in the settings on the printer. Even though the student designs were fairly small, each print took close to 45 minutes from start to finish (including about 15 minutes for the machine to warm up before the printing started). Students came to the library to print during recess, free periods, and before school. A key goal of the 3D Design thread was to give all students the opportunity to work with the 3D printer and print an object, regardless of whether they chose to create a 3D design or to code an animation sequence as their personal project. Students who chose to pursue an animation project were allowed to select a classmate's object to print.

Each week, four or five 30-second Scratch animations were shared during the announcements portion of informal weekly chapel services for the whole Lower School. Because the Scratch animations were saved in Google Drive, they were easily shared with the technology teacher (which allowed her to project them on the assembly room screen). The fourth grade students, although a little embarassed, were clearly pleased that their work had a bigger audience. The younger students were very engaged and curious about the fourth grade students' work. In fact, several asked when they would get to do the Project (they were already starting to think ahead to their own projects).

Selling

The sale of the 3D objects took place on Reunion Weekend in mid-April of 2016. While researching what was important to starting a business, students learned that they needed to know their target audience. They vacillated between selling to the general St. Catherine's population during the spring fundraising event or selling to the returning alumnae on Reunion Weekend. Through discussion with their teachers, they found that there were some costs associated with selling at

the spring fundraiser that didn't exist with selling at Reunion Weekend. Selling to the alumnae won, hands down.

In keeping with the business practice of division of labor and to keep the sale manageable, students went through a selection process to be chosen to work at the sale. The students serving on the Organizing Committee developed a work schedule with three time slots. Four students worked each time slot. The early time slot was for setting up the sale. The second time slot was for selling objects and running demonstrations of 3D design, 3D printing and computer coding for the alumnae. The last time slot was for selling, cleaning up and determining revenue from the sale. An informational note that gave the particulars of the sale and explained the volunteer opportunity for some students went home to all fourth grade parents. The parents were asked to fill out the attached form to indicate whether or not their daughter was free to work the sale and, if she could, what time slots were best for her. Using the information provided by their parents, students indicated their availability to volunteer at the sale by completing a Google Form created by students serving on the Organizing Committee. The technology teacher took the data and selected students using an online number generator. She used the generated number to find the row on the spreadsheet that corresponded to that number, and the student whose name filled that row was selected to work at the sale. Adjustments were made to this process to ensure that there was at least one volunteer from each fourth grade classroom for each time slot.

The sale went very well. The students engaged with the alumnae as they sold their wares and explained 3D design, printing and computer coding to generations of women who did not grow up with these technologies. The alumnae were duly impressed and whole-heartedly showed their support by buying every single 3D object (with a few even making donations to the Project). The fourth grade students proudly displayed their Sold Out sign.

In the week that followed, volunteers from the sale reported to their respective classes about the sale and the revenue collected, which was about three times what the students had hoped to make. The librarian and technology teacher brought up in each class the importance of being generous and giving back to the community that had supported them. Making a donation to the Alumnae Relations Office was strongly suggested and readily accepted by the students. The two teachers walked the students through determining what 15% of the revenue was and indicated that it would make a nice donation. Each class decided that they could easily afford to purchase two rolls of filament instead of one, with each roll being a different color. Using another Google Form, students voted for the color filament they would like to see purchased. Light blue and yellow were the favorites.

Cross-Curricular Support

The success of the Design portion of the Project relied heavily on cross-curricular input from the fourth grade teachers and the Lower School art and science teachers. The Design Project could not have happened without their support and participation.

The fourth grade teachers introduced the Design Project through the YouTube video, "Derby the Dog: Running on 3D Printed Prosthetics." (https://www.youtube.com/watch?v=uRmoowIN8aY). The video was about Derby, a dog born with deformed front legs, and his owner's quest to provide him with plastic prosthetics created on a 3D printer. It was a heart-warming example of how regular people are using 3D design and printing to do good in the world. The students were captivated.

The fourth grade teachers were prepared to cover metric measurement, 3D geometric shapes, positive and negative numbers, and 2D/3D cartesian coordinate systems as students learned to work with these concepts in TinkerCad and Scratch. They regularly incorporated vocabulary, which was key to the Project, in their word studies throughout the year. They posted articles and information about 3D design to the "Fourthies" webpage throughout the duration of the Project.

The Lower School art teacher was ready with two art projects. To illustrate the concepts of positive and negative space, students created a relief print which removed material from a linoleum tile (negative space) in order to reveal the desired image with the linoleum that was left (positive space). The students used their tile images with ink to create a series of prints. For the second project, the

art teacher had the students create teapots (part of an annual unit on Japanese Tea Ceremonies) using the coil method of working with clay. To support the Design Project, she emphasized how this method emulated the way a 3D printer built a print layer by layer.

The Lower School science teacher expanded her unit on the properties of matter to include the properties of ABS and PLA plastic (such as melting point, shrinkage and extrudability). She used science class time to teach the students about the type of filament they would be using in the 3D printer and discussed with them the differences in quality and price of filament. She also talked about what type of material makes a high-quality filament for a 3D printer. Periodically, the science teacher conducted follow-up discussions on the progress of the Project.

Reflections

Outside Our Comfort Zone

The Project was about challenging everyone, students and adults, to step outside of their comfort zones. The students were asked to learn through self-teaching and to accept unsuccessful tries not as failures but as opportunities to redesign and try again. They were expected to reach out beyond the classroom by speaking with school personnel to plan and execute the sale and engaging with the alumnae to sell their objects. They were challenged with giving up their object for sale and not keeping them for themselves and their families.

For us, the main developers, the entire Project was an exercise in self-guided learning. We had to accept not knowing exactly how the Project would run - that we would be “flying by the seat of our pants” through much of the school year. Knowing that each of us was not alone in the experience was key to accepting the discomfort of uncertainty instead of being overwhelmed by it. We were very open in sharing our struggles and successes with the students, which we feel freed them to set out on their own journeys of learning and discovery.

Librarian: When the technology teacher first approached me about this Project, I bravely said, “okay,” but inside, I was pretty nervous. I had little to no experience with either coding or 3D design. Also, I was worried that some of the research and more traditional library skills I needed to teach the students might get pushed aside or overlooked in the process. Ultimately, these worries were unfounded. After completing the same tutorials as the students, I had enough ability to help troubleshoot design issues. As for research skills, the Project provided such a rich opportunity for students to experience the real-life rewards

of purposeful research. It was so much more beneficial than stand-alone lessons. The students were engaged and invested in the results of their research.

Technology Teacher: I was a little more comfortable with the idea of working with new technologies than the librarian was. I had some coding skills but absolutely no experience with 3D design or printing. I had real fears that I was overreaching my abilities, but I did it anyway and am very glad that I did. Both the librarian and I shared our personal growth experiences through the Project with our students. So often as educators, we present to our students this picture of knowing and being in control of everything. We found that our students appreciated our candor, and we felt that they learned quite a bit by witnessing the rewards of tenacity and perseverance and the joys of working alongside a colleague.

In addition to being very proud of the work the students created, we are proud of ourselves for taking a risk and stepping outside of our comfort zones to create an entirely new learning experience for our fourth grade students.

