DAY ONE PROJECT | INSTITUTE FOR PROGRESS

Creating a Public System of National Laboratory Schools

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Summary

The computational revolution enables *and requires* an ambitious reimagining of public high-school and community-college designs, curricula, and educator-training programs. In light of a much-changed — and much-changing — society, we as a nation must revisit basic assumptions about what constitutes a "good" education. That means re-considering whether traditional school schedules still make sense, updating outdated curricula to emphasize in-demand skills (like computer programming), bringing current perspectives to old subjects (like computational biology); and piloting new pedagogies (like project-based approaches) better aligned to modern workplaces. To do this, the Federal Government should establish a system of National Laboratory Schools in parallel to its existing system of Federally Funded Research & Development Centers (FFRDCs).

The National Science Foundation (NSF) should lead this work, partnering with the Department of Education (ED) to create a Division for School Invention (DSI) within its Technology, Innovation, and Partnerships (TIP) Directorate. The DSI would act as a platform analogous to the Small Business Innovation Research (SBIR) program, catalyzing Laboratory Schools by providing funding and technical guidance to federal, state, and local entities pursuing educational or cluster-based workforce-development initiatives.

The new Laboratory Schools would take inspiration from successful, vertically-integrated research and design institutes like Xerox PARC and the Mayo Clinic in how they organized research, as well as from educational systems like Governor's Schools and Early College High Schools in how they organized their governance. Each Laboratory School would work with a small, demographically and academically representative cohort financially sustainable on local per-capita education budgets.
Collectively, National Laboratory Schools would offer much-needed "public sandboxes" to develop and demonstrate novel school designs, curricula, and educator-training programs rethinking both what and how people learn in a computational future.

Challenge and Opportunity

Education is fundamental to individual liberty and national competitiveness. But the United States' investment in advancing the state of the art is falling behind.

Innovation in educational practice has been incremental. Neither the standards-based nor charter-school movements departed significantly from traditional models. Accountability and outcomes-based incentives like *No Child Left Behind* suffer from the same issue.

The situation in research is not much better: NSF and ED's combined spending on education research is barely twice the research and development budget of Nintendo. And most of that research focuses on refining traditional school models (*e.g.* presuming 50-minute classes and traditional course sequences).

Despite all these efforts, we are still seeing unprecedented declines in students' math and reading scores.

Meanwhile, the computational revolution is widening the gap between what school teaches and the skills needed in a world where work is increasingly creative, collaborative, and computational. Computation's role in culture, commerce, and national security is rapidly expanding; computational approaches are transforming disciplines from math and physics to history and art. School can't keep up.

For years, research has told us individualized, competency- and project-based approaches can reverse academic declines while aligning with the demands of industry and academia for critical thinking, collaboration, and creative problem-solving skills. But schools lack the capacity to follow suit.

Clearly, we need a different approach to research and development in education: We need prototypes, not publications. While studies evaluating and improving existing schools and approaches have their place, there is a real need now for "living laboratories" that develop and demonstrate wholly transformative educational approaches.

Schools cannot do this on their own. Constitutionally and financially, education is federated to states and districts. No single public actor has the incentives, expertise, and resources to tackle ambitious research and design — much less to translate into research to practice on a meaningful scale. Private actors like curriculum developers or educational technologists sell to public actors, meaning private sector innovation is constrained by public school models. Graduate schools of education won't take the brand risk of running their own schools, and researchers won't pursue unfunded or unpublishable questions. We commend the Biden-Harris administration's Multi-Agency Research and Development Priorities for centering inclusive innovation and science, technology, education, and math (STEM) education in the nation's policy agenda. But reinventing school requires a new kind of research institution, one which actually *operates* a school, developing educators and new approaches firsthand.

Luckily, the United States largely invented the modern research institution. It is time we do so again. Much as our nation's leadership in science and technology was propelled by the establishment of land-grant universities in the late 19th century, we can trigger a new era of U.S. leadership in education by establishing a system of National Laboratory Schools. The Laboratory Schools will serve as vertically integrated "sandboxes" built atop fully functioning high schools and community colleges, reinventing how students learn and how we develop in a computational future.

Plan of Action

To catalyze a system of National Laboratory Schools, the NSF should establish a Division for School Invention (DSI) within its Technology, Innovation, and Partnerships (TIP) directorate. With an annually escalating investment over five years (starting at $25 million in FY22 and increasing to $400 million by FY26), the DSI could support development of 100 Laboratory Schools nationwide.

The DSI would support federal, state, and local entities — and their partners — in pursuing education or cluster-based workforce-development initiatives that (i) center computational capacities, (ii) emphasize economic inclusion or racial diversity, and (iii) could benefit from a high-school or community-college component.

DSI support would entail:

1. **Competitive matching grants** modeled on SBIR grants. These grants would go towards launching Laboratory Schools and sustaining those that demonstrate success.

2. **Technical guidance** to help Laboratory Schools (i) innovate while maintaining regulatory compliance, and (ii) develop financial models workable on local education budgets.

3. **Accreditation support**, working with partner executives (e.g., Chairs of Boards of Higher Education) where appropriate, to help Laboratory Schools establish relationships with accreditors, explain their educational models, and document teacher and student work for evaluation purposes.

