The Place and Role of the Exploratorium's Teacher Institute in Strengthening the Teaching of Science

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Executive Summary

The Exploratorium's Teacher Institute

San Francisco's Exploratorium is a hands-on, interactive science museum whose mission is to foster deep understandings of scientific inquiry and transform science education. The Exploratorium's Teacher Institute (TI) has been offering professional development programs for middle and high school science teachers for twenty years. The TI has a particular theory of action that guides its approach to strengthening science teaching through teacher development. TI programs are responsive to policy-generated and administrator-led reform initiatives within the secondary education system; however, TI does not direct its programs at system level change. Rather, TI programs serve teachers directly as individual practitioners and as members of a professional "guild" of science teachers. In the TI director's words, "the teachers are the agents of change, as opposed to the school or the district." TI staff members assume that program alumni are able to improve their own teaching of science, and are also able to help spread TI practices and resources through naturally-occurring collegial relationships and leadership roles in schools.

The Study

It is not self evident how an informal science institution that sits outside the school system can make a valuable—even vital—contribution to the capacity of teachers within the system to improve their teaching. The purpose of this report is to shed light on the distinctive role and place of the TI in contributing to the improvement of science teaching in the schools. Four questions guide the study:

1) What is the status of the school system's capacity to support the development of secondary science teachers?
2) What functions does the TI fulfill in the strengthening of science teachers, and how effective are they in fulfilling these functions?
3) In what domains and at what scale does the TI do this work?
4) What are the limitations of the TI's role in strengthening science teaching?

To conduct the study, we drew on ten years' experience studying various aspects of TI programs, as well as targeted observations, interviews, and document data collected between 2003 and 2005.

Major Findings

- **The education system does not have adequate capacity to support effective inquiry-based science teaching and the improvement of science teaching. The Exploratorium TI provides to teachers what the education system values but cannot provide.**

Administrators and teachers working within the system report that the system is severely diminished in its capacity to support science teaching. Funding is available for curriculum adoption but resources for professional development are inadequate. There is a large influx of new science teachers who, while many are certified, are not skilled enough to build a practice of teaching inquiry-based science; new teachers' workplaces and non-science-based induction programs do not provide this kind of support. Federal accountability policy has put pressure on teachers to teach more diverse students but has drawn funds away from professional development. The small schools movement often isolates science teachers from one another. In sharp contrast, the sentiment of administrators and teachers alike is that the Exploratorium—with its deep emphasis on science teaching and learning—has both the capacity and experience to be a vital resource to the system.

- **The TI's core function is to strengthen the discipline basis of teachers' professional knowledge and practice. It does this by grounding teachers' learning in the vision, concepts and appropriate pedagogies of the science disciplines. The hallmark benefit of TI programs is that teachers develop the specialized pedagogical skills of teaching science through a hands-on inquiry approach. These are teaching skills that the education system is not equipped to support.**

TI programs promote a strong vision of science teaching by engaging teachers in personal hands-on experiences of learning science. These experiences kindle teachers' excitement in science and strengthen content knowledge in areas that are relevant to their teaching. TI staff use many strategies to help teachers gain the specialized pedagogical skill of teaching science hands-on through inquiry. School administrators and teachers alike strongly value this contribution because it is consistent with a progressive vision for science education but virtually impossible to actualize without high quality, discipline-centered professional development. The TI also provides teachers with ongoing access to concrete, usable, and inexpensive resources and materials for teaching science. The TI's science-specific support for new teachers is especially significant because the TI is shaping teachers' practice at the most formative

stage. Ultimately, this grounding in the knowledge, pedagogical skills, and material resources of science helps teachers develop confidence as teachers and form strong professional identities as science teachers.

- **TI programs provide teachers with a science-based perspective on practice that can strengthen their ability to learn from the experience of teaching. Also, the TI offers teachers membership in a professional "guild" of science teachers; this guild is fostered by the Exploratorium's institutional culture, which—in contrast to that of most schools—is imbued with deep respect for science teaching and for teachers. Together, these benefits contribute to teachers' capacity to continue improving their classroom practice over their careers.**

An important source of teaching improvement is learning from one's own experience of teaching. Because of the TI's strong discipline-based influence on teachers' practice, teachers can build their practice on a solid foundation and bring the TI "lens" to their reflections on teaching over time. Additionally, the TI offers participants lifetime membership in the Exploratorium, with ongoing access to programs and resources. TI teachers report that they feel a strong sense of professional kinship and community with other TI teachers, and they enjoy the benefit of ongoing immediate access to TI scientist-educators, most of whom have remained at the TI for many years. This experience of professional community is an extension of the Exploratorium's strong institutional culture of service to and respect for teachers, which stands in contrast to the culture that often pervades school systems.

- **The education system espouses rigorous standards for teaching science but does not have adequate capacity to help teachers actualize those standards. TI programs strengthen science teachers' capacity to translate reform policies into practice and contribute to system improvement.**

Ever more rigorous public expectations, combined with ever-changing district and state reform policies, make strong demands on teachers to re-frame their teaching. Amid this turmoil, TI programs remain a steady presence and consistent source of knowledge that help teachers adjust to policy while maintaining high professional standards of practice. Administrators regard the TI as a vital resource for the strengthening of their standards-based school and district science programs.

- **The TI contributes to strengthened science teaching in varied ways and in multiple spheres beyond their Exploratorium-based programs for teachers.**

The TI is often thought of as a provider of programs for individual teachers on site at the Exploratorium, and it is true that this is their most well known work. To a surprising extent, however, TI staff members also offer programs beyond the Exploratorium in multiple professional domains, including formal science and math

education organizations and agencies, informal science organizations and agencies, California districts and schools, university teacher preparation programs, international consortia and agencies, state programs, and community student/parent groups. In the 6-year period 1999-2004, TI staff led 193 programs for about 4,500 participants. In 2004 alone, staff led 73 such programs for over 2,400 participants.

- **There are some limitations on the TI's ability to support improved science teaching. Experienced science teachers want a wider range of programs, and administrators want the TI to play an even larger role in their school efforts. The "spread" of TI-supported practices from participants to their colleagues is much more constrained than TI leaders envision.**

The TI staff will need to consider how to bolster their offerings for more experienced teachers, who want ongoing, differentiated opportunities. TI staff also need to examine the extent to which they wish to promote teacher leadership more deliberately as a vehicle for spreading classroom practices and resources within the school system.

A Conceptual Framework for Understanding the TI's Contributions to Science Teaching and the School System

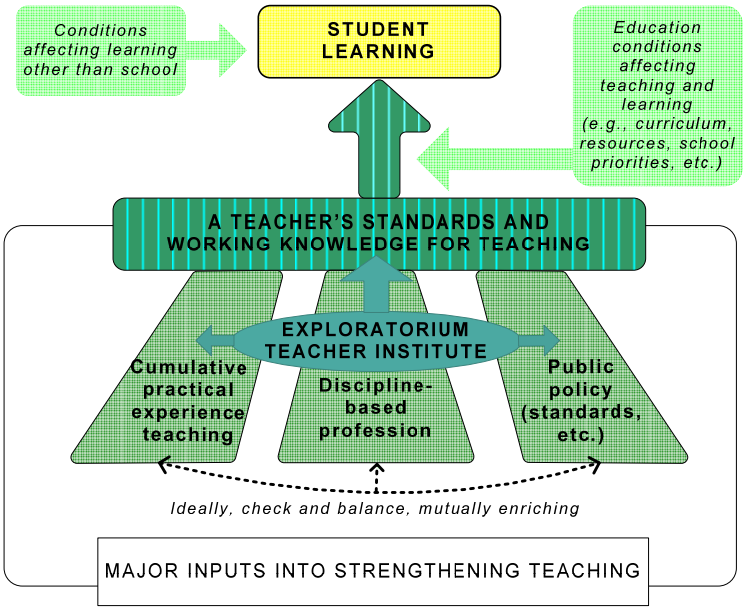
TI programs are supported by a variety of state, federal, and foundation funds. These investors are interested in system change. An obvious question deriving from the study is this: Would the Exploratorium have a broader impact if it altered its theory and strategy to work at the system level rather than primarily at the individual teacher level? Our reflections, based on our long-time study of the Exploratorium, suggests that the answer is no. The first and most simple reason is that work at the system level is not the strength of this institution or of its staff. The second is that, even if the staff were so inclined, a shift toward working at the level of the larger system could actually undermine the role that the TI plays in providing a *professional* perspective (rather than a system policy perspective) on improvement of teaching.

Teachers' working standards and knowledge for teaching are a critically important contributor to student learning. By working standards and knowledge, we mean those that teachers actually draw upon in their practice—the *internalized* standards and knowledge that guide teachers' everyday practices and choices. How do teachers develop the standards and working knowledge they bring into their classrooms? Our research here and on other teacher development networks suggests that they are influenced by three major sources:

1) their own personal standards and experience of teaching,
2) the discipline-based (subject area) profession of which they are a part, and
3) educational policies, particularly content standards.

These comprise what we call the "three-legged stool" of personal, professional, and policy based inputs and perspectives that shape the standards and teaching knowledge that teachers apply in their daily work. Ideally, these inputs are all strong and mutually supportive. Typically, however, the "Professional" (in this case, science discipline-based) perspective and input is weaker than either teachers' personal experience or the pressures of system policy; this is because teachers typically have little opportunity to develop teaching repertoires within dynamic communities that bring scientist-educators and teachers together in a context rich with authentic science. Findings from this study suggest that the TI substantially strengthens the discipline-based leg contributing to teachers' working knowledge and standards.

THE ROLE OF THE EXPLORATORIUM IN STRENGTHENING PROFESSION-BASED CONTRIBUTIONS TO TEACHERS' WORKING STANDARDS AND PRACTICES



The school system, by its nature, does not have the capacity to promote a strongly discipline-based profession. Institutions such as the Exploratorium, therefore, play a critical role in shaping teaching and learning. Thus, the fact that the TI influences teachers in ways that help teachers teach authentic science *and* helps school administrators achieve their policy-oriented agenda does not mean the Exploratorium should start working at the system level. Rather, it means that the TI's discipline-based work with teachers is enabling those teachers to build classroom practice that is grounded in professional knowledge while being responsive to the demands of curriculum policy.