Division Director: I have to admit that I was very excited when our technology teacher first approached me with the idea for this Project; I saw enormous potential in it. As I thought through the Project, I started to list down the pros and cons. It was not the first time that a new idea was brought to me by one of our Lower School teachers, but this was going to be one of the boldest experiments since my arrival five years ago. The Project required extensive faculty collaboration (four departments: science, art, technology and library; two divisions: Upper and Lower School; and four fourth grade classroom teachers) and funds that had not been previously earmarked for such a proposition. I knew that the school would be able to find the funds somehow, and I had complete faith that my librarian and technology teacher could make the process work. Moreover, I recognized that the Project's success would give the girls valuable experience in STEM skills that we know girls need today. Knowing that this Project was important for our girls was the primary motivator for my support for this Project, and I was prepared to answer questions from those who may have had doubts or in case the Project had less than a successful conclusion. Ultimately, the results spoke for themselves, and the Project will continue to be an important experience for each fourth grade girl. I have to congratulate and thank our librarian and technology teacher for all they did to make this new program a reality; it certainly would not have happened without them.

Huge Safety Net

As much as we wanted the students to lead the Project, we knew we had to establish parameters to keep their choices and direction within the realm of the possible. During the development of this Project, we thought through possible scenarios for a student-run sale (considering how it would impact not just our students, but the entire school community). To do so, we reached out to school personnel: the Director of the Alumnae Office, the Parents Association Fundraising Coordinator, the school's Event Coordinator, and Business Office personnel. We learned who was interested in supporting the Project, who was willing to have students come ask them questions, and what restrictions existed. Primed with this information, we were able to nudge the students towards ideas that could be successfully implemented within the school's structure and environment.

Process Over Product

The value of the Project was not in the $1 trinkets that were created for sale or in polished animations, but rather in the lessons learned by students throughout the entire process. Students learned what it takes to start a business, that design is iterative and ever-evolving, and that they were capable of independently teaching themselves new skills. They also learned that constructive feedback is an important and valuable part of the creative process.

Librarian: My first solo 3D print without the technology teacher's help was a huge disaster. I thought I had broken the printer! I overreacted. The problem was fairly simple to fix. I just needed to be patient with myself and think through the problem. I shared this experience with the students early in the design process. I believe hearing my personal experience was very freeing to the students. They learned even their teachers didn't always get it right the first time. It helped them realize there was room for mistakes, and we would all work together to find solutions. On occasion, the technology teacher and I did have to do some behind-the-scenes work in TinkerCad and Scratch to troubleshoot design issues. However, once we found solutions to the problems, we helped guide the students through the issues so that it was 100% their work. It took one pair of 3D designers seven tries to get a successful print. We praised their persistence and tenacity as they redesigned after each failed attempt. We never wrested control of the design work from them just to speed up the process. We provided them with the space, time and support to make mistakes and find solutions.

Protection of Faculty Time

The Project grew in size very quickly, and the team of teachers needed to make it a reality grew right along with it. Ultimately the team was comprised of eight lower school teachers and the K-12 Economics Coordinator. All of these team members were very busy with their own classrooms and duties; pulling them together for regularly scheduled meetings was highly improbable. We decided that it was of major importance that team members' time be respected and not imposed upon any more than necessary. Any additional work connected to the Project was distributed among all the team members so that no one member was overly burdened with extra tasks. Only two organizational meetings were planned. It is also important to note that each faculty member involved in the Project is a master teacher, knowledgeable in her/his field, creative and effective in the work she/he does in the classroom. We felt the best approach was to let everyone know the goals of the Project and then trust everyone to do what they did best.

The weakness of this loose type of organization is that miscommunication and misunderstandings between and amongst team members can easily occur (and they did). It is the camaraderie between the team members and their absolute professionalism that kept the misunderstandings and miscommunications from becoming points of contention. Everyone kept their eye on the ball and the experiences of the students paramount as we found ways to work through confusing or unclear communications or to adjust to changes in direction as the Project progressed through the year.

Assessment

The question of assessment was raised by members of the Project team and by students. During one organizational meeting a team member asked, "Will there be a formal assessment for the students?" Our answer was, "Absolutely not!" We wanted the students to feel free to learn new things without the spectre of receiving a grade. Completion of a personal project would serve as the benchmark of success for each student, regardless of its perceived quality. When being introduced to the self-teaching paradigm, the fourth grade students asked if they would be tested on the material in the tutorials. Once they were informed that there would be no test, we could visibly see them relax and enter into self-guided learning with interest and enthusiasm.

Selling vs. Keeping

In most school environments, what a child makes typically goes home with that child (and so it is at St. Catherine's). The students expect this, as do their parents. We deliberately broke with this practice by having the students sell the 3D objects they created without taking a copy home with them. This was hard for a number of students, as well as for a few parents. We wanted the students to experience giving of one's self for a greater goal that benefited the group rather than the individual. This sacrifice was softened to some extent as the students were able to keep a copy of their design file in their Google Drives. We encouraged them to take the file to a local library that had a 3D printing service to have a copy of the object made for themselves.

Division of Labor

One of the great joys of working with our student population is their enthusiasm and desire to participate in a wide range of activities. Unfortunately, it can also be a source of conflict when the children realize that one cannot do everything in life and that choices must be made. We wanted all the students to feel they played a role in the success of this Project, but we stressed that, like in the real business world, there would have to be a 'division of labor' for them to accomplish their task. Not every child would be able to participate in each activity, meeting, and even the final sale. This was hard for some of them. It was even hard for some of their parents, who were disappointed that their children did not get to participate in events like the sale day. However, we felt emphasizing the concept of division of labor was an important component of this Project and a skill our students needed to practice.

Concerns with 3D Printing with Plastic

With the increased affordability of 3D printers and their growing numbers in school settings, ecological and health issues are being raised. Ecologically speaking, plastic is a no-no (especially plastic that cannot be put in recycle bins). ABS plastic is one of those plastics. To address this issue, we are searching for a company near us that would be willing to take our plastic print waste and use it in their manufacturing process.

After the conclusion of the Project, we became aware of some current research into the safety of 3D printers regarding the emission of ultrafine plastic particles and respiratory ailments such as asthma. Currently we are following the recommendations for safe printing supplied by FlashForge: providing good ventilation for the printer and limiting student exposure to the printer while in

use. We will continue to monitor this issue and take additional precautions as needed.

Conclusion

The Fourth Grade Design Project was viewed as a great success within the St. Catherine's School community. Through trial and error, students learned firsthand that developing and running a business is no small task. They also learned how all aspects of running a business are interrelated (and equally important to the Project). Students also participated in evaluating the project, and their comments were taken into consideration in planning for year two. With some tweaking here and rearranging there, we feel the second iteration of the Project will be better than the first.

We had no doubt our fourth grade students would be able to code and design in 3D, but we were truly blown away by the quality of what they produced in these two media. They showed great perseverance and tenacity as they solved design and coding challenges. These qualities allowed them to bring their creative ideas to life and made the Project successful. It was truly a joy to work side-by-side with these budding designers, coders and entrepreneurs.