4. **Responsible-research support**, including providing Laboratory Schools assistance with obtaining Federalwide Assurance (FWA) and access to partners' Institutional Review Boards (IRBs).

5. **Convening and storytelling**, raising awareness of and interest in Laboratory Schools' mission and operations.

Launching at least ten National Laboratory Schools by FY23 would involve three primary steps. First, the White House Office of Science and Technology Policy (OSTP) should convene an expert group comprised of (i) funders with a track record of attempting radical change in education and (ii) computational domain experts to design an evaluation process for the DSI's competitive grants, secure industry and academic partners to help generate interest in the National Laboratory School System, and recruit the DSI's first Director.

In parallel, Congress should issue one appropriations report asking NSF to establish a $25 million per year pilot Laboratory School program aligned with the NSF Directorate for Technology, Innovation, and Partnerships (TIP)'s Regional Innovation Accelerators (RIA)'s Areas of Investment. Congress should issue a second appropriations report asking the Office of Elementary and Secondary Education (OESE) to release a Dear Colleague letter encouraging states that have spent less than 75% of their Elementary and Secondary School Emergency Relief (ESSER) or American Recovery Plan funding to propose a Laboratory School.

Finally, the White House should work closely with the DSI's first Director to convene the Department of Defense Education Activity (DDoEA) and National Governors Association (NGA) to recruit partners for the National Laboratory Schools program. These partners would later be responsible for operational details like:

- Vetting or establishing an independent, state-level organization to receive federal funding and act as the primary liaison to the DSI.
- Giving the organization the matching funds needed to access DSI funding.
- Ensuring that the organization maintains a board that includes at least one community-college leader, two youth workers or high-school leaders, one representative from the state department of education, and two computation domain experts (one from industry and one from academia). Board size should not exceed eight members.
- Providing DSI with the necessary access and support to ensure that appropriate and sufficient data are collected for evaluation and learning purposes.
- Partnering with philanthropic actors to fund competitive grant programs that ultimately incentivize district and charter schools to adopt and adapt successful curricula and models developed by Laboratory Schools.

Focus will be key for this initiative. The DSI should exclusively support efforts that center:

1. ***New* public schools**, not programs within (or reinventions of) existing schools.
2. **Radically different designs**, not incremental evolutions.
3. **Computationally rich models** that integrate computation and other modern skills into all subjects.
4. **Inclusive innovation** focused on transforming outcomes for the poor and historically marginalized.

Conclusion

Imagine the pencil has just been invented, and we treated it the way we've treated computers in education. "Pencil class" and "pencil labs" would prepare people for a written future. We would debate the cost and benefit of one pencil per child. We would study how oral test performance changed when introducing one pencil per classroom, or after an after-school creative-writing program.

This all sounds stupid because the pencil and writing are integrated throughout our educational systems rather than being considered individually. The pencil transforms both what and how we learn, but only when embraced as a foundational piece of the educational experience.

Yet this siloed approach is precisely the approach our educational system takes to computers and the computational revolution. In some ways, this is no great surprise. The federated U.S. school system isn't designed to support invention, and research incentives favor studying and suggesting incremental improvements to existing school systems rather than reimagining education from the ground up. If we as a nation want to lead on education in the same way that we lead on science and technology, we must create laboratories to support school experimentation in the same way that we establish laboratories to support experimentation across STEM fields. Certainly, the federal government shouldn't run our schools. But just as the National Institutes of Health (NIH) support cutting-edge research that informs evolving healthcare practices, so too should the federal government support cutting-edge research that informs evolving educational practices. By establishing a National Laboratory School system, the federal government will take the risk and make the investments our communities can't on their own to realize a vision of an equitable, computationally rich future for our schools and students.

Frequently Asked Questions

<u>Who</u>

1. Why is the federal government the right entity to lead on a National Laboratory School system?

Transformative education research is slow (human development takes a long time, as does assessing how a given intervention changes outcomes), laborious (securing permissions to test an intervention in a real-world setting is often difficult), and resource-intensive (many ambitious ideas require running a redesigned school to explore properly). When other fields confront such obstacles, the public and philanthropic sectors step in to subsidize research (e.g., by funding large research facilities). But tangible education-research infrastructure does not exist in the United States.

Without R&D *demonstrating* new models (and solving the myriad problems of actual implementation), other public- and private-sector actors will continue to invest solely in supporting existing school models. No private sector actor will create a product for schools that don't exist, no district has the bandwidth and resources to do it themselves, no state is incentivized to tackle the problem, and no philanthropic actor will fund an effort with a long, unclear path to adoption and prominence.

National Laboratory Schools are intended primarily as research, development, and demonstration efforts, meaning that they will be staffed largely by researchers and will pursue research agendas that go beyond the traditional responsibilities and expertise of local school districts. State and local actors are the right entities to design and operate these schools so that they reflect the particular priorities and strengths of local communities, and so that each school is well positioned to influence local practice. But funding and overseeing the National Laboratory School system as a whole is an appropriate role for the federal government.