I. Introduction

The Exploratorium is an informal science institution that sits outside the formal school system, and yet in its teacher development programs, it aims to help improve the teaching of science within the formal system. The Exploratorium has numerous characteristics and assets that distinguish it from other informal institutions: Beyond the floor exhibits that serve both informal and formal education, the Exploratorium has institutes and workshops for teachers, a machine shop where teachers can fabricate classroom resources, a teaching faculty comprising both scientists and educators, a resource library of science and teaching resources, and web-based science and teaching resources. And because the Exploratorium has been serving teachers for nearly twenty years, with a quite stable staff of scientist-educators, all of these resources reflect the deep and rich capacity that derives from cumulative development.

The Exploratorium also has a strong ethos related to the teaching of science and to teachers that sets it apart from the public school system. Unlike the school system, which is beset by pressures from all sides and must address all policies, goals, and problems related to education, the Exploratorium teacher programs have the narrower aim of promoting science learning and serving teachers of science. In a quite literal way, the Exploratorium teacher programs do their best to cater to teachers of science, and they are guided in doing so primarily by the institution's commitment to high quality science and love of learning science.

We at Inverness Research have been studying and evaluating Teacher Institute programs for about ten years, with evolving foci and purposes for our work. Early on, our purpose was to illuminate and portray the nature and quality of TI programs so that others could gain insight into the role of science, institutional culture, and a love for teaching and learning that infuses TI programs and makes them distinctive. As the TI developed the Beginning Teacher Program, we shifted to a more formative purpose of studying the program design and participant experience to provide useful feedback to the staff. Our major focus for that work was on the role of the veteran teachers serving as coaches and mentors. (One outgrowth of that work is that Linda Shore and Laura Stokes co-authored a chapter in *Mentors in the Making: Developing New Leaders for New Teachers*, published by Teachers College Press in 2005.)

Over the summers of 2003-2005, our evaluation work focused on the broader goal of the TI, which is to contribute to improvement of science teaching in Bay Area schools. This report reflects this more recent evaluation work, which was informed by our earlier studies.

This Study

It is not self evident how an informal science institution that sits outside the school system can make a valuable—even vital—contribution to the capacity of teachers within the system to improve their teaching. The over-arching purpose of this study has been to shed light on the distinctive role and place of the TI in contributing to the improvement of science teaching in the schools. These four questions guided our study:

1) What is the status of the school system's capacity to support the development of science teachers?

2) What functions does the TI fulfill in the strengthening of science teachers, and how effective are they in fulfilling these functions?

3) In what domains and at what scale does the TI do this work?

4) What are the limitations of the TI's role in strengthening science teaching?

To answer these questions, we relied on multiple perspectives. Most centrally, these included the perspectives of the intended beneficiaries of the work, especially the teachers who are alumni of TI programs and are teaching in the schools, and also the school- or district-based administrators who have a stake in the improvement of instruction. We selected San Mateo County districts and schools as the main focus for our interviews because of the TI's long history of collaboration with SMCOE leaders and involvement of SMCOE teachers. We also interviewed administrators in two distant counties (Shasta and Los Angeles), where TI staff members have led science programs.

Additionally, we directly observed the three kinds of core summer programs that the TI offers and conducted focus groups with participants to gain current perspective on the design of TI programs and the nature of teachers' motivations and experiences. We also interviewed TI staff, attended a monthly staff meeting, and conducted analyses of TI records of staff outreach activities to schools in order to document the staff's rationale for the TI approach and the nature of TI work with teachers beyond the walls of the Exploratorium. We carried out these tasks between summer 2003 and winter 2005.

A complete list of evaluation activities and data sources is in Appendix A.

A Conceptual Framework for Understanding the Place and Role of the TI

The TI's work is guided by the staff's theory of action about how best to contribute to the improvement of science teaching; in this section we explain that theory. We then posit a conceptual framework that positions the TI's approach to supporting teachers within the larger constellation of factors that influence and shape teachers' classroom practices in a subject discipline. In our report we draw from our research to illustrate the nature and depth of the TI's contributions to science teachers and effective science teaching, and also outline limitations of the TI's approach.

The Teacher Institute's aim and theory of action

The TI's aim, stated most simply, is to provide "a home" for interested science teachers throughout their career and to support a professional "guild" of science teachers who occupy this home[1]. The TI staff and the Exploratorium as an institution are a repository of considerable content and pedagogical expertise, as well as of other resources, and the TI staff sees themselves and these resources as being "at the service" of teachers who want to engage with them. TI staff has deliberately staked out a dual role combining teacher and professor that allows them to be creative and frees them from the expectation that they will offer "typical professional development." Each of them believes in and is expert in science instruction that is hands-on, inquiry-based, and student-centered. They create programs where teachers can deepen their discipline knowledge and teaching skills, create materials to use in the classroom, reinvigorate themselves through immersion in their discipline and interaction with colleagues, and learn the specialized and challenging techniques of teaching hands-on inquiry-based science.

The TI staff deliberately view their work and role as serving teachers directly. They see the education system as having limited capacity to support the development of secondary science teachers, and therefore they see direct support of teachers as an important niche for their work. They see teachers as being able to make real differences for students, and thus see teachers (rather than larger surrounding systems) as the agents of change. In some respects, the TI counts on teachers as having sufficient autonomy to teach science in ways they know best, and the TI thus wants to help teachers become ever-more masterful teachers in their classrooms. In other words, the TI's theory and work are strongly grounded in the assumption that teachers have capacity to learn, change, and improve. Moreover, the capacity for good science instruction lies in the teacher, because teachers are often the only consistent element in

[1] Content of this section is distilled from a focus group with TI staff as well as from TI-written documents about their goals and strategies. Quotation marks signify TI language about their theories and work.

an otherwise turbulent education system. Linda Shore, Co-PI for the Teacher Institute puts it this way:

> *I have always seen the teacher institute as being very teacher focused and teacher centered, so that the teachers are the agents of change, as opposed to the school or the district... you help keep the teacher in the classroom and enjoying what they are doing, and whatever is going on outside the door, maybe it is a mess, maybe things change, maybe they don't change, but at least you are helping somebody survive and they enjoy what they are doing and are doing something other than lecturing…. It would be disingenuous to say we impacted the district. We impact places and people.*

TI staff focus their work primarily on individuals rather than departments or districts because they believe they will be most effective if they "work with teachers who want to work with us." Teachers must apply to attend TI workshops. Because the application process attracts teachers with a strong intrinsic motivation, it provides credibility to the program and stature to the participants. TI teachers are ambassadors for the program, along with key administrators in San Mateo and San Francisco; thus, some schools in the Bay Area have now, or have had in the past, clusters of TI-affiliated teachers.

TI trusts teachers to take back to their classrooms what they need. It may simply be a refreshed attitude or a provocative activity to bring energy to the classroom, or it may be a deepened capacity to explicate the science behind a student activity, or it may be a hand-built set of models or materials that can demonstrate a concept. They believe that TI teachers—especially those who are formal leaders, such as departmental chairs—can help spread TI activities and approaches.

The TI's focus on working directly with teachers does not mean they ignore schools, districts, and other agencies. In the same way that the TI is responsive to teachers, the TI responds to school and district leaders who ask for their help. TI staff members reach out to serve schools, districts, other informal science centers and professional groups to the extent that they can. Further, while the TI does not see its purpose as serving to implement state policy, they are quite sensitive to teachers' and schools' concerns related to policy. The TI discerns which policy initiatives to respond to in large part based on teacher and administrator requests for assistance.

The TI as a science profession-based contributor to improvement of teaching

As we consider the role of the Exploratorium in contributing to the improvement of science teaching within the school system, we take into account its institutional position, ethos, and guiding force. In this section we lay out a conceptual framework that can help explain the role of the Exploratorium in strengthening the teaching of science.

The "three-legged stool" of inputs and perspectives that shape teachers' working knowledge

We have formulated this framework from several years' study of a variety of investments in teacher development.[2] There are two components to this framework. The first is the guiding assumption, or thesis, that teachers' working standards and knowledge for teaching are a critically important contributor to student learning; thus, investment in teachers' development of working standards and knowledge for teaching is a vitally important component of any infrastructure dedicated to educational improvement. By working standards and knowledge, we mean those that teachers actually draw upon in their practice—the *internalized* standards and knowledge that guide their judgment about curriculum, that shape the design of their instruction, that inform their analysis of student work and learning, and that drive the hundreds of decisions they make in the action of the classroom.[3] With respect to science, for example, teachers apply their internalized working standards to decide how long to spend on a particular activity, lesson, or unit based on their understanding of the importance of the concepts and their goals for student learning; and decide on what pedagogical strategies to use (to start with, to switch to, to combine) based on the concept to be taught and how students interact with it.

We do not mean to say that teachers' working knowledge is the sole contributor to student learning. Multiple other forces and conditions both inside and outside the classroom interact with students and with teachers' practices and strongly shape student learning experiences and outcomes. But we do mean to say that *the standards that teachers actually enact* in their classrooms, and *the knowledge and skill teachers actually*

[2] We first formulated this framework as part of our analysis of teachers' interaction with policy standards for the teaching of writing in the context of a National Writing Project program, a network of leading professionals in the teaching of writing. That report is available from http://www.inverness-research.org/reports/ab2002-05_Rpt_NWP-FOS_LessLrned.htm. We are also using it to discuss the contributions of on-line science courses taught by the American Museum of Natural History to the improvement of science teaching.

[3] For an in-depth discussion of professionals' working knowledge, see Mary Kennedy's 1982 essay. She defines "working knowledge" as "the organized body of knowledge" that people use "spontaneously and routinely" in their daily work. (*Working knowledge and other essays*. Cambridge, MA: The Huron Institute.)

bring to bear on their interactions with students, are important contributors to student learning.

Given this assumption, the important question is: How do teachers develop the standards and working knowledge they bring into their classrooms? The second component of our conceptual framework posits that teachers build their working standards and knowledge from three major sources:

1) their own personal standards and their own cumulative experience of teaching,

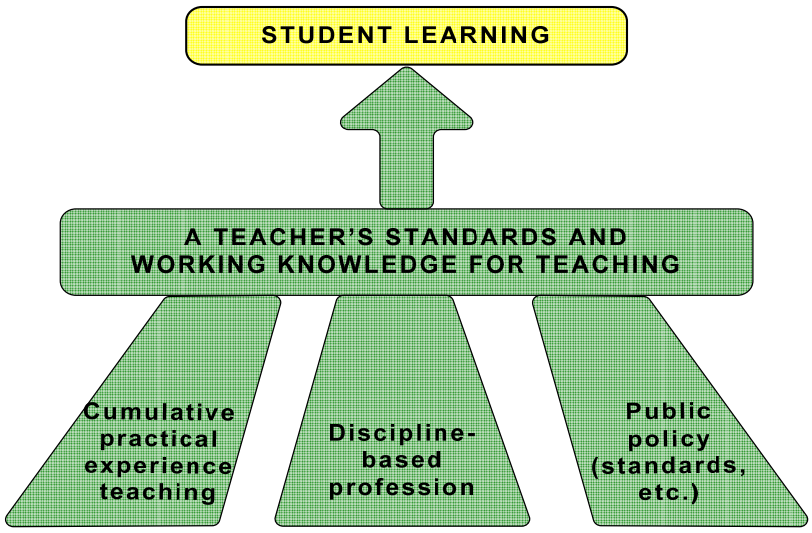
2) the discipline-based (subject matter areas) profession of which they are a part, and

3) educational policies that reflect public/political perspectives and shapes public systems, particularly those policies that specify standards related to teaching and learning in the disciplines.

