Frameworks for Making Science Research Accesible for All

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Imagine a classroom of constructive chaos: a group of students is busy as they monitor their work. Another team of students is on the other side of the room redesigning their experiment. They seem frustrated, but are motivated to make their third trial work. In another corner, a student is explaining an article to his research partners that can really bring out the significance of their work. The partners take notes vigorously, asking questions along the way to make sure they understand the article.

As science teachers, we embrace environments that foster inquiry, discovery and critical thinking. Our students do authentic independent research projects that put students in the role of scientists. At School of the Future (SOF), students must do four research projects, also known as exhibitions, as a part of our graduation requirements. Students need to do one exhibition for each subject: two in the humanities, one in math and one in science. Students are expected to do one of the required four exhibitions each year. Each student is assigned to a sponsor, a School of the Future teacher who acts as the high school equivalent of a research advisor, providing support throughout the process. Much like a college thesis, the students are expected to produce a paper documenting their research as well as present their work in front of a committee of teachers, peers and community members. The student's work is evaluated based on an established rubric.

Because science embraces hands-on experiences, students are usually fascinated and motivated by the subject. But despite the instant engagement and buy-in that science research offers, students aren't always ready for it. Science research requires a set of specific skills and aptitudes. Science exhibitions demand that students have research skills: they should be able to know how to find resources, take notes, read critically, and analyze information. In addition, they need to know how to read and write scientific language.

Ultimately, science exhibitions demonstrate that students have the ability to design experiments, carry them out, and analyze the results. Students should be able to pose a testable question, form a workable hypothesis, design an experiment, and be able to collect data. After all this, students have to make sense of their data and critically examine its validity in order to improve the experiment. Being able to accomplish this is a difficult feat, and we are teaching these skills in a heterogeneous classroom that requires us to differentiate students' topics according to their skills and aptitude. How can we create a supportive and challenging exhibition experience without overwhelming our students?

Developing a School Culture of Research and Rigor

The most crucial factor to successful exhibitions is having a staff that buys in to the process and the teaching styles necessary to support independent exhibition work. At School of the Future, exhibitions are a central topic of conversation during the interview phase for new staff. We often ask what types of projects potential applicants have done in the past that might be useful to our students' exhibition process. New staff members then participate in Summer Institute, a summer orientation program during which significant time is dedicated to curriculum development. We use Grant Wiggins' backwards planning process from Understanding by Design with an emphasis on projects that can be extended to meet exhibition requirements. Veteran SOF staff act as "in-house" professional development leaders facilitating workshops in the Habits of Mind, coaching new teachers on how to utilize these critical thinking skills in everyday lessons so that students have constant exposure to and experience with the skills that the exhibition rubrics make explicit.

In addition to Habits of Mind professional development, SOF's high school division has a Faculty Exhibition Committee comprised of master exhibition sponsors who design and lead professional development for the

whole school throughout the year. From previous years, certain exhibitions are identified as “anchor papers” that have the student initiative and demonstration of mastery of the skills the exhibition is designed to highlight. Anchor papers are read by faculty members and graded using the established rubrics so that we can establish inter-rater reliability. A key component of sponsor development comes directly from the administrative staff. They are mindful of the time they set aside throughout the year to assist new and existing staff with the issues that arise from this deep work.

Building Structure Throughout the Exhibition Process

Because of our commitment to the exhibition process, SOF designed a weekly exhibition class. At the ninth grade level, the focus is on orienting the students into the exhibition culture. They learn to understand the rubrics, examine anchor papers, and learn about the role of committee members. Throughout the later grades, exhibition class is focused on the content’s specific skills and understanding. In addition to the class, students are mandated to meet periodically with their exhibition sponsors. Sponsors are expected to keep records of student progress detailing meeting dates (since many meetings happen after the regular hours of the school day), assignments, and contact with parents when significant issues arise.