2. Why is NSF the right agency to lead this work?

For many years, NSF has developed substantial expertise funding innovation through the SBIR/STTR programs, which award staged grants to support innovation and technology transfer. NSF also has experience researching education through its Directorate for Education and Human Resources (HER). Finally, NSF's new Directorate for Technology, Innovation, and Partnerships (TIP) has a mandate to "[create] education pathways for every American to pursue new, high-wage, good-quality jobs, supporting a diverse workforce of researchers, practitioners, and entrepreneurs." NSF is the right agency to lead the National Laboratory Schools program because of its unique combination of experience, in-house expertise, mission relevance, and relationships with agencies, industry, and academia.

3. What role will OSTP play in establishing the National Laboratory School program? Why should they help lead the program instead of ED?

ED focuses on the concerns and priorities of existing schools. Ensuring that National Laboratory Schools emphasize invention and reimagining of educational models requires fresh strategic thinking and partnerships grounded in computational domain expertise.

OSTP has access to bodies like the President's Council of Advisors on Science and Technology (PCAST) and the National Science and Technology Council (NSTC). Working with these bodies, OSTP can easily convene high-profile leaders in computation from industry and academia to publicize and support the National Laboratory Schools program. OSTP can also enlist domain experts who can act as advisors evaluating and critiquing the depth of computational work developed in the Laboratory Schools. And annually, in the spirit of the White House Science Fair, OSTP could host a festival showcasing the design, practices, and outputs of various Laboratory Schools.

Though OSTP and NSF will have primary leadership responsibilities for the National Laboratory Schools program, we expect that ED will still be involved as a key partner on topics aligned with ED's core competencies (e.g., regulatory compliance, traditional best practices, responsible research practices, etc.).

4. What makes the Department of Defense Education Activity (DoDEA) an especially good partner for this work?

The DoDEA is an especially good partner because it is the only federal agency that already operates schools; reaches a student base that is large (more than 70,000 students, of whom more than 12,000 are high-school aged) as well as academically, socioeconomically, and demographically diverse; more nimble than a traditional district; in a position to appreciate and understand the full ramifications of the computational revolution; and very motivated to improve school quality and reduce turnover

5. Why should the Division for School Invention (DSI) be situated within NSF's TIP Directorate rather than EHR Directorate?

EHR has historically focused on the important work of researching (and to some extent, improving) existing schools. The DSI's focus on invention, secondary/postsecondary education, and opportunities for alignment between cluster-based workforce-development strategies and Laboratory Schools' computational emphasis make the DSI a much better fit for the TIP, which is not only focused on innovation and invention overall, but is also explicitly tasked with "[creating] education pathways for every American to pursue new, high-wage, good-quality jobs, supporting a diverse workforce of researchers, practitioners, and entrepreneurs." Situating the DSI within TIP will not preclude DSI from drawing on EHR's considerable expertise when needed, especially for evaluating, contextualizing, and supporting the research agendas of Laboratory Schools.

6. Why shouldn't existing public schools be eligible to serve as Laboratory Schools?

Most attempts at organizational change fail. Invention requires starting fresh. Allowing existing public schools or districts to launch Laboratory Schools will distract from the ongoing educational missions of those schools and is unlikely to lead to effective invention.

7. Who are some appropriate partners for the National Laboratory School program?

Possible partners include:

- A federal, state, or local agency that already sponsors a workforce-development initiative pursuing a cluster-based strategy: i.e., an initiative that might benefit from a Laboratory School as part of an attempt to address, for instance, talent-pipeline challenges.

- A federal, state, or local agency that already sponsors an education-innovation initiative: e.g., a state public university that may wish to establish a National Laboratory School as a foundation for a forward-looking graduate school of education.

- A state department of education seeking to lead by example to incubate local educational innovation.

- A local school district committed to educational transformation that is interested in supporting a National Laboratory School and intentionally transplanting its practices into district schools over time.

8. What should the profile of a team or organization starting a Laboratory School look like? Where and how will partners find these people?

At a minimum, the team should have experience working with youth, possess domain expertise in computation, be comfortable supporting both technical and expressive applications of computation, and have a clear vision for the practical operation of their proposed educational model across both the humanities and technical fields.
Ideally, the team should also have piloted versions of their proposed educational model approach in some form, such as through after-school programs or at a summer camp. Piloting novel educational models can be hard, so the DSI and/or its partners

may want to consider providing tiered grants to support this kind of prototyping and develop a pipeline of candidates for running a Laboratory School.

To identify candidates to launch and operate a Laboratory School, the DSI and/or its partners can:

- Partner with philanthropists in education to tap into preexisting networks.
- Pursue a basic press and messaging strategy through op-eds in relevant publications.
- Host well-publicized competitions (akin to the XQ Super School competition) to encourage development of novel educational models.
- Partner with graduate schools of education and departments of computer science to identify candidates and advertise the opportunity.