These comprise what we have come to call the "three-legged stool" of Personal, Professional, and Policy based inputs and perspectives that shape the standards and teaching knowledge that teachers apply in their daily work.

The diagram below represents this framework:

PERSONAL, PROFESSIONAL AND POLICY INPUTS TO TEACHERS' WORKING STANDARDS AND PRACTICES



From the perspective of investment in improvement, the relevant question is how best to help teachers strengthen their standards and working knowledge such that they

reflect the best of what can be learned from practice, from the profession, and from public policy.

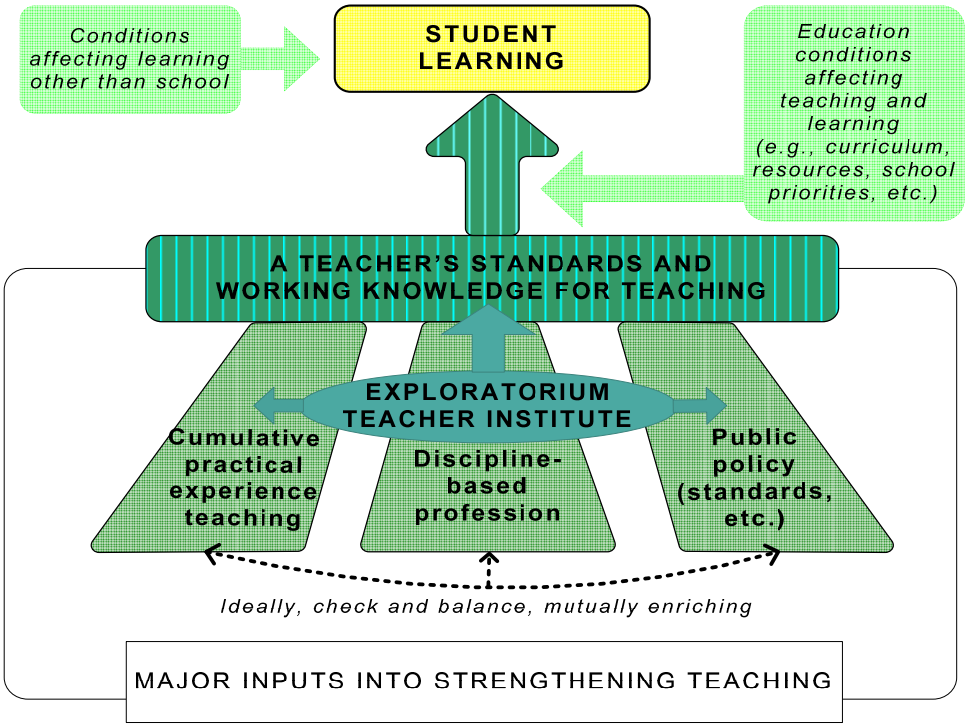
Ideally, these broad perspectives and inputs are mutually enriching and supporting, and act as a check and balance with one another. In reality, they often do not; it is difficult for teachers to strengthen their working knowledge when one leg is too weak or too strong, or when the perspectives are in conflict with one another. For example, science teachers—especially new ones—are often isolated from one another and left to their own devices to form their classroom practice; for these teachers, the "personal experience" leg may be the only one available to them (i.e., is too "strong" as a sole influence), and their working standards are under-influenced from either policy inputs or profession-based knowledge. Teachers who have formed their practice in isolation may work in schools that are heavily influenced by public policy, e.g., schools that strongly encourage the implementation of state standards. If the state standards are of high quality and policy implementation is well supported by the education system, the "policy leg" can challenge teachers' personal experience-based standards and thus contribute to better working standards. In a typical scenario, however—especially for new teachers—schools give teachers very little opportunity to master state standards and translate policy statements into truly high quality practice. Thus, teachers frequently experience a dissonance that they have little opportunity to resolve, and tend to fall back on familiar experience or adopt an overly mechanistic approach to "checking off" public standards. And while teachers can choose to take more coursework in subject areas to enhance their content knowledge, they often lack opportunities to make pedagogical sense of that knowledge in a professional community steeped in the teaching and learning of the subject.

Our research suggests that the ideal scenario is one in which teachers have ongoing opportunities to enhance their subject knowledge within a supportive, discipline-oriented professional community, *and* to learn systematically from their experience, *and* to be guided by well-constructed public policy, all in ways that bring the best of each perspective to bear on the other. A strong professional grounding—typically involving membership in a discipline-rich community of teachers—can give teachers the knowledge and capacity to make good sense of policy and also challenge their personal experience of teaching. In other words, the strong "discipline-based professional leg" seems to a) enable teachers to form daily working standards that are grounded in discipline-rich knowledge and discipline-appropriate pedagogy; and b) serve an integrative role, enabling teachers to learn in constructive ways from their own experience and also teach in ways that are sensitive to public policy.

Exploratorium programs anchor teachers' development to a discipline-based profession

Our research over several years suggests that—as shown below—Exploratorium programs more strongly reflect the perspective of the discipline-based profession than the other perspectives, and that the TI can serve as a discipline-rich professional community of practicing science teachers. Science disciplines (physics and biology, centrally) and the learning of science, as represented by the human drive to perceive and comprehend the natural world, are most important to the Exploratorium. Its programs for teachers want to bring that perspective to bear on teaching in schools. The Exploratorium thus has the potential to play a critically important role in the strengthening of teaching—a role that is distinctly different from, but important to, a system that is pressured strongly by public policy and populated by individuals who bring a wide variety of personal perspectives to their work. The profession-based perspective can enhance and expand the standards that teachers develop from their own (usually quite isolated) personal experience of teaching, and can also provide a stronger and more authentic discipline-based perspective than that which results from political public policy processes.

THE ROLE OF THE EXPLORATORIUM IN STRENGTHENING PROFESSION-BASED CONTRIBUTIONS TO TEACHERS' WORKING STANDARDS AND PRACTICES



The questions we ask in this report have to do with the extent to which the Exploratorium actually fulfills its promise as a science-rich professional resource for teacher development and professional involvement. They also have to do with the extent to which and the ways in which teachers' experiences in Exploratorium programs create benefits for the policy-driven system in which they teach.

II. The Status of the Education System's Support for Science Teachers

Teachers and administrators we interviewed for this study describe a state education system that presents formidable challenges to teachers, schools and districts seeking to provide high quality science education to all secondary students. The challenges are familiar to those knowledgeable about California education: the diminishing capacity to support teachers in science, an increasingly heavy emphasis on responding to accountability policies (which emphasize literacy and mathematics over science), the influx of new teachers, an increasingly diverse student body, and the many factors that impinge on the ability of science departments and department chairs to support their teachers. The bleakness of the current landscape of support for science and science-related professional development can make teachers feel undervalued by the system.

A diminished capacity to support teachers in science. From administrators' points of view, lack of funding is an overriding factor in science education today. It limits professional development offerings and reduces the number of science leadership positions that can be supported.

> *We have funds for aligning curriculum and getting it organized. We don't have funds to train teachers how to flesh out or implement curriculum[4]. (School administrator)*

Limited funds mean that districts have limited ability to tap internal leadership that is content-rich; instead they rely on external sources such as the Exploratorium:

> *There may be one science specialist in a district and they generally have expertise in one, maybe two science content areas. Having personally experienced the Exploratorium TI as a classroom teacher, the content specialist often turns to the Exploratorium for expertise outside his/her personal subject area. (District administrator)*

Moreover, the funding that is available from the state and private funders for science in schools tends to follow "the new thing," for example biotech in San Mateo, rather than strong and ongoing support for improvement of science across the board.

[4] Throughout this report, quotations have been lightly edited for clarity.

An increasingly heavy emphasis on responding to accountability policies. Practitioners say that the system is policy-heavy now, with few structures for teacher learning in a community of practice and little capacity to strengthen teacher knowledge in their discipline. Science educators feel like they are fighting a back-to-basics movement that focuses on covering large amounts of content and goes against what they consider good science teaching. Within the context of our conceptual framework, the balance of power for shaping curriculum has shifted toward the policy system and away from the discipline-rich profession.

> *We're constantly fighting the fundamentalist, back to basics groups—'The textbook is the way to teach science.' And, the state of California, as evidenced in the Framework, is in the back to basics swing. It's demanded that we deliver standards based curriculum, as measured by standardized test scores. We also want to teach science. We have to work within those boundaries and teach what we know is good science. (TI alumnus[5])*

In recent years science has taken a back seat to literacy and mathematics because it hasn't been assessed. However, the addition of statewide science testing at the eighth grade is expected to bring science more to the forefront, especially at the middle school level. This in turn is likely to increase the demand for teacher development in an already stressed system.

> *An 8th grade statewide science test may actually help build up the rationale for why middle school science is going to have to be taught more. (County administrator)*

At the high school level, administrators are challenged by No Child Left Behind requirements that require schools to bring up the performance of low performing students. These students need to take more science than they have in the past, so courses must accommodate a broader range of students than ever before. Some course sequences must be changed to meet state requirements. One veteran teacher expressed the downside of the new requirements for both students and teachers:

> *The state is testing certain years and the schools are responding by saying, 'Okay, if they are going to test students in this course, then we have to make sure the students take this course,' and so the structure of our curriculum is being driven by testing—which is about the stupidest thing that I can ever think of to drive curriculum—and not necessarily by what a student needs. (TI alumnus)*

Another veteran teacher lamented that funds that once flowed toward professional development for science teachers are being diverted towards testing. Teachers can be resourceful, though, and sometimes use what little professional development time they do get for their own purposes.