Timeline

April 2015
Technology teacher approached librarian with idea of long-term project involving 3D printing and coding

May 2015
Received administrative approval to proceed with project
Researched and purchased 3D printer

June 2015
Organizational meeting with all parties: Technology teacher, Librarian, fourth grade classroom teachers, art teacher, science teacher and Upper School economics coordinator

July 2015
Technology teacher and librarian ran first test print on 3D printer

August 2015
Technology teacher and librarian mapped out tentative year-long schedule for project
Second organizational meeting with all parties

September 2015
Introduced project to students
Students began TinkerCad tutorials
Students began working on supporting art projects (through the fall months)
Students engaged in science unit on Properties of Matter

October 2015
Students began Scratch tutorials
Students completed research on starting a business (next year, this will come before the TinkerCad and Scratch tutorials)

November 2015
Students continued working on tutorials
Students introduced to Engineering Design Process and began the 'doodle' and storyboard phase of design work

December 2015
Students continued to brainstorm ideas and began to fine-tune designs and storyboards
Students began to create designs in TinkerCad and animations in Scratch

January 2016
Students met with staff in Alumnae Relations to establish sale event (This meeting will be planned earlier next year)
Students continued to work in TinkerCad and Scratch
First successful student 3D print
Students selected for advertising and event organization committees

February 2016
Students continued work in TinkerCad and Scratch
3D designs printed daily
Began showing Scratch animations during announcements after chapel
Economics teacher visited classrooms to teach about revenue, profit, and expenses

March 2016
Students met with Business Office personnel and Events Coordinator to nail down specifics related to sale
Continued printing student designs
Continued showing Scratch animations during announcements after chapel
Students set price for product
Permission slip to participate in sale sent home with students and students selected for sale

April 2016
Continued showing Scratch animations during announcements after chapel
Completed the last of the 3D prints
Students created posters for sale (plan on doing this earlier next year)
Sale Weekend!!!
Students evaluated and provided feedback on overall project
Students decided to give 15% to Alumnae Development office

May 2016
Students selected new color printer filament to purchase with profits

Resources

BizKids http://bizkids.com/clip/profile-student-painters

Derby the dog: Running on 3D Printed Prosthetics
https://www.youtube.com/watch?v=uRmoowIN8aY

KidRex http://www.kidrex.org/

Project Ignite https://projectignite.autodesk.com/

Scratch https://scratch.mit.edu/

Scratch video tutorials https://scratch.mit.edu/help/videos/

Explora by EBSCOHost https://www.ebscohost.com/us-elementary-schools

Starting your own business. AUTHOR(S). Hugel, Bob. PUB. DATE. February 1999. SOURCE. Scholastic Choices;Feb99, Vol. 14 Issue 5, p16. SOURCE TYPE.
http://connection.ebscohost.com/c/articles/1517111/starting-your-own-business

The Big6 http://big6.com/

TinkerCad https://www.tinkercad.com/

AP US History Final Project: So What? Now What?

Dr. Sarah G. Cunningham
Marymount School of New York
New York, NY

Abstract

The AP US History curriculum, directed toward preparation for the AP exam in early May, offers limited opportunities for design-thinking project learning. While the course races through topics and seeks to build historical thinking skills primarily expressed in traditional argumentative essays, a post-exam deep-dive final project invites students to explore more reflectively a topic of particular interest to them, and then to present their findings in a compelling, creatively designed, non-paper project. This project also engages the larger questions, "So what? Now what?" Students responded to the invitation with enthusiasm, even occasional glee, and reported enjoyment of and satisfaction with the project as a summary exercise and demonstration of their achievements.

The Project

AP US History at Marymount School combines a traditional curriculum and innovative approaches, incorporating design thinking wherever possible in a highly structured curriculum. While the course most directly points to the AP US History examination in early May, the month of class following the exam offers the opportunity for students to undertake a more individualized and self-directed exploration of a historical question of their choice.

The "So, What? Now What" project seeks to engage students' intellectual curiosity while also offering them the opportunity to design their own investigative approach, craft their research question, select their primary and secondary sources, and then utilize a variety of strategies and materials to share their findings with their colleagues. The larger questions, "So what" and "Now what?" encourage students to connect their school work to their individual goals

and values, and to lean toward how they can continue to follow their ideas forward into further study and action.

Table 1. Project Description and Guidelines

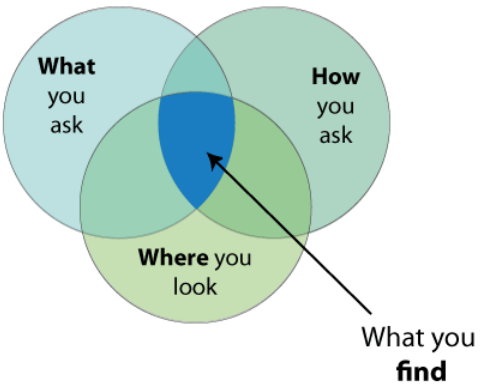
APUSH Final Project: Doing history: So What? Now What?
May 2016

Congratulations on mastering the challenges of AP US History! You have worked hard and moved fast, and can feel proud that you completed the curriculum and gave your best effort on a nationwide exam. Bravo!

Now, while other Marymount history students will be studying for history finals, you have no more assigned readings, no more tests to take--you finally have the opportunity to decide where and how you do history, and make it meaningful.

In place of a final exam, you get to demonstrate the research, analysis, and writing skills you have developed this year with a research/creative project on a US history topic from 1609 to 1996 that interests you, something you want to learn more about but that flashed by as we rushed through the questions, themes, and centuries this past year.

You will seek to answer a research question that, again, is up to you: How? Why/why not? And, most importantly, So what? What now?



1. Topic: what intrigues you: what do you want to learn/explore/understand?

2. Question: what you ask (you'll put your research question at the head of your paper)

3. Evidence and method: how you ask and where you look (your process)

4. Discovery: what you find

5. Presentation of findings: how you share your learning experience with others

Reminders

• A successful paper will display the skills you've developed this year: independent research presented in crisp writing, with an evidence-based thesis based your analysis of at least two different primary sources, in conversation with at least two secondary sources.

• A successful presentation will engage your audience, not only using a creative approach to share with them what you've learned, but also exciting them about what makes it important!

Perhaps you already have an idea about a topic to investigate, or about a method or evidence or presentation mode you'd like to use.

Resources
To get your creative juices flowing about historical exploration, you might take a look at these three sites, which offer some intriguing and provocative perspectives on doing history:

• Check out the Library of Congress's flickr collection—images in their photostream and albums may spark your imagination. (https://www.flickr.com/photos/library_of_congress/albums)

• Explore a gallery of exciting ideas for visual presentation of information on a wide variety of topics from the Stanford Visual History Group. (http://web.stanford.edu/group/spatialhistory/cgi-bin/site/gallery.php)

• There's some exciting work using technology happening at the Virginia Center for Digital History. (http://www.vcdh.virginia.edu/index.php?page=Projects

• If you're really stumped for a topic or approach, • leaf through the textbook, • look back at the APUSH course outline, themes, and skills, • scroll around The New York Times, or • try noodling around this site, (http://www.oblicard.com/) with some prompts for sparking your creative impulses

• For help refining your research question, try this site (http://www.williamcronon.net/researching/questions.htm#_Making_your_question) from historian William Cronon (you've read his work on environmental history)

Remember, you're thinking about • topic • question • method/skills/process, and evidence, so you have lots of room to PLAY around. Yes, you'll have to do research, and yes, you'll have to write it up in 4-5 pages (with parenthetical citations and a Works Cited page in MLA format), and, then you get to

interpret/share/present your work in a creative format and style that work for you and the message/meaning you're trying to convey.

Your project will be driven by your research question, which you will answer with your thesis, and you will be expected to investigate at least TWO substantial PRIMARY sources (documents, images, witnesses) and consult TWO secondary (scholarly) sources as well. To ensure you're doing history (rather than journalism, important but different), you should stick to the period 1609 –1996.

Table 2. Project Timeline

Project Timeline

Monday, May 9
• Project Introduction

Wednesday, May 11
• Focus on your question

Friday, May 13 – Thursday, May 19
• Work periods (x3): Research/writing/making/conferencing

Monday, May 23 – Friday, May 27
• Presentation days (x3) (8-10 minutes each)
• Papers due Friday 5/27

Wednesday, June 1
• Summary class: Reflections, evaluations, celebrations

In conjunction with the handout, an in-class slide show invites students to consider incorporating data visualization into their presentation, in an effort to encourage them to enhance their historical-thinking skills with their technological capabilities.