What

1. What is computational thinking, and how is it different from programming or computer science?

A good way to answer this question is to consider writing as an analogy. Writing is a tool for thought that can be used to think critically, persuade, illustrate, and so on. Becoming a skilled writer starts with learning the alphabet and basic grammar, and can include craft elements like penmanship. But the practice of writing is distinct from the thinking one does with those skills. Similarly, programming is analogous to mechanical writing skills, while computer science is analogous to the broader field of linguistics. These are valuable skills, but are a very particular slice of what the computational revolution entails.

Both programming and computer science are distinct from computational thinking. Computational thinking refers to thinking *with* computers, rather than thinking *about* how to communicate problems and questions and models to computers. Examples in other fields include:

- In math: computational approaches to algebra can embrace parallels between variables in mathematics and variables in programming, shifting the focus of algebra classes from symbolic manipulation—which computers are good at—to conceptual understanding. Other subjects normally considered "advanced"—like discrete mathematics and linear algebra—are made accessible to a much broader audience by computational approaches. But current algebra curricula emphasize ideas and approaches appropriate to pencil, paper, and blackboard.

- In life sciences: computational approaches have transformed the practice of biomedical science and research with machine learning accelerating this trend, creating whole fields like bioinformatics and systems biology. But the content and form of biology class in high school remains largely unchanged.

- In economics and social sciences: increasing data availability is transforming these fields alongside increasingly sophisticated computational approaches for evaluating and making sense of these data—including approaches that center computational and mathematical constructs like graphs to represent social networks. And still, social studies, psychology, US history and government classes all look much as they did twenty years ago.

These transitions each involve programming, but are no more "about" computer science than a philosophy class is "about" writing. Programming is the tool, not the topic.

2. What are some examples of the research questions that National Laboratory Schools would investigate?

There are countless research agendas that could be pursued through this new infrastructure. Select examples include:

1. Seymour Papert's work on LOGO (captured in books like *Mindstorms*) presented a radically different vision for the potential and role for technology in learning. In *Mindstorms*, Papert sketches out that vision *vis a vis* geometry as an existence proof. Papert's work demonstrates that research into making things more learnable differs from researching how to teach more effectively. Abelson and diSessa's *Turtle Geometry* takes Papert's work further, conceiving of ways that computational tools can be used to introduce differential geometry and topology to middle- and high-schoolers. The National Laboratory Schools could investigate how we might design integrated curricula combining geometry, physics, and mathematics by leveraging the fact that the vast majority of mathematical ideas tackled in secondary contexts appear in computational treatments of shape and motion.

2. The Picturing to Learn program demonstrated remarkable results in helping staff to identify and students to articulate conceptions and misconceptions. The National Laboratory Schools could investigate how to take advantage of the explosion of interactive and dynamic media now available for visually thinking and animating mental models across disciplines.

3. Bond graphs as a representation of physical dynamic systems were developed in the 1960s. These graphs enabled identification of "effort" and "flow" variables as new ways of defining power. This in turn allowed us to formalize analogies across electricity and magnetism, mechanics, fluid dynamics, and so on.

Decades later, category theory has brought additional mathematical tools to bear on further formalizing these analogies. Given the role of analogy in learning, how could we reconceive people's introduction to natural sciences in cross-disciplinary language emphasizing these formal parallels?

4. Understanding what it means for one thing to cause (or not cause) another, and how we attempt to establish whether this is empirically true is an urgent and omnipresent need. Computational approaches have transformed economics and the social sciences: Whether COVID vaccine reliability, claims of election fraud, or the replication crisis in medicine and social science, our world is full of increasingly opaque systems and phenomena which our media environment is decreasingly equipped to tackle for and with us. An important tool in this work is the ability to reason about and evaluate empirical research effectively, which in turn depends on fundamental ideas about causality and how to evaluate the strength and likelihood of various claims. Graphical methods in statistics offer a new tool complementing traditional, easily misused ideas like *p*-values which dominate current introductions to statistics without leaving youth in a better position to meaningfully evaluate and understand statistical inference.

The specifics of these are less important than the fact that there are many, many such agendas that go largely unexplored because we lack the tangible infrastructure to set ambitious, computationally sophisticated educational research agendas.

3. How will the National Laboratory Schools differ from magnet schools for those interested in computer science?

The premise of the National Laboratory Schools is that computation, like writing, can transform many subjects. These schools won't place disproportionate emphasis on the field of computer science, but rather will emphasize integration of computational thinking into all disciplines—and educational practice as a whole. Moreover, magnet schools often use selective enrollment in their admissions. National Laboratory Schools are public schools interested in the core issues of the median public school, and therefore it is important they tackle the full range of challenges and opportunities that public schools face. This involves enrolling a socioeconomically, demographically, and academically diverse group of youth.

4. How will the National Laboratory Schools differ from the Institute for Education Science's Regional Education Laboratories?

The Institute for Education's (IES's) Regional Education Laboratories (RELs) do not operate schools. Instead, they convene and partner with local policymakers to lead applied research and development, often focused on actionable best practices for today's schools (as exemplified by the What Works Clearinghouse). This is a valuable service for educators and policymakers. However, this service is by definition limited to existing school models and assumptions about education. It does not attempt to pioneer new school models or curricula.

5. How will the National Laboratory Schools program differ from tech-focused workforce-development initiatives, coding bootcamps, and similar programs?