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[5] By "alumnus" we mean TI participants (male and female) who have attended the Classic Summer Institute and at least one summer program for alumni. Current participants in the New Teacher Program and alumni whose first exposure to the TI was through the New Teacher Program are generally specified as such; in a few cases it was not clear on a focus group transcript whether the speaker was a New Teacher Program participant, so the speaker is simply identified as a TI participant.

> *We are always being told, 'You have to write the course of study for this, you have to give that standard based assessment, the course of study that you wrote last year is now out of compliance, because they changed the state standards.' It never ends. So, once or twice a year we work on it with our colleagues from the district, and the usefulness of it is we get to spend time with our district colleagues and share ideas. We get together and we start talking about ideas that we do in our classrooms and equipment that we can share, or activities that we could do together, etc. We spend as little time as we possibly can on what we are supposed to be doing and the rest of the time on sharing ideas. (TI New Teacher Program alumnus)*

At the system level, another consequence of the dominance of policy's influence is that a small number of underperforming schools may be targeted for extra support by the county or districts, leaving less support for the rest of the schools in their service areas.

The influx of new teachers. At least one administrator we talked to describes his teaching force in the same way that the national science teacher corps has been described. There are many new teachers, and on the whole, they differ dramatically from their veteran colleagues. The veterans tend to be well-trained but perhaps traditional in their approach, while the newer teachers sometimes have weaker paper qualifications and often lack the classroom management skills to undertake the hands-on approach to instruction to which they have been introduced in their preparation programs. These new teachers have heavy demands on their time as they not only learn how to teach, but also take coursework and participate in BTSA (Beginning Teacher Support and Assessment) to meet credentialing requirements. Attending activities as part of the Exploratorium New Teacher Program can feel like a burden to them, even though what they experience there is likely to be a good match for their vision of teaching science content.

Language issues. Issues of language acquisition and multiple language backgrounds are important drivers of how science is taught where there are large numbers of English language learners. Teachers tend to water down their science curriculum for these students. There is, however, an emerging awareness that science—and especially hands-on science—can be used as an effective vehicle to improve the language development of English learners.

Science departments are feeling pressures that constrain chair leadership. We were told about some departments that function as islands of sanity and excellence, where science teachers who like to teach inquiry-based science often seek like-minded colleagues with whom to work.

> *At our department right now, everybody is teaching in their college majors and so they are experts at their thing. It is a pretty bright crowd and they are well respected in terms of their subject matter. There is a predominant number that use a similar approach. (TI alumnus)*

More commonly, however, we heard of several factors that are impinging on the capacity of school science departments to provide support to teaching staff. Top-down directives regarding standards and assessments, for example, seem to be increasing. TI alumni who are chairs tell us these directives tend to compromise the development of a professional community and impose counter-productive pressures on teacher attitudes.

> *We are forced to get together, and then the issue, once we are together is, 'What is the common assessment?' I am not going to say that there aren't 5 minutes here and 10 minutes there where people say, 'Hey, have you tried this, have you done that?' But that is at most 15%, no more. The rest is all what the district wants us to do. And I find the district to be an impediment. I think the state and the administrators do not understand the nature of math and science education. They are completely oblivious. (TI alumnus)*

Several of the more experienced departmental chairs we spoke with have stepped back from the proactive roles they took as chairs earlier in their careers.

Education systems continue to shift in unanticipated ways that affect discipline excellence.
New panaceas for the perceived failures in education continue to emerge regularly and may affect the TI in the future. The move to small interdisciplinary schools or academies, for example, is said to isolate science teachers from one another and to threaten coordinated professional development in districts. One administrator we spoke with sees the Exploratorium as being well-positioned to provide the networking that teachers want but which their districts cannot provide.

A common theme from our interviews is that the TI behaves and functions in ways that stand in sharp contrast to schools and districts. The various pressures and challenges that secondary science teachers face make the Exploratorium—and all that it does for teachers—look all the better.

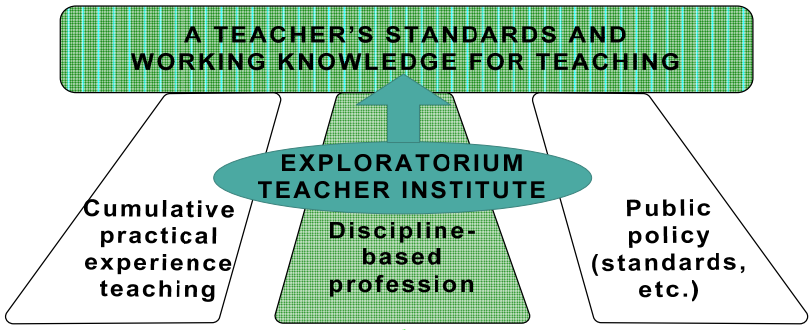
> *Responding to the latest district directive has nothing, zero to do with good teaching or getting the most out of our students. The Exploratorium is just the opposite. You go in there and the people are all real nice and they have great senses of humor and they are extremely helpful and they even feed us. It is some kind of Shangri-La. (TI New Teacher Program alumnus)*

III. The Role of the TI in Strengthening Teachers' Working Knowledge for Science Teaching

In this section we describe the functions that the TI fills related to the "three legged stool" of personal, professional, and policy inputs and perspectives that shape the standards and teaching knowledge that teachers apply in their daily work. We elaborate on each function by quoting extensively from interviews with TI participants and administrators at various levels in the California school system who are familiar with the TI[6].

The TI's core function: Strengthening discipline-based professional knowledge and practice

The TI's central function is to ground teachers in the vision, concepts and appropriate pedagogies of the science disciplines. This contributes directly to the strengthening of the discipline-based profession as the strongest "leg" contributing to teachers' working knowledge and standards.



[6] Our interviews and focus groups yielded more rich quotes than could be included in the body of the report. Appendix B includes additional quotes arranged by report section for possible use by the TI in staff discussions, publicity materials, proposals, etc.

The TI promotes a strong vision of science teaching through personal engagement in science learning

TI staff share a common vision of science teaching and learning, and this vision infuses the multiple examples and explanations of inquiry-based science that teachers experience when they attend TI programs. This builds and helps reaffirm participants' vision for their own practice.

> *What I thought was very powerful about being here for 4 weeks was that there was a consistent pedagogical orientation if you will, towards teaching and learning, that was consistent for the entire 4 weeks. You do not get that, at least in my experience, in other workshops, because everybody has their own orientation and it is kind of random. But here it is very, very clear. Having a common goal means a lot to me. (TI alumnus)*

> *There is a common ethic around inquiry and testing things out and relating it to knowledge that makes it really helpful. (TI New Teacher Program participant)*

Teachers' formation of a strong vision of science teaching derives, in part, from their own experiences in the TI as learners of science. Their experiences of grappling with challenging concepts on an adult level open a window onto the discipline that helps them better understand their students' learning.

> *The depth of the science comes across at many different levels. First of all, it gets you thinking like a student, so you have more empathy towards what children are going through in your classroom. I think that is really important for any level of teaching experience, because you do get in the habit of thinking, 'Well I am on this side of the desk'… What science is really about is, 'What can we find out together?' Science is a part of every day life. (TI alumnus)*

> *Given the strengths of the Exploratorium, which obviously is in the physical sciences area, I think for 8th grade science teachers it is absolutely wonderful, because for maybe the first time in their lives, they get a chance to actually experience it and figure out and play with these rather difficult physics concepts. (County science supervisor)*

This personal engagement with science can happen, because, at their best, TI staff artfully model student-centered instruction.

> *Paul goes in and starts talking at whatever level, let's say level 5 on a scale of 1 to 10, and then as soon as you start asking questions, he will hone in on the level of the questioner by responding and watching how the questioner is perceiving this. So he will start at level 5, but if he thinks, okay, this person could know more, he will go to 6 or 7. If 7 is too high, he will go down to 6. He has this uncanny way of really moving up and down the levels, and he taught me a lot in the early years of teaching physics. (TI alumnus)*

It is not only teachers who respond to the strong vision of science as inquiry. A district science specialist sees how TI-developed instructional materials fit in the curriculum:

> *We use other materials too, but there is a certain appeal to the Exploratorium's. The Snackbooks really require that the student be at the center of learning, not as a passive participant, but with choice and voice.*

TI programs kindle excitement in the discipline and strengthen teachers' content knowledge

> *What they offer in content in the sciences is unmatched. In the areas in which they specialize, they are the best—in areas like light, color, and sound—nobody can touch them. (District science administrator)*

The TI staff's own depth of content expertise is the foundation for strengthening the content knowledge of teachers who attend their programs. Opportunities to use the Exploratorium exhibits and to deepen personal understanding through a series of experiences together help teachers build a "big picture" of conceptual understanding.

> *I only took 2 years of chemistry when I was in college. The instructors here at the TI, they introduce a lot of concepts and link them together, so when you can see the bigger picture, you actually have a better way to explain the concepts. (TI New Teacher Program participant)*

> *I have been in other workshops, and if I had a tough question, they just kind of went, 'Oh your kids don't need to know that.' At the TI they answer those questions in a really understandable manner. (TI alumnus)*

Teachers appreciate and find fun in the opportunity to dig deep into science concepts, and they want to generate the same excitement back in the classrooms.

> *Their excitement brings us to have excitement, which brings our kids to have excitement for science. (TI alumnus)*

> *It was very relaxed, but the science went so deep. It was really wonderful to see in-depth curriculum and kind of a natural, fun, hands-on type of thing. (TI alumnus)*

On occasion, TI participants also have the opportunity for their students to experience real science along with themselves.

> *The second year we were unable to go [to Bolivia] because of political unrest so we arranged with the Exploratorium to watch a real time video webcast with about 30 of our most disadvantaged students at the Exploratorium. The kids were there and asking questions of the scientists. It was fantastic. It changed some of those kids' lives! (A county science administrator who participated with the Exploratorium in a volcano expedition in Bolivia)*

Experienced teachers come to programs knowing that they can count on being reinvigorated through learning new things and keeping current.

> *I still find new things when I go there. It is really important for me as I am teaching longer to keep that excitement about science. I always come away with that. It has been a wonderful source of continuing education for me, just keeping that seed of excitement about science and learning. (TI alumnus)*

> *At some point in your teaching development, you don't necessarily need new ideas on how to present something. You just need to keep current on information. (TI alumnus)*

Teachers develop classroom skill in teaching hands-on science

TI programs support teachers in developing specific hands-on classroom practices that are consistent with and reinforce a "real science" vision of teaching. Nearly every teacher we spoke with commented upon this, sometimes at length. It is important to remember that, while many school administrators want teachers to teach science as active inquiry, teachers do not find adequate opportunities to build repertoires of appropriate strategies in their early preparation or in their workplaces. This is the area in which the TI's contributions are best known, so we offer just a small sample of participant remarks.