Students have produced a wide variety of projects, from playing and singing original songs about turn-of-the-20th-century murder ballads, to dynamic data visualizations that analyze trends in contraception use and maternal death rates. Students have also created material art objects to draw attention to period technologies. For example, as shown in Image 1, a student investigating shifting immigration dynamics in New York's Five Points neighborhood produced a fictional early-19th-century journalist's notebook to highlight the importance of hand-written notes and on-site sketches in the absence of recording and photography technology.

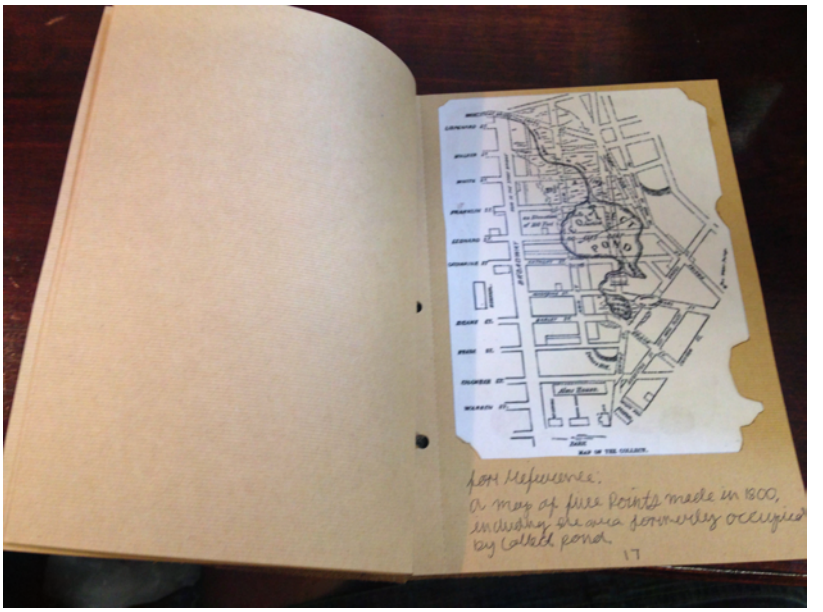


Image 1. A student's fictional early-19th-century journalist's notebook

Another student sought to set the comic-book superhero Captain America in his original social and political context, and drew her own slides to explore how and why the character has been updated to reflect contemporary movie technologies and political concerns.

An open-ended, inquiry-based, design-thinking project does provoke some anxiety from students who have long been confident in and relied upon their reading and writing abilities and who have been successful in conventional academic assessments. Overwhelmingly, however, students respond to the project with enthusiasm and relief that they can pursue their ideas and make connections outside the classroom. They evaluate themselves as learners using a reflective rubric as shown in Table 3.

Table 3. Final Project Evaluation and Reflection

APUSH Final Project Student Evaluation/Reflection 2015-2016
• What did you learn about yourself doing your final project presentation and paper?
• What part of the project presentation and paper did you do your best work on, or are you most proud of? Why?
• What do you wish you had spent more/less time on, or done differently?
• What changes would make the final project a better assignment?

Student responses included:

- I can do well and so much more than I expected of myself!
- I learned how to analyze history and understand why things happen, how simple incidents can lead to global events.
- I learned that I like drawing connections instead of just memorizing facts, and that I enjoy learning about ALL aspects of history.

In conclusion, students look forward to the "So what? Now what" project all year, and demonstrate in their work how they can integrate their learning across disciplines and into their lives.

[1] Data Visualization Guidelines: https://www.scribd.com/document/325262889/AP-US-History-Data-Visualization

[2] Captain America Project: https://www.scribd.com/document/325263094/AP-US-History-Captain-America-Project

Design for a Better Future – The Bus Stops Here

Lorna LaRiviere, Brunswick School
Annette Grueterich, Sacred Heart Greenwich
Greenwich, CT

Abstract

The Bus Stop Project is an industrial design and architecture project for eighth grade students from Brunswick School and Sacred Heart Greenwich in Greenwich, CT. The project is part of an effort to include STEAM initiatives in the schools' respective visual arts curricula and to foster cooperation between the neighboring schools. For this project, the schools' art teachers, head librarian and their 8th grade students collaborated on a real-world design challenge and documented design and learning processes observed in this new course. Students learn a broad range of research strategies for this human-centered design project and their bus stop designs are based on the shared results of extensive inquiry, innovative, participatory research and shared conversations. Extensive exploration with materials as well as technical lessons provided the tools necessary to bring the students' designs to life. Students build architectural models that are to scale and engage in individual and group reflections on the design process. This project is derived from a college course offered by Amy Leidtke, faculty member at the Rhode Island School of Design. While the project introduces students to design-thinking and approaches design from a problem-solving perspective rather than from a visual arts perspective focused on aesthetics, it also covers visual arts learning standards of Creating, Presenting, Responding and Connecting.

Introduction

The Bus Stop Project was born of the plan to offer an art + design course at the middle school level. This course melds art and design curricular objectives with school-wide STEAM objectives that focus on design thinking - a systematic problem solving approach to creating a desirable future and to making a positive change in your community. The original RISD course that inspired this project approached the future of urban transportation as a design challenge that is needed to reduce traffic volume and travel times, to increase productivity, to limit carbon emissions and to increase the quality of life in cities.

Students were introduced to the problems of urban transportation and to the resulting design challenges through video clips from the documentary 'Urbanized', directed by Gary Hustwit, which includes an interview with the mayor of Bogota, Colombia, on the city's process of designing a new urban bus system. For this 8th grade course we modified the design challenge to be locally relevant and more student-centered so that it could reasonably be researched in our schools' setting: suburban with minimal public transportation and reliance on cars or school busses. For the purposes of this course the objective was to increase ridership of school buses in order to make change locally and improve air quality and traffic conditions, to save time for drivers and to let students gain valuable lessons in independent commuter time.

This chapter chronicles the students' process during this course and summarizes learning outcomes for both students and teachers.

Research

Students in the Bus Stop Project participate in hands-on, active research. Drawing from a broad range of research strategies taken from the book *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions* design teams selected and implemented methods and techniques most fitting for this human-centered design project. Students worked in teams at their respective schools to collect quantitative and qualitative data as a basis for their designs.

Photo Studies

Students began with simple photo studies of existing bus stop designs and evaluated the possible pros and cons of each. Sacred Heart students worked individually or in pairs to create a shared slide presentation as the basis for class discussion. Brunswick students created an image board about their global research on bus stops.

Pro: Very cool and creative, shelter, easy to find for new users
Con: can't see bus coming not very practical, kind of small for city stop, might be hot in summer (no ventilation?)

Pro: very creative and unique, can see buses coming from far away, can be seen from far away
Con: very dangerous, risk of falling, can't really fit people, no shelter, schedule info?

Students discovered that merging decorative design ideas with functionality is a key aspect for any design that is to be beneficial for the end user. The classes formulated their first research questions based on insights gained from the photo studies. They pondered questions such as: How much space does a person need in a bus stop to be comfortable? How tall, wide, or spacious is the ideal bus stop? Who are the bus riders or other bus stop users? What are their needs and wants? In what types of locations might school bus stops be placed so that they can best serve our school communities?

Body Storming

"Bodystorming situates brainstorming in physical experience, combining role-playing and simulation to inspire new ideas and empathic, spontaneous prototyping." [1] In order to better understand dimensions and scale needed for their designs students measured seat width, backpacks, sports bags, wheelchairs and door dimensions. They researched and measured possible bus stop locations on their school property and did photo studies of the area. They also collected dimensions of school busses in use in the district.