These types of programs focus on the training and placement of software engineers, data scientists, user-experience designers, and similar tech professionals. But just as computational thinking is broader than just programming, the National Laboratory Schools program is broader than vocational training (important as that may be). The National Laboratory Schools program is about rethinking school in light of the computational revolution's effect on all subjects, as well as its effects on how school could or should operate. An increased sensitivity to vocational opportunities in software is only a small piece of that.

6. Can computation really change classes other than math and science?

Yes. The easiest way to prove this is to consider how professional practice of non-STEM fields has been transformed by computation. In economics, the role of data has become increasingly prominent in both research and decision making. Data-driven approaches have similarly transformed social science, while also expanding the field's remit to include specifically online, computational phenomena (like social networks). Politics is increasingly dominated by technological questions, such as hacking and election interference. 3D modeling, animation, computational art, and electronic music are just a few examples of the computational revolution in the arts. In English and language arts, multimedia forms of narrative and commentary (e.g., podcasts, audiobooks, YouTube channels, social media, etc.) are augmenting traditional books, essays, and poems.

7. Why and how should National Laboratory Schools commit to financial and legal parity with public schools?

The challenges facing public schools are not purely pedagogical. Public schools face challenges in serving diverse populations in resource-constrained and highly regulated environments. Solutions and innovation in education need to be prototyped in realistic model systems. Hence the National Laboratory Schools must commit to financial and legal parity with public schools. At a minimum, this should include a commitment to (i) a per-capita student cost that is no more than twice the average of the relevant catchment area for a given National Laboratory School (the 2x buffer is provided to accommodate the inevitably higher cost of prototyping educational practices at a small scale), and (ii) enrollment that is demographically and academically representative (including special-education and English Language Learner participation) of a similarly aged population within thirty minutes' commute, and that is enrolled through a weighted lottery or similarly non-selective admissions process.

8. Why are Xerox PARC and the Mayo Clinic good models for this initiative?

Both Xerox PARC and the Mayo Clinic are prototypical examples of hyper-creative, highly-functioning research and development laboratories. Key to their success inventing the future was living it themselves.

PARC researchers insisted on not only building but using their creations as their main computing systems. In doing so, they were able to invent everything from ethernet and the laser printer to the whole paradigm of personal computing (including peripherals like the modern mouse and features like windowed applications that we take for granted today).

The Mayo Clinic runs an actual hospital. This allows the clinic to innovate freely in everything from management to medicine. As a result, the clinic created the first multi-specialty group practice and integrated medical record system, invented the oxygen mask and G-suit, discovered cortisone, and performed the first hip replacement.

One characteristic these two institutions share is that they are focused on applied design research rather than basic science. PARC combined basic innovations in microelectronics and user interface to realize a vision of personal computing. Mayo rethinks how to organize and capitalize on medical expertise to invent new workflows, devices, and more.

These kinds of living laboratories are informed by what happens outside their walls but are focused on inventing new things within. National Laboratory Schools should similarly strive to demonstrate the future in real-world operation.

<u>Why?</u>

1. Don't laboratory schools already exist? Like at the University of Chicago?

Yes. But there are very few of them, and almost all of those that do exist suffer from one or more issues relative to the vision proposed herein for National Laboratory Schools.

First, most existing laboratory schools are not public. In fact, most university-affiliated laboratory schools have, over time, evolved to mainly serve faculty's children. This means that their enrollment is not socioeconomically, demographically, or academically representative. It also means that families' risk aversion may constrain those schools' capacity to truly innovate. Most laboratory schools not affiliated with a university use their "laboratory" status as a brand differentiator in the progressive independent-school sector.

Second, the research functions of many laboratory schools have been hollowed out given the absence of robust funding. These schools may engage in shallow renditions of participatory action research by faculty in lieu of meaningful, ambitious research efforts.

Third, most educational-design questions investigated by laboratory schools are investigated at the classroom or curriculum (rather than school design) level. This creates tension between those seeking to test innovative practices (e.g., a lesson plan that involves an extended project) and the constraints of traditional classrooms.

Finally, insofar as *bona fide* research does happen, it is constrained by what is funded, publishable, and tenurable within traditional graduate schools of education. Hence most research reflects the concerns of existing schools instead of seeking to reimagine school design and educational practice.

2. Why will National Laboratory Schools succeed where past efforts at educational reform (e.g., charter schools) have failed?

Most past educational-reform initiatives have focused on either supporting and improving existing schools (e.g., through improved curricula for standard classes), or on subsidizing and supporting new schools (e.g., charter schools) that represent only minor departures from traditional models.

The National Laboratory Schools program will provide a new research, design, and development infrastructure for inventing new school models, curricula, and educator training. These schools will have resources, in-house expertise, and research priorities that traditional public schools—whether district or charter or pilot—do not and should not. If the National Laboratory Schools are successful, their output will help inform educational practice across the U.S. school ecosystem.

3. Don't charter schools and pilot schools already support experimentation? Wasn't that the original idea for charter and pilot schools—that they'd be a laboratory to funnel innovation back into public schools?