Teachers develop skill in teaching hands-on science in several ways:

- experiencing masterful teaching by TI staff, who draw upon long years of experience crafting effective, exciting activities that model what teachers aspire to do themselves

  What makes these TI classes distinctive is that the teachers who teach us model exactly what it is that they are teaching us. They model what it is to have hands-on, interactive science. (TI participant)

- using TI staff as expert consultants when teachers want to teach beyond the confines of their textbooks

  A lot of times, something you are really interested in doesn't show up books, it is kind of left out. Not only will TI teachers help you with the answer, but they will help you find an experiment that demonstrates that. (TI participant)

- trying hands-on activities in their own classrooms and seeing how and why they work

  I would say that more than anything else, I take those activities directly into my classroom. They are really good. (TI New Teacher Program participant)

- having classroom visits by staff and designated TI alumni (primarily for novices in the New Teacher Program, but sometimes at the request of other participants)

  I was teaching 7th grade science. Tory came into the room one day and helped to teach a lesson on building a model eyeball. So we make this eyeball out of gelatin and Dixie cups and there are all of these different parts, construction paper and strings and a lens from a disposable camera and all of these parts represent parts of the real eye. So, you study the eye with kids, and see diagrams and charts and everything and then you make this real eyeball model. The culminating activity is after the gel has set, you send it home with them and they dissect it for the family and teach the eyeball anatomy to the family. That is something that I learned from them and I have been doing ever since. It fits perfectly with my 5th grade curriculum. (TI New Teacher Program participant)

> *I don't think I would have been able to teach hands-on unless one of them had come in and basically shown me the steps. It was 30 days long and he came in every single day. (TI New Teacher Program participant)*

Gaining high quality hands-on techniques is valuable to new teachers, experienced teachers, and to the administrators who want to support effective teaching but who do not have adequate capacity to do so:

- New teachers say that their preparation programs do not offer sufficient opportunities to learn the practical techniques for teaching inquiry, or as one teacher put it, how to "really do it, day after day":

> *My colleagues are always saying, 'You have such great innovative ideas, where did you get that?'', and every time I say the Exploratorium Teacher Institute. I try to get other teachers involved because I think it is so beneficial to new teachers and to the ones that have been around forever. When we take our classes in college, they don't teach us how to teach science. They teach us the philosophy behind teaching, whereas the Exploratorium teaches you really how to do it, day to day. (TI New Teacher Program participant)*

- Experienced teachers rely on fresh hands-on experiences at the TI to keep building their repertoire and to keep them from slipping away from the kind of teaching and learning that they personally value.

> *It gives you new ideas, like little labs, hands-on things, and sometimes it reminds you of things that you used to do, but dropped along the way. So you pick it up again and it reminds you of things." (TI alumnus)*

> *I think without the Exploratorium, and without the TI specifically, I would probably fall back into those old patterns of lecturing more, of teaching from the book. (TI New Teacher Program alumnus)*

- District science leaders believe that the TI has capabilities in this area that their own districts lack. Administrators value the way that the TI's hands-on activities help them put into practice the high quality science programs they want for all their students, including English language learners.

> *The Exploratorium thinks out of the box in ways that school districts tend not to. They have tried and true activities that I doubt we could provide ourselves. (District science administrator)*

> *We thought it made sense to collaborate with the TI if we got the funding. They have the track record and they have some amazing things they have done with teachers. They take a whole concept and have lots of activities for it. (County science administrator)*

> *I think overall the TI is good for just about everybody, because of the fact that they emphasize an inquiry-oriented, hands-on approach. We are using math/science as a vehicle with our English learners because we find that if we give these youngsters an activity where they can do something, they get so much more out of it. It is a very nice connection to constructivist theory of*

learning, and the youngsters with their language challenges begin to build and develop their own sense of what is going on. (County science administrator)

The TI provides access to material resources needed for hands-on teaching

The teaching of science as inquiry is inherently complicated by the "stuff" factor: the amount and variety of material resources that hands-on learning involves. The TI provides teachers with easy access to usable, low-cost materials for science teaching, and teaches teachers how to create their own. Teachers say they "walk away with things [they] can use."

It is awesome, because when you come, you get the equipment, you make the things and so you can take them back. In other workshops, you don't make the things and so you forget about the activities that you learned and you don't do them. (TI participant)

What you are also getting is stuff that is useable in class, but they are not little set pieces like artificially constructed things that you just follow along and do, it is actual inquiry and it is real science. (TI New Teacher Program participant)

They tie things in that they have on the floor and say how you can do this in the classroom and to do it on the cheap too. They don't expect you to go out and buy tons of things. They know that you have budget crises. It is really bringing the Exploratorium attitude into your classroom. (TI participant)

When TI institutes have ended and teachers are back in their classrooms, they can still access these kinds of resources simply by asking for help from the TI staff.

When I email and ask Paul, Linda, Eric, Modesto, what I get back is credible information and so I feel confident. (TI alumnus)

Feeling comfortable to ask people, 'Can I observe you, can you come in here, how do you do this, can I borrow this?' -- those things are all easy. (TI New Teacher Program participant)

A few TI participants told us that they share TI resources with their colleagues, students and even parents enthusiastically and with confidence because of their own experiences at the TI.

I am a librarian and I used the resources in their library collection. It has not only given me resources to share with other people, but it has given me personally a huge growth in the way that I think about science. (TI alumnus)

They had a quarterly newsletter with very cool ideas. I used them for starting points for lots of professional development. Now I use their snacks. I use their internet site all the time! They have the best website link for science projects. They must have 1,000 ideas up there! I refer parents who want science projects there all the time. (District science specialist)

Budget-strapped administrators appreciate the low cost associated with using TI activities.

> *We got a wealth of information from them—how to do a lot of science activities in the classroom with cheap and inexpensive materials. (County science specialist)*

> *If you go with FOSS or Science and Technology for Children, or something like that, you have to have a $700 kit. We did a lot of training with those but you have to have money. The Exploratorium has the appeal of being low cost and having the same intellectual quality. (District science specialist)*

Participating in the TI shapes teachers' professional identity and builds their confidence as teachers of science

Teachers develop confidence in themselves as teachers of science through opportunities to form a strong vision of science teaching and learning, and to have ongoing access to the practical tools and resources to bring that vision to life in their classrooms.

A major step for many teachers is learning that they don't always need to know the answer to questions.

> *It is good to know that everyone has questions about science. A frequent complaint of teachers in my department is, 'I don't know it all and I am expected to, and how can I ask a question?' This is the place where you can hear those questions. (TI alumnus)*

Teachers gain stature as professionals through presenting ideas to peers and engaging in substantive conversations about their classroom activities.

> *If there are things that you have thought about, it is nice to be able to present them to other people and to listen in on what their experiences are. The Exploratorium people encourage that. There is time at every institute for people to share lessons. (TI participant)*

For many participants, and especially women, using tools to build exhibits based on Exploratorium exhibits is memorable and empowering.

> *I think a high point was working in the shop and creating my own mini-Exploratorium exhibit. I feel really empowered to build more by myself. Being a girl, I am not usually playing with power tools. So now I am real macho and capable. (TI New Teacher Program participant)*

The self-assurance that teachers develop in their first institute relates to more than the specific skills and knowledge they acquire. For many participants, it initiates a shift in how they see themselves, making them more confident learners when they return for additional programs at the TI. Even more importantly, for many alumni, their experience at the TI provides them with new confidence when they communicate about science teaching and learning with colleagues.

Just being here and participating in the program gives you confidence as a scientist and so that, you walk out every day feeling more and more confidence, like it is easy to understand and like oh, you can build on what you got the previous year and then come back and say, oh, I am going to try this and try that. (TI alumnus)

This is not drill and kill, this is not about any particular set of facts, but it is an attitude, an orientation towards learning and an attitude towards science, that we have all experienced here and I think that helps us communicate when we are back in our community. (TI participant)

Focus on the TI New Teacher Program: Establishing a Professional Foundation of Practice in Teachers' Formative Years

> *Here you are doing real science, you are learning yourself, and you are learning ways to help your kids learn in the same way. (TI New Teacher Program participant)*

Early in their professional lives, teachers have little personal teaching experience from which to draw as they design their curriculum and seek to employ effective instructional strategies. Moreover, they lack personal experience in implementing policy in the best ways. Therefore, it is particularly important that the TI program helps teachers in their most formative years build a strong profession-based "leg" of working knowledge. The TI provides an array of discipline-rich experiences to new teachers, ranging from institutes and workshops at the Exploratorium to customized coaching in their classrooms.

The TI programs help fill gaps in teachers' preparation associated with specific methods of effective science teaching.

> *Modeling for new teachers is the key. The Exploratorium and Gene Connection do it. But others don't— not BTSA[7], unless you're lucky. It wasn't done in my teacher training. It was more about a theory of teaching. (TI alumnus)*

> *The Exploratorium has basically taken over the USF science methods courses for middle school. That is great, because anyone with a middle school science credential coming out of USF I would think would have a very good background experience, because of the Exploratorium. (County science administrator)*

By augmenting teachers' preparation, the TI helps new teachers learn to put into practice the kinds of science programs that district leaders want.

> *So many elementary teachers have never really had an exciting science course or an exciting science experience, and so they don't know what that looks like or feels like and much less know how to teach it to their own students. So when we say, for example, that 'we should be teaching a more inquiry kind of program,' many teachers don't even know what inquiry is, because they haven't experienced it themselves. (County science administrator)*

The TI contributes significantly to the formative teaching repertoires of new teachers because it advances their acquisition of both content knowledge and pedagogy. Some new teachers who bring strong content knowledge lack knowledge of effective pedagogy, while others teachers lack content knowledge. As noted above, new teachers may have never experienced for themselves high quality science teaching and learning. At the TI, they see for the first time what exciting science could look like, sometimes in programs at the Exploratorium and sometimes in their own classrooms.

By drawing upon the classroom experience of staff and mentors from the TI alumni, the program provides multiple models and examples of effective science teaching.