Students taped dimensions on walls and floors in their classrooms and experimented with the personal space people need when passing each other in a doorway or when sitting next to each other with backpacks and bags. They tried a variety of seating and storage arrangements by moving chairs, taped lines and props. This process allowed students to brainstorm and role-pay in a physical space and to simulate how the users' experience differs in a variety of designs and what constraints and problems students might face as designers.

Interviewing

Students took to the halls, classrooms and playgrounds to interview students who use the school bus as well as those who don't use the busses to find out how choices about school bus use are made, how users experience their time waiting for the bus and how they navigate getting on and off the bus in the morning and the afternoon. They interviewed different age groups of students as well as students who travel to school with more than just a backpack, such as musicians and athletes. The interviewing teams prepared questionnaires based on their own experiences and edited and refined questions in the process of interviewing as they learned about critical issues they had not anticipated. As a summary of their findings Sacred Heart students created a movie with typical answers that illustrated what it would take to get students to switch from private transportation to the school bus. Brunswick students also interviewed teachers to

collect their insights on school bus usage, since they supervise drop-off and dismissal.

Critical Incident Technique

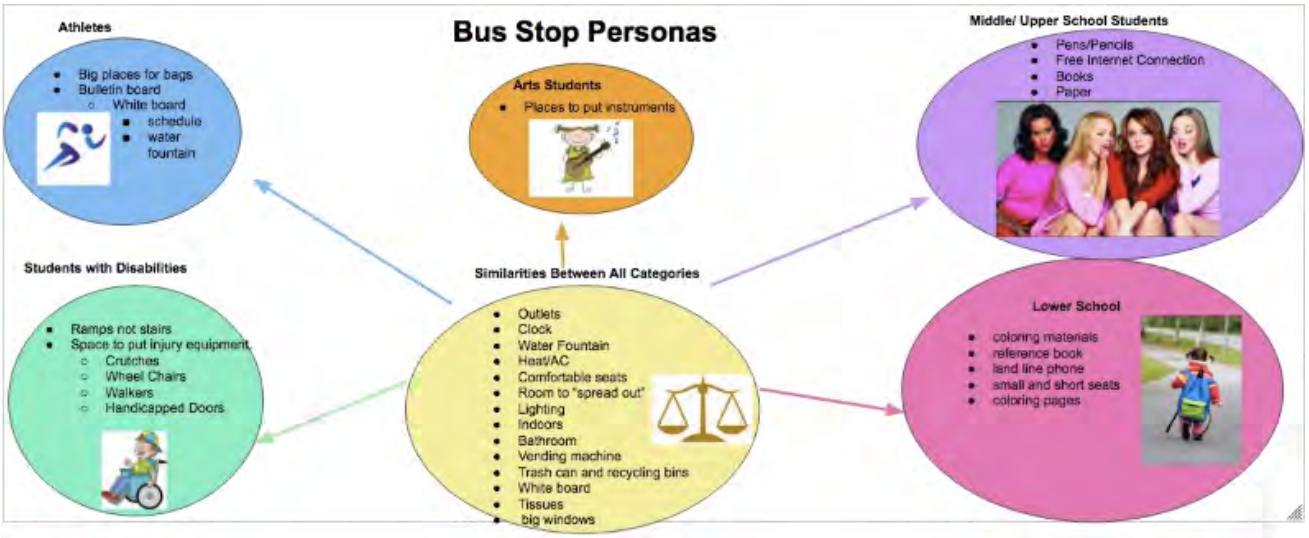
Based on their interviews with students these teams developed three situations in which a choice is made for or against use of the school bus. The cartoon shows a problem situation and offers a solution that is designed to improve the user experience. The short cartoons illustrated the students' findings that weather, availability of alternative means of transportation and the specific design features of a bus stop, such as seating and storage are the biggest factors influencing the user's choice. The critical incident method helped students focus on the problem-solving aspect of the design process and help them think through what their designs would need to accomplish at a very basic level. Students use an online cartoon creator to make the cartoons.

Personas

In creating personas, researchers "consolidate archetypal descriptions of user behavior patterns into representative profiles, to humanize design focus, test scenarios, and aid design communication." [1]

Students described athletes, students with disabilities, high school students, elementary students and music students as groups with different needs. Body size was a major factor in differentiating groups as well the amount of bags or equipment students need to take to school. Students in these teams first used

sticky notes to organize their thoughts and then created a diagram to illustrate shared needs as well as individual needs of these user groups.



The Design Process

Design Considerations: Based on the research findings students developed individual plans for a bus stop design that described all aspects they planned to consider in their design: research findings and particular user needs, any constraints or opportunities presented by the planned location of their bus stop, aesthetic or environmental considerations. They were encouraged to be guided in their planning and throughout the process of designing by the "Ten Principles of Good Design" by functionalist industrial designer Dieter Rams.

Experimentation: Through rich materials explorations the course exposed students to a variety of modeling techniques and tools. Practicing scoring, folding, cutting, gluing and measuring various materials such as cardboard, tagboard, kraft paper, and acetate provided the tools for students to develop their own designs and generate new ideas.

Sketch Modeling: Students then created a series of sketch models from cardboard and tag board to help them visualize their ideas. They used a scale model of a school bus as a reference to help them develop the scale and proportions of their bus stop. They also learned to make orthographic sketches to help them visualize their ideas. The big idea for students to grasp was that the design process is iterative in nature. Students used formal critiques and informal discussion to revise and refine their design ideas. They also assisted each other

with problem solving construction challenges and manipulating materials to a desired effect.

Sharing: During the sketch modeling phase teams from Brunswick School and Sacred Heart came together to share and discuss research findings with the other research teams and to present their sketch models. Students explained how their planned design addressed particular user needs or problems and described their design process discussing any revisions, challenges and new ideas they faced.

This sharing session allowed them to see that designers are inspired by different perspectives on research and how similar problem statements can be solved and interpreted through a wide variety of designs. Students also learned about different research methods, as not all techniques were duplicated at each school, and had an opportunity to reflect on the quality of their own data collection processes.

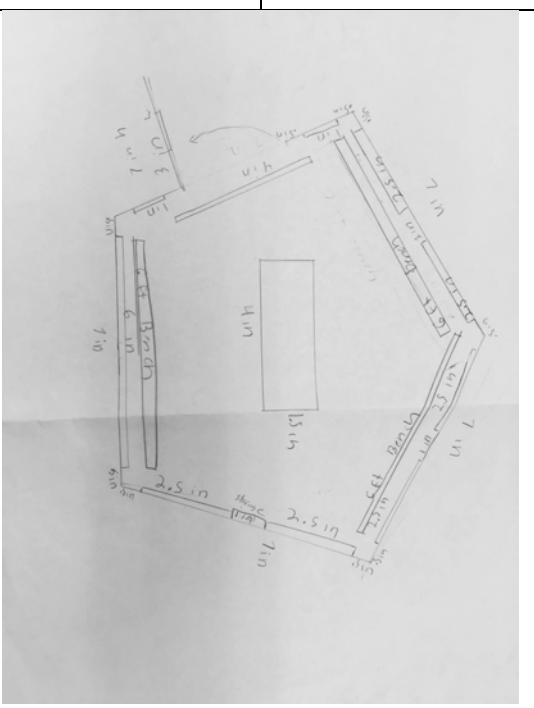
Technical Drawings + Final Models: Students decided on their individual final designs after their research collaboration and sharing of sketch models.They first drew construction plans and elevation drawings on a scale of 1":1' or ½" : 1' to help them measure materials and construct a scale model.They then built their final architectural models including furniture, vegetation, scaled figures and other design details.They learned how to make two-point perspective drawings of their models as the final illustration of their bus stop design.