Yes, but this transfer hasn't happened for at least two reasons. First, the vast majority of charter and pilot schools are not pursuing fundamentally new models because doing so is too costly and risky. Charter schools can often perform more effectively than traditional public schools, but this is just as often because of problematic selection bias in enrollment as it is because the autonomy they're given allows for more effective leadership and organizational management. Second, the politics around charter and pilots has become increasingly toxic in many places, which prevents new ideas from being considered by public schools or advocated for effectively by public leaders.

4. Why do we need invention at the school rather than at the classroom level? Wouldn't it be better to figure out how to improve schools that exist rather than end up with some unworkable model that most districts can't adopt?

The solutions we need might not exist at the classroom level. We invest a great deal of time, money, and effort into improving existing schools. But we underinvest in inventing fundamentally different schools. There are many design choices which we need to explore which cannot be adequately developed through marginal improvements to existing models. One example is project-based learning, wherein students undertake significant, often multidisciplinary projects to develop their skills. Project-based learning at any serious level requires significant blocks of time that don't fit in traditional school schedules and calendars. A second example is the role of computational thinking, as centered in this proposal. Meaningfully incorporating computational approaches into a school design requires new pedagogies, developing novel tools and curricula, and re-training staff. Vanishingly few organizations do this kind of work as a result.

If and when National Laboratory Schools develop substantially innovative models that demonstrate significant value, there will surely need to be a translation process to enable districts to adopt these innovations, much as translational medicine brings biomedical innovations from the lab to the hospital. That process will likely need to involve helping districts start and grow new schools gradually, rather then district-wide overhauls.

5. What kinds of "traditional assumptions" need to be revisited at the school level?

The basic model of school assumes subject-based classes with traditionally licensed teachers lecturing in each class for 40–90 minutes a day. Students do homework, take quizzes and tests, and occasionally do labs or projects. The courses taught are largely fixed, with some flexibility around the edges (e.g., through electives and during students' junior and senior high-school years).

Traditional school represents a compromise among curriculum developers, standardized-testing outfits, teacher-licensure programs, regulations, local stakeholder politics, and teachers' unions. Attempts to change traditional schools almost always fail because of pressures from one or more of these groups. The only way to achieve meaningful educational reform is to demonstrate success in a school environment rethought from the ground up. Consider a typical course sequence of Algebra I, Geometry, Algebra II, and Calculus. There are both pedagogical and vocational reasons to rethink this sequence and instead center types of mathematics that are more useful in computational contexts (like discrete mathematics and linear algebra). But a typical school will not be able to simultaneously develop the new tools, materials, and teachers needed to do so.

6. Has anything like the National Laboratory School program been tried before?

No. There have been various attempts to promote research in education without starting new schools. There have been interesting attempts by states to start new schools (like Governor's Schools),there have been some ambitious charter schools, and there have been attempts to create STEM-focused and computationally focused magnet schools. But there has never been a concerted attempt in the United States to establish a new kind of research infrastructure built atop the foundation of functioning schools as educational "sandboxes".

How?

1. How will we pay for all this? What existing funding streams will support this work? Where will the rest of the money for this program come from?

For budgeting purposes, assume that each Laboratory School enrolls a small group of forty high school or community college students full-time at an average per capita rate of $40,000 per person per year. Half of that budget will support the functioning of schools themselves. The remaining half will support a small research and development team responsible for curating and developing the computational tools, materials, and curricula needed to support the School's educators. This would put the direct service budget of the school solidly at the 80th percentile of current per capita spending on K–12 education in the United States.

With these assumptions, running 100 National Laboratory Schools would cost ~$160 million. Investing $25 million per year would be sufficient to establish an initial 15 sites. This initial federal funding should be awarded through a 1:1 matching competitive-grant program funded by (i) the 10% of American Competitiveness and Workforce Improvement Act (ACWIA) Fees associated with H1-B visas (which the NSF is statutorily required to devote to public-private partnerships advancing STEM education), and (ii) the NSF TIP Directorate's budget, alongside budgets from partner agency programs (for instance, the Department of Education's Education Innovation and Research and Investing in Innovation programs). For many states, these funds should also be layered atop their existing Elementary and Secondary School Emergency Relief (ESSER) and American Rescue Plan (ARP) awards.

2. Why is vertical integration important? Do we really need to run schools to figure things out?

Vertical integration (of research, design, and operation of a school) is essential because schools and teacher education programs cannot be redesigned incrementally. Even when compelling curricular alternatives have been developed under the auspices of an organization like the NSF, practical challenges in bringing those innovations to practice have proven insurmountable. In healthcare, the entire field of translational medicine exists to help translate research into practice. Education has no equivalent. The vertically integrated National Laboratory School system will address this gap by allowing experimenters to control all relevant aspects of the learning environment, curricula, staffing, schedules, evaluation mechanisms, and so on. This means the Laboratory Schools can *demonstrate* a fundamentally different approach, learning from great research labs like Xerox PARC and the Mayo Clinic, much of whose success depended on tightly-knit, cross-disciplinary teams working closely together in an integrated environment.

3. What would the responsibilities of a participating agency look like in a typical National Laboratory School partnership?