One of the fundamental structures that guide students’ exhibition process is the exhibition rubric. Our rubric explicitly organizes the criteria by which students’ exhibitions will be judged according to the Habits of Mind. This rubric is used throughout the process of the exhibition to help students check their own thinking on their project. For example, during the topic brainstorming part of the exhibition, students must examine the significance of their project. What real life applications do their ideas connect to? What are some current science and math developments in their topic area? We refer them to the significance portion of the rubric. This discussion helps students weed out any project ideas that lack substance and meaning, as well as maintain rigor through critical thinking in the research process. By identifying the strengths and weaknesses of the project through the rubric, it can be also seen as a great differentiation tool.

As tools to help focus on skills proficiency, we created templates that support students to organize their exhibition papers while maintaining the standards of our exhibition rubric. These templates are highly structured, presented in a graphic organizer format that reflects a lab report. Under each section, students are given specific questions to tackle. These questions are designed so that they address the standards of the rubric. Students use the template like a workbook, working on sections of it throughout different phases of their exhibition process. The students do not have to respond to each question in complete sentences. Students who struggle with organization, writing and critical thinking find the templates worthwhile.

We love using these templates as the focal point of our one-on-one meetings with our students: the structure of the template allows us to identify students’ needs and work with them. After the template is completed, students can then focus on their writing by putting their bullet points in essay format. By chunking the process, we have seen more progress with our struggling kids toward successful completion of the exhibition. We mandate the use of the template at the beginning, but as students find their own individual systems that are successful, we allow them to create and maintain their own writing and thinking processes.

Our classrooms are designed to be equipped with resources to help students become independent with their exhibition projects. Sections of the room are dedicated to exhibition experiments. We find that giving students space to work offers them more ownership of their research. Classroom libraries are stocked with reference material, with a variety of books and journals that best suit the needs of our learners. For example, we keep multiple copies of science dictionaries in all reading levels as quick references. In addition, the science department has print and online subscriptions to popular journals, such as Scientific American and Popular Science. We find that most of these resources are sufficient for our student population.

However, when we need to find higher level reading materials for our students, we seek support from community organizations. For example, our work with the Science Teachers Research Program in New York City, one of the largest teacher research programs in the United States, has assisted us in identifying and obtaining journal articles to support authentic student research. We feel that our partnerships with the program played a huge role in offering the funds, expert personnel and professional development to create a strong science exhibition program at SOF.

Tinkering with Student Curiosity

In order to help kids jump start their research engines, and explore their interests, the tenth grade exhibition research course, Advanced Placement biology lab, serves as a launching pad. For two months, our classroom was very much like a real research lab. We divided our science exhibition class into groups of four students, with each team doing one of the AP Biology labs. As real research teams would, we had a class meeting on each lab as the teams reported on their background research, design, results, struggles and conclusion. On the pedagogical level, all students are able to be exposed to five to six different research experiments in addition to conducting a full length experiment within their own teams.

The great thing about using the AP lab curriculum is that it contains advanced experiments outside of students' course work that play around with a variety of variables to bring out the complexity of an investigation. Therefore, if students are interested in taking on one of the labs as their exhibition, they have multiple points of entry. For example, one of our students was so interested in the physiology lab that she decided to make it into her exhibition project. Her research is on examining the effect of nicotine on daphnia heart rate. Another team examined the perfect "recipe" for bacterial transformation.

Of course, students are more than welcome to examine topics outside of the AP labs for their exhibitions. As we write, a group of students intrigued with research on sound and its effects on proteins took on examining the effect of different sound tones on plant growth. Another student wants to extend her pinhole camera project, a lab that was conducted in our vision unit. For these students, the AP labs helped them refine their research interests. Thus, we have found that using these AP biology labs as anchor eliminated the "creativity gap" we experienced before when helping students find topics for their exhibitions. They provide the perfect environment and structure for students to explore, reflect and refine their research interests. Because of the high availability of AP lab kits and their defined experiments, the teacher planning and prep time for this experience was relatively simple.

However, a two month experience is only a part of what we do to guide students toward their science exhibition topics. We make an effort to point out possible extensions of short experiments done in class. Students usually take on an old lab, perhaps working on a different variable they might be interested in or working on redesigns that can improve on the class experiment. We keep a list of successful past exhibition topics for students to revisit.