Designer Visit: Amy Leidtke's visit to our schools provided students with an opportunity to observe an industrial designer in action as they they observed her approach to handling materials, creating quick sketch models and revising and rethinking her designs within the space of a short hour. Bringing an outside professional into the classroom created a positive impact on the project process. Students liked getting professional feedback on their models and felt validated in all their efforts and struggles with materials and concepts. Ms.Leitdke also explained to students the extent of the industrial design field, its reach into a wide variety of product categories and she described a variety of career paths designers take.

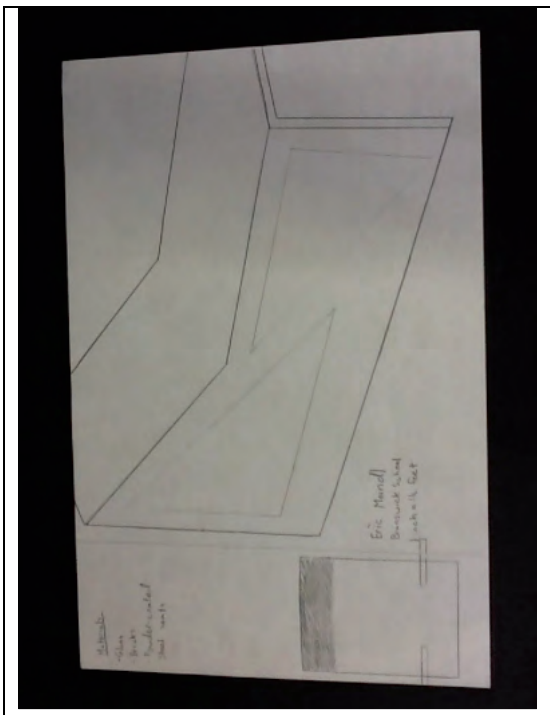
Design Samples

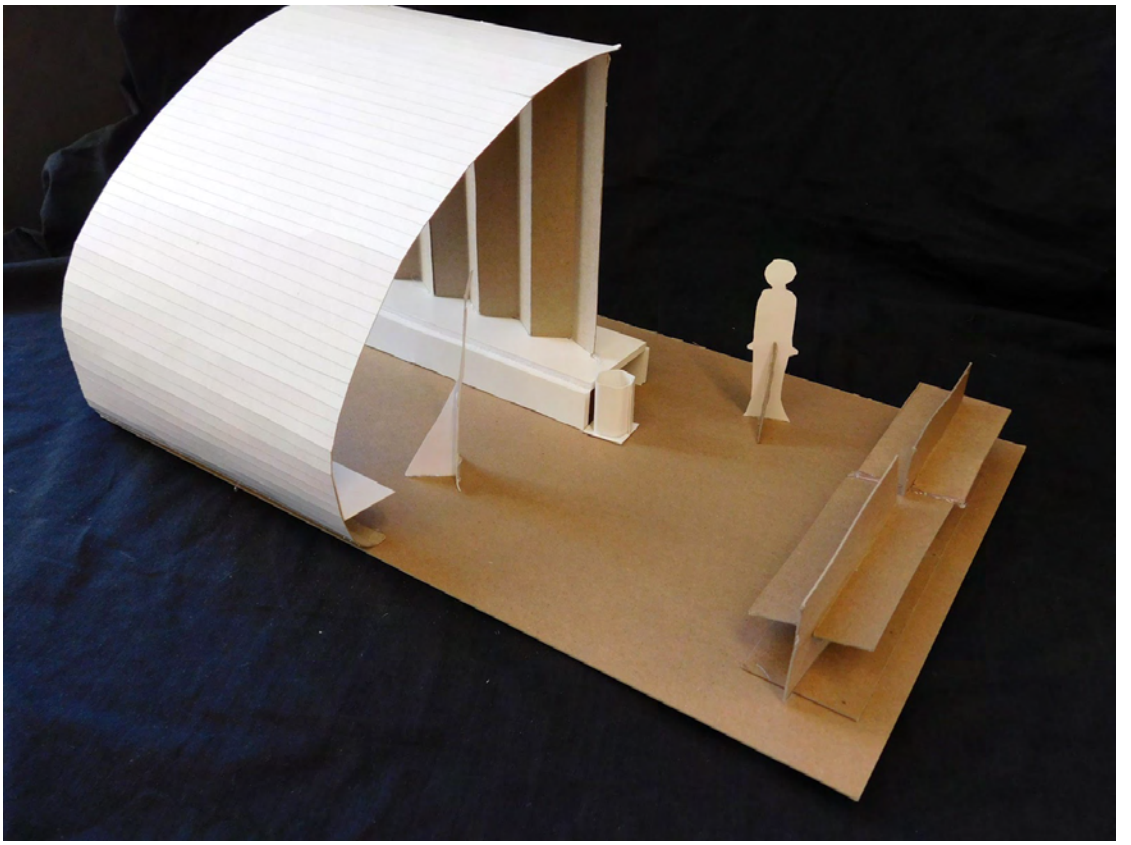
The following section showcases selected student work, including some of their sketches, model sketches, floor plans and final models.

Alice created a hexagonal design that provides protection from bad weather and provides views into and out of the structure in all directions, letting in as much natural light in as possible. The slanted roof lets water drain more easily than a flat roof. Alice chose the hexagon to create a structure that is more whimsical and can be decorated with creative designs or public art installations on the outside.



Gabe focused his design considerations on comfort and functionality for all four seasons. For warm weather he created outdoor seating and for colder months, he incorporated a heating system. Visually, Gabe wanted the bus stop to echo the overall aesthetic of his school: "The zigzag wall holding up the overhang which blends well with the modern theme as well as the simple style benches. I want people to feel they are still at Brunswick."





Sharing of Final Models and Student Reflection

During the sharing of the final scaled models, students were teamed up in mixed groups to discuss the design process and their individual findings. To facilitate the process and encourage everyone's participation each team assigned a moderator, a time-keeper, a photographer and a writer. Each student designer had to discuss construction challenges, how they solved the problems and a new insight they gained after going through this process and completing the project. The responses were recorded on a collaborative padlet presentation. A final group discussion on implications for implementation and community concerns completed the sharing session.

At the end of the course students were assigned a 40 minute period to do a culminating writing assignment reflecting on the design process, their challenges and success working with materials to create their designs, and the collaborative and iterative aspects of the project.

Teacher Reflections and Conclusions

Students entered the research phase of the project with some hesitation because they assumed that research meant they would be working in the library. But they soon discovered that research is defined in much broader terms in the design process and that it leads to unexpected discoveries and reveals their own assumptions about other users. They also came to understand that interesting and strong designs spring from careful research and data collection which allow the designer to develop empathy and understanding for the end user's situation in order to help formulate the specific design problem.

The combination of individual work with collaborative structures is critical for successful design and integral to a successful student experience. Students learn that all the steps in the process are necessary for effective problem solving. They experience that sharing information and participating in collaboration enriches their own findings and supports a deeper understanding of the challenges.

Time spent on material exploration is also crucial for design success. Innovative design depends on an understanding of what is possible with any given material. Time for exploration also includes time for sketch-modeling. It is critical that students come to understand that the design process is also an ongoing learning process in which designs get altered and revised several times before a final solution is reached. Through this process, students gain self-confidence through newfound competence handling new tools and employing techniques.

Students were also excited to discover how much design shapes all objects in their lives and that design thus affects all humans in a myriad of ways. In a similar way students also came to understand that the design process is applicable to many other problem solving challenges and that they can use this particular way of design-thinking not only in other classes and for other school projects but that it is a general life skill.