A participating agency will have some sort of educational or workforce-development initiative that would benefit from the addition of a National Laboratory School as a component. This agency would minimally be responsible for:

- Vetting or establishing an independent, state-level organization to receive federal funding and act as the primary liaison to the DSI.
- Giving the organization the matching funds needed to access DSI funding.
- Ensuring that the organization maintains a board that includes at least one community-college leader, two youth workers or high-school leaders, one representative from the state department of education, and two computation domain experts (one from industry and one from academia). Board size should typically not exceed eight members.
- Providing DSI with the necessary access and support to ensure that appropriate and sufficient data are collected for evaluation and learning purposes.
- Partnering with philanthropic actors to fund competitive grant programs that ultimately incentivize district and charter schools to adopt and adapt successful curricula and models developed by Laboratory Schools.

4. How should success for individual Laboratory Schools be defined?

Working with the Institute of Education Sciences (IES)' National Center for Education Research (NCER), the DSI should develop frameworks for collecting necessary qualitative and quantitative data to document, understand, and evaluate the design of any given Laboratory School. Evaluation would include evaluation of compliance with financial and legal parity requirements as well as evaluation of student growth and work products.

Evaluation processes should include:

- Comprehensive process and product documentation of teachers' and students' work.

- Mappings of that work back onto traditional academic standards (e.g., Common Core Mathematics and English Language Arts standards).

- Financial audits of a School's operation to evaluate resource-allocation decisions.

- Enrollment and retention audits that document the socioeconomic, demographic, and academic composition of School cohorts.

- An annual report produced by the School describing its model and the primary questions and challenges confronted that year.

- A common (i.e., across the National Laboratory School system) series of diagnostic/formative assessments to evaluate student numeracy and literacy. These assessments should be designed and administered by the DSI and its partners. Assessments should not be overly burdensome or time-consuming for School staff or students, so that the assessment process does not detract from the innovation and experimentation missions of the National Laboratory School system.

Success should be judged by a panel of experts that includes domain experts, youthworkers and/or school leaders, and DSI leadership. Dimensions of performance these panels should address should minimally include depth and quality of students' work, degree of traditional academic coverage, ambition and coherence of the research agenda (and progress on that research agenda), retention of an equitably composed student cohort, and growth (not absolute performance) on the diagnostic/formative assessments.

In designing evaluation mechanisms, it will be essential to learn from failed accountability systems in public schools. Specifically:, it will be essential to avoid pushing National Laboratory Schools to optimize for the particular metrics and measurements used in the evaluation process. This means that the evaluation process should be largely based on holistic evaluations made by expert panels rather than fixed rubrics or similar inflexible mechanisms. Evaluation timescales should also be selected appropriately: e.g., performance on diagnostic/formative assessments should be measured by examining trends over several years rather than year-to-year changes.

5. What makes the Small Business Innovation Research (SBIR) program a good model for the National Laboratory School program?

The SBIR program is a competitive grant competition wherein small businesses submit proposals to a multiphase grant program. SBIR awards smaller grants (~$150,000) to businesses at early stages of development, and makes larger grants (~$1 million) available to awardees who achieve certain progress milestones. SBIR and similar federal tiered-grant programs (e.g., the Small Business Technology Transfer, or STTR, program) have proven remarkably productive and cost-effective, with many studies highlighting that they are as or more efficient on a per-dollar basis when compared to the private sector via common measures of innovation like number of patents, papers, and so on.

The SBIR program is a good model for the National Laboratory School program; it is an example of the federal government promoting innovation by patching a hole in the funding landscape. Traditional financing options for businesses are often limited to debt or equity, and most providers of debt (like retail banks) for small businesses are rarely able or incentivized to subsidize research and development. Venture capitalists typically only subsidize research and development for businesses and technologies with reasonable expectations of delivering 10x or greater returns. SBIR provides funding for the innumerable businesses that need research and development support in order to become viable, but aren't likely to deliver venture-scale returns.

In education, the funding landscape for research and development is even worse. There are virtually no sources of capital that support people to start schools, in part because the political climate around new schools can be so fraught. The funding that does exist for this purpose tends to demand school launch within 12–18 months: a timescale upon which it is not feasible to design, evaluate, refine an entirely new school model. Education is a slow, expensive public good: one that the federal government shouldn't provision, but should certainly subsidize. That includes subsidizing the research and development needed to make education better.

States and local school districts lack the resources and incentives to fund such deep educational research. That is why the federal government should step in. By running a tiered educational research-grant program, the federal government will establish a clear pathway for prototyping and launching ambitious and innovative schools.

6. What protections will be in place for students enrolled in Laboratory Schools?

The state organizations established or selected to oversee Laboratory Schools will be responsible for approving proposed educational practices. That said, unlike in STEM fields, there is no "lab bench" for educational research: the only way we can advance the field as a whole is by carefully prototyping informed innovations with real students in real classrooms.

7. Considering the challenges and relatively low uptake of educational practices documented in the What Works Clearinghouse, how do we know that practices proven in National Laboratory Schools will become widely adopted?

National Laboratory Schools will yield at least three kinds of outputs, each of which is associated with different opportunities and challenges with respect to widespread adoption.