> *When I first started teaching physics, I pretty much taught it as I was taught it and that is by doing problems and looking at it as abstract subject matter, with a laboratory component. The Exploratorium certainly changed my way of thinking about how to teach physics and moved me far more into the hands-on realm, making that the focus. (TI alumnus)*

> *As a beginning teacher, I walked into a physics lab chock-full of all of this equipment that had been lying around for god knows how many years, and it wasn't that there was any shortage of stuff, I just lacked direction. I wondered what am I going to do with all of this? The TI was very helpful in just giving me that direction. (TI New Teacher Program alumnus)*

[7] California's Beginning Teacher Support and Assessment program

With the new teacher program, there is much more of what I call outreach where the folks from the Exploratorium are actually going out to the classrooms and there is much more conversation about some basic things that are not necessarily totally about science, such as assessment systems. It is really, really important. The novices get paired up with these experienced science teachers and they know the same kinds of things that those new teachers are actually going through and what they need to know. That makes a tremendous difference . . . The science mentors are not only content specialists, they are just great teachers . . . When you work with new teachers you are literally starting from scratch, and the mentors go out and lay out how they should set up their desks, for example. (County science administrator)

Besides institutes and classroom coaching, the TI program involves new teachers in collaborating with mentors (TI alumni) in designing whole units of instruction through a process called "Teaching Boxes." This enables new teachers to bring to life a vision of hands-on science teaching beyond the activity or lesson. As we noted in our 2003 report to NSF,[8] "Beginning and veteran teachers universally agreed that the Teaching Box provides a focus for bringing experienced and novice teachers together for meaningful dialogue and collaboration. The beauty of the Teaching Box activity is that it provides a clear structure for inquiry-based learning, shared experiences and thoughtful reflection – hallmarks of the Exploratorium's approach to the teaching of science."

The main benefit was sitting and talking about what he [the novice] had done before with the subject and what was unsatisfactory about it and then talking about what we could do to make it more successful for him. So we scaled back on how many topics he was trying to cover and decided to go into more depth. He had a lot of involvement in planning the box. I think that was the point of doing the boxes, not to have one product, but to have gone through the process of thinking through a unit and deciding how to make it feel better next time he taught it and take the model and that experience and use it in his other subjects. It was sort of like an ongoing work in process; he could refine it and add to it and change it as he taught it and got feedback. (Mentor)

What has been opened to me is the wealth of resources that I didn't know about before. It is more than building a curriculum box—it is the process of the curriculum box. I started to see the linearity of planning a lesson—how to go from A to B. We started with the end result, which was to teach the concept of density, and by extension, I now have developed a curriculum that starts with linear measurement and works all the way through. (New teacher)

The box is a metaphor, a focal point for me to share my story with the novices and to convey ideas. (Mentor)

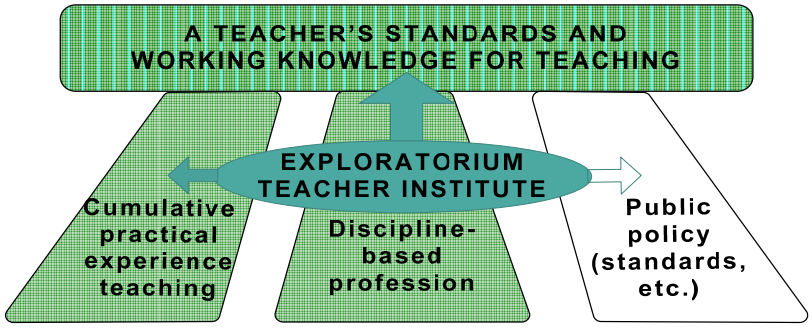
Not surprisingly, the TI has developed a reputation for excellence among preservice students.

In my credential program, this is <u>the</u> workshop to go to. This is perceived as the most exciting, most effective, very professional place to go as a science teacher, and if you have this under your belt, that is an awesome thing. (New teacher)

[8] "The Coaching Component of the TI Teacher Induction Program: Summary of Formative Findings, 2002-03."

Strengthening Teachers' Learning-from-practice within a Professional Guild of Science Teachers

The TI's influence on teachers' classroom practice is profound. It is only in the TI, we heard many times, that teachers develop the particular skills, confidence and materials needed to embed a hands-on approach effectively into science instruction. Participating in the TI, therefore, directly shapes the knowledge and standards of effective teaching that teachers bring to their daily practice. Following on that, teachers' personal experiences of learning from their own teaching are altered in fundamental ways because they can then begin to learn from reflection on more effective practice. In other words, the TI helps start teachers on a pathway of teaching development that is more grounded in discipline and inquiry than what teachers devise on their own or from school-based professional development. This new pathway of practice provides teachers with a whole new lens through which to learn from and improve their practice.



Most teachers find it challenging, however, to reflect critically on their practice in the isolation of their schools. Beyond offering teachers one-time workshops, the TI aims to support a professional community of science teachers so that, throughout their careers, teachers can be in contact with one another and with the Exploratorium resources. In this section we examine how the culture of the TI supports teacher learning from teaching in ongoing ways.

The Exploratorium, as an institution, and TI programs are imbued with a culture of deep respect for and service to teachers, teaching and learning

TI staff work hard to foster a culture that serves teachers in a way that parallels the way that good teachers strive to put students at the center of their classroom practice.

> *The instructors and the staff said 'Anything you ask, the answer usually turns out to be yes.' At first you hear that and you think it is just rhetoric, but they lived it. Every time we asked somebody for something, the answer was always yes. They walk the walk and not just talk the talk. (TI New Teacher Program participant)*

What accounts for this culture of caring service to teachers? Participants say that it derives from both the professional qualifications and personal qualities of the staff. TI staff bring strong content knowledge and pedagogical skills honed by many years of experience engaged in science education.

> *One of the things about them, they are highly qualified, all of them, and they also know the popular misconceptions. Professionally, their experiences lend to you their credibility. (TI alumnus)*

> *I think the teachers that work here, besides being super-qualified in content knowledge, they just genuinely care and they genuinely feel that they are doing important work working with teachers. (TI New Teacher Program participant)*

The unique place of the TI – serving formal education, but sitting outside of it – is seen as a major factor as well by both participants and administrators.

> *They are very accommodating and they have the focus on the right stuff, on learning and on supporting teachers and not necessarily setting rules or being bureaucrats, and that is really part of the special atmosphere. (TI alumnus)*

> *The thing that has always really impressed me about all of the people and all of the programs is that there really doesn't seem to be any kind of an agenda except to help us teach science better. (New Teacher Program alumnus)*

> *They have the ability to get the most engaging and dynamic people to work with teachers. Everyone I talk to knows that if it's by the Exploratorium, it's going to be really, really good. They plan things well. They do things well. It's not to say that a staff developer couldn't do that, but because of their reputation, and because they are their own institution, they have fewer constraints. (District science administrator)*

The value of the gift of time to reflect on personal practice in building professional identity should not be underestimated.

> *The Exploratorium just provides a place where one can explore oneself, as a teacher. I think that far too often we end up stuck in our classrooms and while I may not use everything that we go over at a particular institute or a particular Saturday session, I find it interesting and it is always nice to keep the mind working. (TI alumnus)*

> *It is teachers showing teachers how to do things, more than anything. And the Exploratorium is providing us with the time and the place. (TI participant)*

In sum, teachers feel "valued and honored as individuals" and that they are "taken care of." And they in turn emulate TI staff in their dealings with their instructors and one another.

> *It is a wonderful thing to come to the Exploratorium and feel valued and feel like you can get whatever you need. When you feel valued, you are more likely to help someone else. (TI alumnus)*

The TI invites teachers to be lifelong "members" in the Exploratorium "guild" of science teachers providing a home base for ongoing professionalization

In order to develop and maintain a professional teaching identity and to continue learning from classroom experience, a teacher must have opportunity and motivation to connect with peers and professional mentors in an ongoing community. The TI builds a sense of belonging in teachers from their first day of the "classic" institute that is the entrée for all TI participants into the institutes, workshops, and other resources available through the program. The atmosphere is characterized by mutual respect among its members, sharing, and a genuine love of science, learning, and teaching. The community becomes a lasting one in part because everyone wants to be there – in contrast to typical school-based professional development.

> *I remember the first day, when I first pressed the button [by the Exploratorium door] and said 'Teacher Institute, let me in,' I wondered, well are they going to let me in? That to me epitomizes the whole thing—you are Teacher Institute, you are in. (TI alumnus)*

> *A high point has been forming a community of people that I know that I can depend on and call on and continue relationships with and continue relationships with the Exploratorium. The low point is leaving. (TI New Teacher Program participant)*

> *Not only do we have sharing and trust, and the common goals, but you feel like you are a valued member of the community as well, you are not just being tolerated, but you are being listened to, and other people ask you for support and ideas. Just our being there is a wonderful thing for people at the Exploratorium; that is the sense that I get. (TI alumnus)*

> *When you are in the shop and somebody says, 'What did you build? How did you build that? Where did you get that?' or somebody says, 'Let me get that for you', that is where I feel like you build community. People here are doing nice things for each other all the time and so that whole positive thing leads to I think more friendships. I have done other week long things and you feel like, I will stay in touch with those people and you really don't, but here, they have this great network and you have to stay in touch, because of the way it is set up. (TI alumnus)*

The overall effect of the TI's invitation to join the "guild" of science teachers is that those who continue to attend TI programs see themselves as a group of lifelong learners who carry an ongoing curiosity about science and the teaching of science.

> *They promote learning as a life long experience. We keep coming back and we get hooked. This is my third year. Every fall they have sessions and I have been coming. It is wonderful because you actually do grow as you are learning and that energy goes on forever, and so it goes through us to our students. (TI alumnus)*

> *They still have things to offer me. They still have Saturdays, they still have summers. They say 'Look, there is more to look at, and there are more things that we have been thinking about, there are more ideas', and you know, if there are ever things that I would want to look at, I could always suggest topics and they would look into it. (TI alumnus)*

The TI does not engineer or support teacher networking in the schools beyond the programs it offers, and TI alumni have not taken it upon themselves to organize such

networking. Rather, TI alumni "run into each other" at the Exploratorium or other science-related events in the Bay Area, and because they shared the same experience, they feel a sense of kinship that can naturally foster informal professional dialogue about teaching. It is important to remember that these teachers belong to a profession where there are often few other opportunities for collegial connections outside their school other than through the Exploratorium.

> *I haven't kept in touch with anybody on a regular basis, but I do run into people from time to time that I have either been in the program with or met at a Saturday workshop or something. It is always nice. We chat about the Exploratorium and I think it has made me feel part of a larger community of teachers. One of the problems with being a teacher is that you tend to get so isolated. (TI alumnus)*

> *There's a teacher in the East Bay that I run into at TI workshops and it is fun, because we both teach out of the same books and so we compare notes about lessons and activities that have worked. For me, the Exploratorium is where I see more adults than I normally do. (TI alumnus)*

In tandem, the twin TI resources of ongoing workshop and web-based resources and interactions do a great deal to maintain loose but ongoing personal and professional connections. Together, they extend the boundaries within which teachers typically craft their practice, affording them access to science teachers from all levels of schools.