From a teacher's viewpoint, the collaboration and shared lessons gave us each new perspectives on the lesson by seeing the results by different students. Due to scheduling differences between our schools we each emphasized different portions of the design and building process. This proved to be another source of feedback on our individual methods. We refine the project each year and improve our delivery of the lessons by working together. Part of the process of teacher reflection was also the annual development of a new blog that allows sharing of all aspects of the project with the school communities and beyond.

.

References

[1] Hannington, Bruce & Martin, Bella, Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions, Rockport Publishers, 2012.
[2] Sutherland, Martha, Model Making: A Basic Guide, Norton Professional Books for Architects & Designers, W. W. Norton & Company,1999.
[3] Roke, Rebecca, Nanotecture: Tiny Built Things, Phaedon, 2016.
[4] Gary Hustwit, Urbanized - A documentary about the design of cities, 2011
[5] Penalosa, Enrique, Why buses represent democracy in action, TED Talk, 2013, retrieved Novmeber 1, 2015 from https://www.ted.com/talks/enrique_penalosa_why_buses_represent_democracy_in_action
[6] Bogota: Cuidad y TransMilenio 2010, 2013, retrieved November 1, 2015 from https://www.youtube.com/watch?v=F8eHXwaXwwo
[5] Rams, Dieter, Ten Principles of Good Design, retrieved November 1, 2015 from https://www.vitsoe.com/us/about/good-design

About the Authors

Don Buckley
Co-Founder, Tools at Schools
Email: donbuckley@gmail.com
Twitter: @donbuckley

Don Buckley believes in design thinking as a methodology to solve wicked problems and is dedicated to creating new possibilities in education. He is an author, public speaker, and workshop facilitator with at a wide variety of local, regional, national and international conferences. Don is based in New York City and is the co-founder of Tools at Schools, an organization that co-designs products with students and teaches them design thinking. He is also part of the faculty of the Teachers College, Columbia University. Don is an author of *Interactive Science*, the first web-based science series for schools published by Pearson. He is also featured in the book, *Blended Leadership – Six Simple Beliefs for Leading Online and Off* published by Wiley.

Sofia Cabrera
Class XII Student
Marymount School of New York
Email: scabrera@marymountnyc.org

Sofia is a senior at Marymount School of New York, where she serves as co-president of the Global Awareness Club and as vice-president of La Mesa Espanola, the National Spanish Honor Society chapter. Sofia represented Marymount at the National Coalition of Girls' Schools 2016 Global Forum on Girls' Education, where she presented a session entitled *#Globaleducation: Connecting Students Through Innovative Learning Experiences*, that focused on global exchange programs. When not in school, Sofia spends her time volunteering with the East Harlem Tutorial Project as a fourth grade teacher's assistant and she spends her summers doing community service in the Dominican Republic.

Elaine Chu
Third Grade Teacher
Little Red School House & Elisabeth Irwin High School
Email: echu@lrei.org
Twitter: @LREI
Elaine Chu has twelve year's experience teaching in independent and public elementary schools in New York City. Currently a third grade teacher at the Little Red School House & Elisabeth Irwin High School, Elaine also offers professional development to teachers and administrators on developing social studies curricula using an Imaginative Inquiry approach. She has worked in the field of education throughout her professional career, designing curricula and professional development programs for schools and museums, and has worked internationally to help create educational infrastructure in developing countries. Elaine is an alumnae of Tufts University and Bank Street College.

Dr. Sarah G. Cunningham
AP US History Teacher
Marymount School of New York
Email: scunningham@marymountnyc.org
Sarah G. Cunningham coordinates the Class IX Humanities program and teaches AP U.S. History and history senior electives in the upper school at Marymount. A teacher for more than 20 years, Sarah hopes her students will build multiple competences, capabilities, and resourcefulness as they explore the events and dynamics of history, and about themselves as learners and global citizens. She is particularly interested in material history and the social impacts of new technologies, and founded the interdisciplinary, team-taught Humanities course that combines history, English, and art history in a skills-based study of the cultures of the ancient world.

Annette Grueterich
Middle School Studio Art and Computer Art
Sacred Heart Greenwich
Email: gruetericha@cshct.org
Annette Grueterich teaches Middle School Art and Computer Art at Sacred Heart Greenwich in Connecticut. Annette has been teaching students of all ages in the visual arts for eighteen years. After a career in advertising and marketing, Annette was able to combine her lifelong passion for the visual arts and her interest in the psychology of thinking and cognitive development to lead her into the field of education. She holds two Master's Degrees from Columbia University. An understanding of the visual arts as a medium for research as well as communication informs her teaching practice. In her artistic practice, Annette

is interested in exploring the intersection of art and the natural sciences. She works in a variety of media: ceramics, photography and mixed media.

Ann Hamilton-Dixon
Lower School Instructional Technology Specialist/Coordinator
St. Catherine's School
Email: ahdisxon@st.catherines.org
Ann teaches technology skills to students in grades K through 4 and provides tech support for the Lower School faculty and staff. She is also a coach for the 4th and 5th grade FLL robotics teams, a role she has filled since 2001. Ann earned her B.A. degree in Psychology from Gettysburg College. She came to St. Catherine's School in 1982 after teaching third grade for two years at St. Francis Indian School in St. Francis, South Dakota. She joined St. Catherine's as a first grade teacher, a position she held for fifteen years. She helped establish the Lower School technology program in the mid-1990s and served as the first in-house computer teacher for the Lower School. She returned to the classroom to teach third grade for a number of years at which time she earned her M.Ed. from Virginia Tech through the online graduate school program in Instructional Technology. She entered her current position in 2009.

Allison Hupper
Class XII Student
Marymount School of New York
Email: ahupper@marymountnyc.org
Alli is co-president of the Metropolitan Museum of Art Club at Marymount and also serves as the project manager for the Environmental Science Club. Alli also represents Marymount as a Student Ambassador, giving prospective students tours as well as meeting with prospective Lower School parents. Over the summer, Alli interned at the Go Project, a non-profit organization that gives year round academic, emotional, and social support to underperforming K-8 students.

Christina Irving
Lower School Librarian
St. Catherine's School
Email: cirving@st.catherines.org
In addition to managing the Lower School library at St. Catherine's, Christina teaches weekly library and information literacy classes to students in the junior kindergarten through fourth grade. Christina earned her B.A. in History from Hendrix College and her Master of Library and Information Science from the University of South Carolina. Christina has over ten years experience as an

elementary school librarian. Prior to working in schools, Christina was a children's librarian in public libraries in Virginia and Arkansas.

Ana Kapetanis
Director of Lower School
St. Catherine's School
Email: akapetanis@st.catherines.org
Ana earned her B.A. in Psychology and Economics from Smith College, her M.A. in Learning Disabilities/Neurological Impairment from New York University and her Ed.D. in Administrator Leadership for Teaching and Learning from Walden University. She has been an educator for over thirty-five years, starting as a special education teacher in the private and public school systems in New Jersey. After teaching special education, Ana became an elementary school teacher, teaching several grade levels over fifteen years at two large independent schools in southern Florida. Ana has been a school administrator for over ten years and is now in her sixth year at St. Catherine's School.

Jessie Kirk
Third Grade Head Teacher
Little Red School House & Elisabeth Irwin High School
Email: jkirk@lrei.org
Twitter: @jcheits
Jessie Kirk has been a third grade teacher at Little Red School House & Elisabeth Irwin High School in New York City for four years. She has a B.A. in Human Development from Connecticut College, and a M.S.Ed. in Childhood General Education from Bank Street College of Education. Prior to teaching at LREI, Jessie taught at The Learning Project in Boston, and at Bank Street School for Children and Growing Up Green Charter School in New York. Jessie grew up in Berkeley, California and enjoys spending her free time at her family's house in Cape Cod.