The first output is **people**. Faculty trained at National Laboratory Schools (and at possible educator-development programs run within the Schools) will be well positioned to take the practices and perspectives of National Laboratory Schools elsewhere (e.g., as school founders or department heads). The DSI should consider establishing programs to incentivize and support alumni personnel of National Laboratory Schools in disseminating their knowledge broadly, especially by founding schools.

The second output is **tools and materials**. New educational models that are responsive to the computational revolution will inevitably require new tools and materials—including subject-specific curricula, cross-disciplinary software tools for analysis and visualization, and organizational and administrative tools—to implement in practice. Many of these tools and materials will likely be adaptations and extensions of existing tools and materials to the needs of education.

The final output is **new educational practices and models**. This will be the hardest, but probably most important, output to disseminate broadly. The history of education reform is littered with failed attempts to scale or replicate new educational models. An educational model is best understood as the operating habits of a highly functioning school. Institutionalizing those habits is largely about developing the skills and culture of a school's staff (especially its leadership). This is best tackled not as a problem of organizational transformation (e.g., attempting to retrofit existing schools), but rather one of organizational creation—that is, it is better to use models as inspirations to emulate as new schools (and new programs within schools) are planned. Over time, such new and inspired schools and programs will supplant older models.

8. How could the National Laboratory School program fail?

Examples of potential pitfalls that the DSI must strive to avoid include:

- **Spreading resources too thinly.** It is popular to *claim* to support innovation. Hence there are strong incentives for stakeholders to launch innovation initiatives but then hollow them out (in budgetary or other terms) by spreading resources too thinly across many different efforts.

- **Premature scaling.** It will be tempting for stakeholders to prioritize rapidly scaling efforts, proposing, for instance, to incubate a Laboratory School for only one to three years before "scaling up" the school to hundreds or thousands of students. But rapidly scaling up high-touch educational models (*i.e.* those involving significant teacher-student interactions and relationships) has never worked. Instead of emphasizing scale-up, the National Laboratory School program should emphasize building human capital (e.g., using schools to train teachers and leaders), developing tools and materials (e.g., curricula), and creating long-term partnerships to incubate and translate Laboratory Schools' insights into practice.

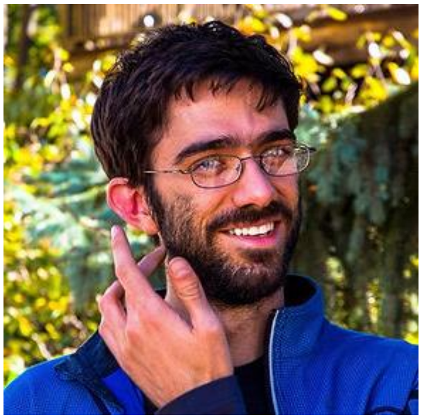
- **Incrementalism.** It is risky to try to invent something new. It is much safer and more comfortable to merely improve or support things that exist. The National Laboratory School program must resist the temptation to develop "Band-Aid" solutions to fundamental problems with existing school models instead of inventing new models that might obviate those issues entirely.

- **Impatience.** Similarly, research and invention are fundamentally unpredictable, creative processes that often take many years of investment to bear fruit. If we knew what we needed to do in education, we wouldn't need to invest in research in the first place. The funding landscape for research and reform in education is heavily weighted toward efforts carried out on a one to five year timeframe. The National Laboratory School program must remain committed to ambitious, longer-term initiatives.

- **Neglecting the importance of team.** When undertaking risky work, it can be tempting to only support all-star teams of established experts thought to have the greatest chance of success. But while expertise matters when it comes to developing entirely new school models, it is equally if not more important to actively bring in fresh voices and fresh perspectives. Furthermore, National Laboratory Schools are not theoretical, but practical. Their success will depend on committed, creative teams working closely together to create an excellent, operating learning environment. Building teams characterized by drive, creativity, and persistence will play an outsized role in the likelihood of success of any given Laboratory School.

- **Neglecting the importance of domain expertise.** In education, there is a tendency to treat teaching and learning as skills and activities that happen in a general, domain-agnostic way. In reality, one cannot think about thinking and learning without thinking about thinking and learning *something*. Innovations in tools, materials, human capital, and pedagogy almost certainly need to be domain-specific. Given the focus of the National Laboratory School program on the computational revolution and on integrating new computational approaches into traditional disciplines, it will be important to ensure that every level of the National Laboratory School program includes computational domain experts as well as experts in education and educational theory.

About the Authors



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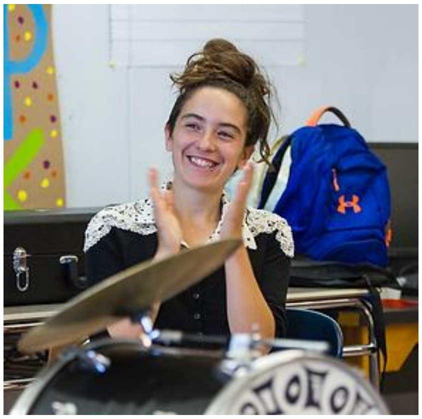

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