> *The Pinhole, the online-community electronic board that we can tap into, is not just a general thing; it is for <u>us</u> and so we know whom we are talking to. And this is reinforced by the face-to-face ongoing two week workshops where we will meet again in other combinations, so it is a combination of personal contact, and personal friendships as well as the ongoing online conversations. (TI alumnus)*

> *One of the nicest things in addition to all of the training and ideas and the relationships, is the list serve that it created. It is open to science teachers and scientists I think throughout the country and occasionally you see somebody from the university come back and respond. You basically just send out an email and ask questions, like 'My student is studying such and such for her science fair project, but we don't really understand this or that' and then you get people who respond with either practical or scientific knowledge, pretty heavy weight. (TI alumnus)*

By participating in the TI "guild," teachers also expand their professional perspective across schools and districts, especially in the Bay Area. The TI also encourages and helps alumni to connect with other professional opportunities such as professional meetings, grants, etc., further broadening their professional world.

> *I can go to four weekend workshops during the year, and it connects me with other teachers in the Bay Area, which is wonderful, just to talk to other people in other school districts and to find out what other things are going on. (TI alumnus)*

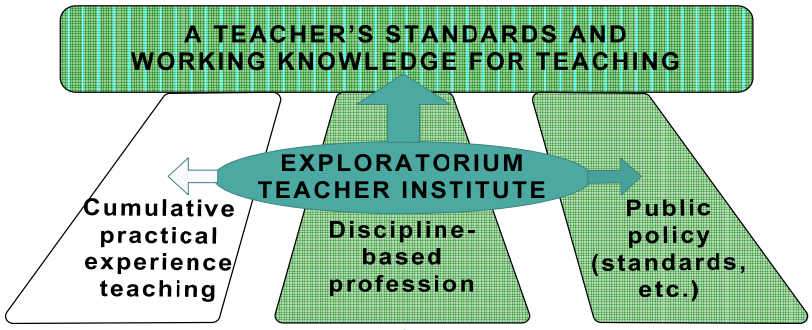
> *They put you in contact with [professional groups] like the AG (the American Geophysical Association), which has a conference every December. They have contacts if you need a grant or if you want a workshop, so they are this information source. (TI alumnus)*

There is a big conference in Canada every year that a large number of Exploratorium people go to. A number of years back they asked me to do a presentation and they keep asking me back and so I keep doing. (TI alumnus)

Strengthening science teachers' ability to put reform policy into practice and contribute to system improvement

The Exploratorium programs have a great balance – It's not just a museum, it's not just for content. They understand the science concepts we have to impart to students; they know the information we need; and they have activities. (District science administrator)

The TI programs help teachers bring a discipline-based perspective and knowledge to the challenge of implementing state policy, primarily content standards, in their daily practice. Whereas the education system expects teachers to adhere to standards, the system has very little capacity to support effective implementation of them at the classroom level. The programs and ongoing professional community of the TI serve as a discipline-rich context in which teachers can gain the content and pedagogical knowledge that helps them bridge policy and practice. Thus, the TI enables state policy to affect classroom teaching in a constructive way.



TI programs help teachers teach to state and district science standards and use standards-based curricula

Individual teachers, novices and veterans alike recognize the applicability of TI activities to state standards for teaching secondary science, even if they don't personally like the standards.

> *I know the state standards, and everything we did at the Exploratorium was on the standards. (TI participant)*

> *They take our California standards, which are the worst in the nation, and they translate them into first-rate activities that really capture the minds of the students. (TI participant)*

Through the TI programs, teachers gain facility and confidence in linking what they learn at the Exploratorium to their district curricula (if any) and standards in a high quality way.

> *We sat there at one of those teacher work days in our district, and they said, 'Here are your state standards, now we need an activity to go with all of them.' And I could literally go through every single one of my state standards and I could find an activity that I learned here at the TI. And you can ask them, 'Can you help me find something to go with this state standard?' and somebody in the Exploratorium will help you find whatever you need. But they are not forcing you, and that is nice. (TI participant)*

The teaching boxes created by teams of mentors and novices at the New Teacher Institute are particularly valuable for enabling novice teachers to design and deliver inquiry-rich instruction within a standards-based program.

> *It is hard to keep inquiry in the classroom because of the pressure to meet all of these state standards in terms of a body of facts. Well the great thing is, this teaching box and the activities in it give us inquiry that directly feeds into those state standards. Inquiry is in there, but it is not just inquiry. That is the easy tie-in, but I have to write lesson plans, and tie in state standards and list them all. And for every one of these activities it is like ding, ding, ding, a state standard is being emphasized. (TI New Teacher Program participant)*

Ever-changing district and state reform policies make strong demands on teachers to re-frame their teaching. Amid this policy-induced turmoil, the Exploratorium and the TI programs remain a steady presence and consistent source of knowledge that helps teachers make adjustments to policy while maintaining high professional standards of practice.

> *This is a field that is constantly changing. We adopted a new textbook in my school last year and so I have new curriculum that I am dealing with. That is another need that is served by my ongoing relationship at Exploratorium, as our situations change. (TI alumnus)*

Teachers also see links between the hands-on teaching approaches espoused by the TI and student improvement on the standardized tests that are part of the policy system.

> *The Exploratorium gives teachers ways to DO things with kids, ways to teach things to the kids so they get excited about it and remember it. When I see my former students, the things they remember are the things we did. Activities that emphasize concepts remain important to help students remember things for the tests. (TI alumnus)*

District science leaders that we spoke with appreciate the Exploratorium's contributions to strengthening teachers' ability to meet state standards, and they draw upon TI resources (programs and faculty) in varying ways and extents. Three of the districts have contracted with the Exploratorium to provide workshops for their teachers. One district—which had a USP grant they could use to contract for chemistry and physics workshops—queried its teachers to help TI staff set workshop agendas, and reports that the workshop outcomes were very positive. Another district simply tells the Exploratorium what they want to see and has lead teachers make the links between activities and standards. The third asks the TI to suggest activities to go with standards that teachers must teach to. These district leaders seem to perceive and use the TI as an "outside the system" resource to help them in specific ways in meeting standards. The fourth district science leader simply depends on Exploratorium to know the standards and for their activities to enrich the teachers' teaching repertoire.

> *I put a request to all district physics and chemistry teachers asking them what they needed help with, which standards did they have trouble with? Where did they need ideas? The Exploratorium took topics from the standards that teachers found difficult for the workshops: Each workshop had a content theme. The teachers told me later that they were trying what they had learned in the workshops, and found they worked great. (District science administrator)*

> *It's demanded of us to deliver standards-based curriculum as measured by standardized test scores. We have to work within those boundaries and teach what we know is good science. We gave our teachers a boring, dry document— the Instructional Guide (what I should teach on what day, suggested time line and periodic assessments, for grades 4 and 8, the grades that are being tested.). We know that inquiry is good practice. We asked the Exploratorium to suggest activities to go with what teachers must teach from that document. (District science administrator)*

> *We let the Exploratorium know what we want to see and we take care of other stuff. Our lead teachers are really good about making sure what standards the TI activities are based upon, and keeping us up with NCLB. (District science administrator)*

> *They know what our teachers are expected to teach and can enrich the experience. The Exploratorium does that very well. (District science administrator)*

Enhancing teachers' leadership

Science administrators recognize and value the contribution that the TI makes to teacher leadership. One way that the TI builds leadership is through hiring alumni to help with TI programs.

> *I think the way that they sometimes invite some of their alumni back to the TI to help with workshops is absolutely critical and a great way of developing that teacher leadership. If you are a teacher leader teaching other teachers, you are going to be that much more effective as a teacher yourself, because there are other insights and perspectives that you gain when you assume that role. (County science administrator)*

Some districts also have TI participants bring back what they have learned and share it with other teachers. In one district, at mini-conferences held for all teachers five times a year, the shared science lessons are often ones that teachers learned at the Exploratorium. And Northern California districts participating in Project ARISE[9] involve their "#1 teachers in the district" in the TI programs. They in turn conduct trainings at their schools.

Enhancing teachers' skill in linking science to other disciplines, especially mathematics

Another way in which TI participants contribute to local improvement efforts is by broadening what they learn to other subject areas. Because of the culture created at the TI programs, math teachers can feel comfortable there. They develop confidence around incorporating science activities and topics into their math classes.

> *I am a math teacher and 3 years ago I started at the Exploratorium, just to get some background in science. It has opened my eyes because I am doing science in my math classroom now. It is wonderful because I never felt intimidated by anyone in the TI classroom, even though I have no science background. (TI alumnus)*

> *I find that most of the ideas that I have really liked from the Exploratorium have been used when I teach trig. Trigonometry really lends itself to cycles and there is lots of stuff that you can bring in from a science perspective. There are pendulums, there is light, and there is sound. (TI alumnus)*

The interest and expertise around ethnomathematics that resides in TI staff transfers to some teachers as well.

> *I feel that I have gained a background not only in math and science, but also different cultures. I hadn't looked at that before. (TI New Teacher Program participant)*

[9] A Fermilab project supporting a physics-first high school science curricular sequence.

Summary

The Exploratorium serves a number of functions vital to teacher development—from enriching their experience of and content knowledge in the discipline, extending into the details of classroom practice and resources that reflect authentic science, and then expanding beyond techniques of practice to a strengthened professional identity and community membership. When held up against the diminished capacity of teachers' workplaces and the formal education system to support teachers' development in *any* of these functions, the TI's fulfillment of them can be seen as a critically important contribution to the strengthening of science teaching. In sum, the TI adds value to—and sometimes stands in for—the system's capacity to serve science teachers.

IV. In what domains and at what scale does the TI work?

The TI is often thought of as a provider of institutes and workshops for individual teachers on site at the Exploratorium, and it is true that this is their most visible and thoroughly documented work. Year-round, however, TI staff move out from the Exploratorium and serve many different kinds of audiences in a range of domains. As one administrator noted:

> *They are always very open and willing to lend us advice or a helping hand. We really have developed a very close relationship with them. (Shasta County science administrator)*

Through this work, the TI extends the reach of its science-discipline-based, professional perspective beyond core programs and directly to schools and districts. This section portrays the domains for TI's "outreach" work and the scale at which it occurs.