Lorna LaRiviere
Art Teacher and Arts Coordinator
Brunswick Middle School
Email: LLariviere@brunswickschool.org
Lorna's interest in teaching middle school art lies in the exploration process for a student, rather than the finished product. Lorna's classes include strategic planning in student teams, design thinking approaches and materials exploration in the classroom. Her students gain creative confidence through a variety of skill development and project work. Lorna holds a B.F.A. from the Rhode Island School of Design and a M.A.T. from Manhattanville College.

Caroline Lin
Class XII Student
Marymount School of New York
Email: clin@marymountnyc.org
Caroline is President of CODE, the Upper School coding Club and she teaches Lower Middle School students how to use Scratch as part of the LMS AfterSchool program. Caroline also serve as President of Mathletes, the school's Math Club and Math Team, as well as the President of the Environmental Science Club. Outside of school, Caroline interns at a research laboratory and she is on the Youth Board of a community women who blend digital media and writing.

Caitlin McLemore
Academic Technology Specialist
Email: caitlin.mclemore@harpethhall.org
Twitter: @edtechcaitlin
Caitlin McLemore is the Academic Technology Specialist at Harpeth Hall School, an all girls' private school in Nashville, Tennessee. In her role, Caitlin works with faculty and students to provide meaningful and successful integration of technology into the learning experience. Caitlin is a Common Sense Media EdTech Mentor, Google Certified Educator, and former President of the ISTE Mobile Learning Network. In 2014, Caitlin and a colleague won the ISTE Librarians Network Technology Innovation Award. Caitlin has a M.Ed. from the University of Florida and is currently pursuing an Ed.D. from Johns Hopkins University.

Julia Ranocchia
Class XII Student
Marymount School of New York
Email: jranocchia@marymountnyc.org
Julia is the co-President of Science Olympiad at Marymount and co-Vice President of CODE, the Upper School Coding Club. She also serves as Vice President of the National Honor Society. Over the summer, Julia interned at Vosshall Laboratory at Rockefeller University, where she assisted graduate students in conducting research on mosquito behavior. She also volunteers for the ASPCA outside of school.

Dr. Reshan Richards
Adjunct Assistant Professor, Teachers College, Columbia University
Email: rbr17@columbia.edu
Twitter: @reshanrichards
Dr. Reshan Richards is an Adjunct Assistant Professor in the Math, Science, and Technology Department at Teachers College, Columbia University and the Chief Learning Officer at Explain Everything, which he co-founded. Reshan also

teaches Startup 101, an entrepreneurship course for graduating seniors at Montclair Kimberley Academy in Montclair, NJ. Reshan authored *Blended Leadership: Six Simple Beliefs for Leading Online and Off* (Wiley/Josey-Bass). An Apple Distinguished Educator and member of Mensa, Reshan has an Ed.D. in Instructional Technology and Media from Teachers College, Columbia University, an Ed.M. in Learning and Teaching from Harvard University, and a B.A. in Music from Columbia University.

Molly Rumsey
Director of Information Services
Harpeth Hall School
Email: mrumsey@harpethhall.org
Twitter: @mollycrumsey
Molly Rumsey is the Director of Information Services at the Harpeth Hall School in Nashville, Tennessee. Molly has been at Harpeth Hall for twenty-two years where she served in many different capacities, including Dean of Students, Technology Integration Specialist, co-chair of the STEM for Girls Think Tank, Director of Summer Programs, and mathematics teacher. In addition, she has served as the Interim Director of One Schoolhouse (formerly the Online School for Girls) and currently serves on the Board of Directors. Molly also serves as a consultant for the Folio Collaborative.

Mark Silberberg
Director of Learning & Innovation
Little Red School House & Elisabeth Irwin High School
Email: msilberberg@lrei.org
Twitter: @silberbergmark
Mark Silberberg is thrilled to be a member of the Little Red School House & Elisabeth Irwin High School (LREI) learning community and is inspired each day by students and colleagues alike. Mark currently works with faculty, students, and families as the school's Director of Learning and Innovation. Prior to that, Mark served for more than a decade as the school's Middle School principal. A lifelong learner, Mark began his formal adult life in schools as a teacher of physics, chemistry and English. Mark also taught an experiential business simulation class in the public schools, where he also worked as a school administrator and technology coordinator. For the ten years prior to coming to LREI, Mark was a co-founder and co-director of a progressive K-12 public charter school where he currently still serves as a board member. When not immersed in things LREI, Mark enjoys spending time with his family and completing sundry home repair and tinkering projects. He is an avid soccer player and skier and wishes he had more time to play the guitar and bass.

Eric A. Walters
Director of STEM Education
Marymount School of New York
Email: eric.walters@marymountnyc.org
Twitter @EWaltersScience
Eric A. Walters serves as the Director of STEM Education at Marymount School of New York, where he teaches AP Physics, Honors Physics, Atmospheric Science, and Videography: Shot on iPhone. An Apple Distinguished Educator, Eric believes that transformative teaching and learning occurs when students construct their own knowledge, collaborate with their peers and then publish their work. Eric also serves as moderator for the Student Tech Team @ Marymount, which plans the annual Student Technology Conference, a global, virtual free conference by students, for all, that provides an international forum for the presentation, discussion, and sharing of educational technology best practices in schools and other academic settings. Eric also serves as moderator for CODE, the Upper School's Coding Club. Eric has a B.S. in Meteorology from the University of Massachusetts at Lowell; an M.S. in Atmospheric Science from the State University of New York at Albany; a professional certificate in online learning from the University of California-San Diego; and a certificate in television writing from UCLA. Eric also has a second career as an aspiring television sitcom writer. His dramatic comedy, *My Life with Liam* and his animated webseries, *Skippy & Dude*, will debut in mid-2017.

Lisa Yokana
Art, Architecture and STEAM Educator
Scarsdale High School
Email: lisayokana@gmail.com
Twitter: @lyokana59
An educator for over fifteen years, Lisa Yokana currently teaches art, architecture and STEAM courses at Scarsdale High School, where she also works with teachers across disciplines to integrate design thinking and making into their curriculum. She has co-designed and co-teaches STEAM courses for Scarsdale's Design Lab, which will open in Spring 2017. Lisa is also a Teacher Coach for IDEO's Teachers Guild and guides other teachers from around the world through the design thinking process in order to solve the biggest challenges in education. She is the author of curriculum for outside organizations, including the U.S. History Advanced Placement course. In 2012, Lisa received a grant from Scarsdale Schools' Center for Innovation to research innovative education programs and spaces. In 2014, Lisa received another grant from the CFI to integrate Maker projects across grade levels. Agency by Design (Harvard's Project Zero) selected Lisa as one of thirty Maker Teachers across the country to participate in their learning community. She leads Innovation Education, Design

Thinking, and Maker Workshops, which encourage and enable educators to shift their practice. Lisa earned her B.A. in Studio Art and French Literature from Williams College, where she was elected to Phi Beta Kappa, and her M.A. in Art History from Columbia University. She also has a degree in building and district level administration from Stony Brook University.

Making and Learning Institute
Marymount School of New York

Sponsored in part by a grant from the E.E. Ford Foundation, the Making and Learning Institute offers a new paradigm in professional development. Instead of self-contained, teacher-centered workshops, you will be immersed in innovative teaching practices, maker culture, design thinking, and digital learning.

From Prototype to Pitch:
New Pathways in Design, Maker, and Entrepreneurship Education

Email Us: making@marymountnyc.org
Connect with us: making.marymountnyc.org