Using Collaboration at All Levels

Managing 25 to 30 students as they work on science exhibitions can be a logistical nightmare, especially if each student is conducting an experiment. We encourage students to team up on their exhibition projects. Together, they design the experiment and implement However, students are responsible for producing their own exhibition paper and presentation. The only aspect of the exhibition paper they share is their experiment data. This allows students to work together, yet assures that each student produces her or his own work that demonstrates effort and understanding. Collaboration on exhibition experiments helps maintain a real lab-like atmosphere. It is also a differentiation tactic—long term experiments have multiple layers, from research to implementation to interpretation. While some students can work independently to produce a successful exhibition, others work best with friends or partners that complement their thoughts and work habits. Finally, managing groups of two or three students increases the teacher's support time for students.

The calendar for exhibitions is established prior to the start of the school year. In addition to the school-wide deadlines, a first draft due date is established for each grade. These drafts are assigned to members of the Faculty Exhibition Committee who act as a second set of eyes assessing the state of the research and writing. This reader serves two purposes. The first purpose is to ensure that the sponsor receives additional feedback during the process. The second purpose is to give the student additional motivation to work with his or her sponsor. It is assumed that the student is working closely with his or her sponsor from the beginning stages. The Exhibition Committee reader serves as a second adult voice to stress the importance of the collaborative effort between student and sponsor. This reader is often a stop-gap for students who are in critical danger of not completing their exhibitions. It bears noting, however, that members of the Faculty Exhibition Committee are, for the most part, full-time teachers who are volunteering their time because of

their deep dedication to the philosophy of the school, further reinforcing the need to hire committed personnel.

Over the past few years, the science department has put extensive time and energy into identifying spiraling content and skills, establishing not just rubrics by which teachers assess skill development, but also a living content document complete with anchor experiments that the department has deemed essential to science education. The plan is that even with the flux of personnel, there are certain activities that are such rich learning experiences that SOF would like to see them in curricula year after year. In this way, there is continuity in the department, as well as expectations for learning. The senior year science teacher knows that no matter who taught ninth grade science, certain activities were covered and can be referenced in her class. This is valuable as a pre-assessment tool, and can be used to identify students who will need extra scaffolding during the exhibition process.

We hope that we have given you some frameworks to refine your research exhibition program with your students and colleagues. Because SOF's culture of sharing and collaboration between colleagues, classroom observations (which we call "intervisits") are frequent, and reading student work is commonplace. However, the exhibitions process allows staff members that might not see each other on a regular basis to open a dialogue about skill development and teaching strategies. We encourage you to visit School of the Future and other schools that have been successful in implementing research projects for heterogeneous communities. Talking to students, sitting in on student presentations, reading sample papers—these experiences can help you examine ways to perfect your exhibition program.

For more on School of the Future's science exhibitions, including samples of completed science exhibitions and exhibitions process guidelines, please visit CES ChangeLab at www.ceschangelab.org. You'll find School of the Future's science exhibition material when you click on School of the Future and follow the assessment links.

We use the School of the Future Habits of Mind with our students in order to develop critical thinking throughout all of our classes. The Habits of Mind are represented by a list of five aspects of critical thinking:

- using evidence
- making connections
- examining alternatives
- seeing a problem from different points of view
- understanding the significance of an issue

The primary aim of the Science Research Program for Science Teachers is to provide New York metropolitan area middle and high school science teachers with sustained hands-on experience in scientific research so they can better understand the practice of science and better transmit to their students and fellow teachers a feeling for its practice. Each teacher spends two consecutive summers working as a laboratory research assistant under the supervision of a Columbia faculty mentor. To learn more, go to www.scienceteacherprogram.org.

Related Resource

For more on School of the Future's science curriculum and pedagogy, please see "Scientific Literacy through Inquiry: Practicing Scientific Process through Pinhole Photography" by Annie Chien and Allison Godshall in "Teaching and Learning Essential Literacy Skills: CES Teacher Voices," Horace volume 22, issue #2. It's online at www.mschien.com.

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for six years. For the last three years, she has also been Exhibition Coordinator for the high school which includes working with new sponsors one on one, developing rubrics, and scheduling.

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