A note on the data sources for this section: Until fairly recently, the TI did not consistently document the many ways that its staff members serve teachers, schools and districts other than through its core summer and school year programs.[10] To remedy this gap, TI staff have expanded their database to document the answers to the following questions, "*From 1999 to the present [i.e., early 2005], what events and activities have we engaged in that have benefited teachers, administrators, museum educators, and university faculty? What organizations and agencies have we supported and interacted with? How much time did we spend? How many educators benefited?*" Staff members reviewed their appointment calendars back to 1999, and reconstructed a record that is more comprehensive for the last several years than it is for the first several years. We used these records, along with interviews of TI staff (that surfaced additional activities not accounted for in the quantitative analyses later in this section[11]) to help bring to light this work.

The surprising magnitude of the "hidden" contributions of the TI to science education

One of the surprises of this study was the variety of the contributions made by TI staff in numerous arenas germane to the improvement of science teaching and learning, especially in the Bay Area, but also beyond. What was less surprising was the organic,

[10] The core work of the TI encompasses summer institutes for experienced and new teachers as well as Saturday workshops throughout the school year for former summer participants and school year support for participants in the Beginning Teacher program.

[11] Events described in additional staff interviews that are not included in the TI database have served very conservatively several hundred additional teachers over the past 6 years.

relationship-based, and service-oriented manner in which the TI's relationships to the outside world develop, and the modesty of staff members about these accomplishments. In the same way that the staff are collectively and individually responsive to the expressed needs of teachers who have participated in their core programs, they take opportunities that come their way to reach out to teachers, administrators, museum educators and university faculty. We believe that this report represents the first attempt to portray the breadth of their contributions to the teaching, learning and appreciation of science locally and beyond.

In what domains does the TI work?

As stated in the introduction, the TI sits at the nexus between informal and formal science education and assumes responsibilities to both worlds. TI staff provide leadership to a number of professional associations for science and mathematics teachers, and simultaneously are active in the world of informal science institutions. They also provide direct service to districts, schools, and teachers as well as to the public.

The four tables on the following pages detail areas in which the TI provides expertise and leadership, the range and types of organizations and agencies with which the TI works, and the formats for its contributions. Specifically, they detail five years of work with and contributions to:

- Formal science and math education organizations and agencies
- Informal science organizations and agencies
- California districts and schools
- Teacher preparation programs
- International consortia and agencies
- The policy environment
- Students, parents and community (beyond the Exploratorium)

I. The TI's contributions to formal and informal science and math organizations and agencies (1999-2004)

AREAS IN WHICH THE TI PROVIDES EXPERTISE AND LEADERSHIP	ORGANIZATIONS AND AGENCIES WITH WHICH TI STAFF WORK	FORMATS FOR THE TI'S CONTRIBUTIONS
FORMAL SCIENCE AND MATH EDUCATION ORGANIZATIONS AND AGENCIES		
Local and regional professional associations for science and math teachers	Bay Area Science Project (BASP) Bay Area Math Project (BAMP) Council of Math and Science Educators of San Mateo County (CMSESMC) Organization of Northern California Ethnomathematics (ONCE)	Speakers, workshops, board membership
State professional associations for science teachers	California Science Teachers Association (CSTA)	Keynotes, demos, workshops, booths
National professional associations for science teachers	National Science Teachers Association (NSTA) American Association of Physics Teachers (AAPT) National Association of Biology Teachers (NABT) American Geophysical Union (AGU)	Keynotes, demos, workshops, booths, serving on editorial board
INFORMAL SCIENCE ORGANIZATIONS AND AGENCIES		
Informal science centers	Cal Academy Monterey Bay Aquarium San Francisco Zoo San Jose Tech Museum Science Fiction Museum (Seattle) Orlando Science Center	Exchanges of information with teacher educators, consultation on teacher needs, workshops, alerting participants to opportunities at TI
Museum Consortium	ISI-ExNet	Workshops for 520 teachers in 9 cities across the country
Exploratorium programs other than TI	CILS (Center for Informal Learning and Schools)	Modeling of workshops
	Exploratorium explainer program (50 students a year)	Training
	Public programs (e.g., Transit of Venus, Eclipses)	Community outreach
	Webcasts	Real time demonstrations, archived Presentations
Network of Informal Science Centers	Association of Science and Technology Centers (ASTC)	
Materials resource center for Bay Area teachers	RAFT (Resource Area for Teachers)	Workshops for 150 teachers a year

II. The TI's contributions to teachers, schools and districts (1999-2004)

AREAS IN WHICH THE TI PROVIDES EXPERTISE AND LEADERSHIP	ORGANIZATIONS AND AGENCIES WITH WHICH TI STAFF WORK	FORMATS FOR THE TI'S CONTRIBUTIONS
CALIFORNIA DISTRICTS AND SCHOOLS		
Districts	SFUSD	40+ workshops, inservices and meetings over 6 years
	Oakland	Continuing education workshops for biology teachers (2002-03)
	Los Angeles	Weeklong institute to assist district in implementing a new science curriculum (2004)
	Bolinas, Jefferson Union, Grant Elementary	Various
Schools	Fairfield Middle School	All day inservice
	Siskiyou County schools participating in Project ARISE	2002 workshop leading to relationships with individual schools
TEACHER PREPARATION PROGRAMS		
Colleges and universities	San Francisco State University of San Francisco Alliant University	Science and math methods courses, supervision of preservice students
INTERNATIONAL CONSORTIA AND AGENCIES		
Work with teachers, administrators, museum educators	ExNet International agencies	Presentations, workshops
WORK WITH OTHER ORGANIZATIONS		
School network	California Association of Independent Schools	Teacher professional development days

III. The TI's contributions to and responses to the policy environment (1999-2004)

AREAS IN WHICH THE TI PROVIDES EXPERTISE AND LEADERSHIP	ORGANIZATIONS AND AGENCIES WITH WHICH TI STAFF WORK	FORMATS FOR THE TI'S CONTRIBUTIONS
TI New Teacher Program	NA	Summer institute, classroom visits, school year support
New teacher projects (BTSA)	Various local sites	Conduct workshops, sit on panels
State program	CDE Health Alliance	Presentation to teachers
After school programs	Several California cities	Train staff in use of *Math Explorations*
State project	California Technical Assistance Project (CTAP)	Workshops

IV. The TI's contributions to students, parents and community beyond the Exploratorium (1999-2004)

AREAS IN WHICH THE TI PROVIDES EXPERTISE AND LEADERSHIP	ORGANIZATIONS AND AGENCIES WITH WHICH TI STAFF WORK	FORMATS FOR THE TI'S CONTRIBUTIONS
Students	School and district science fairs	Judging
Parents	Science night at schools (e.g., Ravenswood in East Palo Alto)	Parent science night once a year
Local community	Great America's Science, Physics and Math Day	Short presentations to teachers and students
	San Francisco Symphony and SFUSD	Conduct 2-day "science of sound" workshop for 140 people every 3 years
	Cesar Chavez Solar Calendar (at Berkeley Marina)	Develop curriculum, conduct mini-workshops
Internet audience	Webcasts (e.g., "Mayonnaise and the origins of life")	Real time and archived

At What Scale Does the TI Work?

To get a sense of the scale at which the TI works, we summarized its contributions in the most recent year for which we had data, as well as contributions over the six years documented in the TI's database. As noted earlier, TI database records on staff activities are incomplete, so all figures presented below are probably very conservative.

The contributions of the TI in a single year, 2004

In the most recent year for which TI staff contributions were analyzed, staff documented **70 different activities** in which they engaged beyond their core work: speeches, workshops, presentations, meetings, and so on. They devoted approximately **328 hours** – the equivalent of 44 person days – to this work (not counting undocumented preparation and travel time for these activities).

They supported science education in California through activities and events such as the following:

- presenting one and two day workshops for 60 LAUSD teachers, as well as a week long institute for 10 teachers and nine administrators in connection with the Los Angeles Professional Development Center

- giving 2-day workshops for staffs of two elementary schools (37 teachers total)

- playing leadership roles in the Council of Math and Science Educators of San Mateo County (including keynoting an annual meeting of 60 teachers and meeting with 7 administrators about curriculum)

- playing leadership roles in the Organization of Northern California Ethnomathematics (ONCE) along with university faculty

They shared their vision for science teaching and learning, as well as low-cost and engaging activities, with national audiences through activities such as:

- giving keynote speeches, presenting workshops and running booths at the major professional organizations for science teachers: the National Science Teachers Association, the American Association of Physics Teachers, National Association of Biology Teachers (reaching a total audience of approximately 425 teachers and 10 university faculty)

- keynoting and presenting to 50 museum educators at the annual meeting of ASTC (the Association for Science and Technology Centers)

The staff also reached 750 educators in 4 other countries in 2004. They gave presentations and workshops in Costa Rica, Mexico, Italy and China. 397 teachers, 150 university faculty, and 205 museum educators attended.

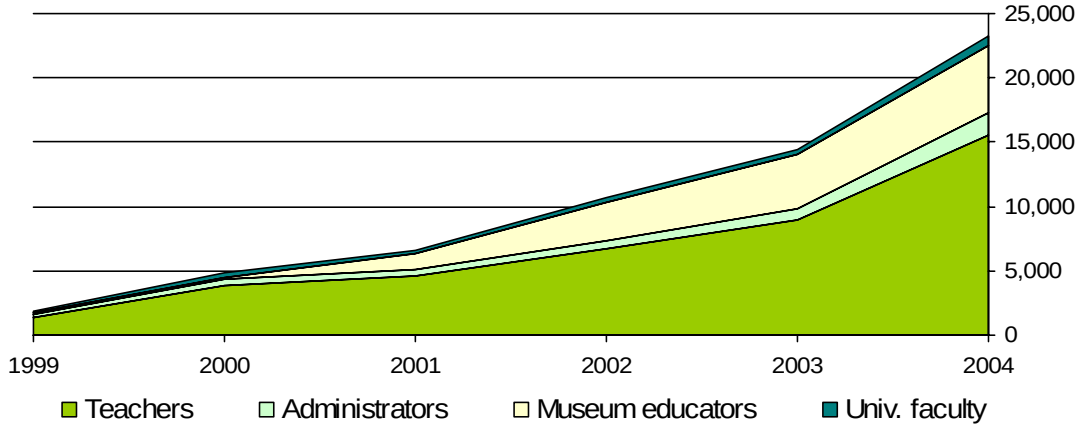
In total, there were **2,425 educator-participants**[12] at these events. The majority of the beneficiaries (76%) were teachers. In all, the TI documented 1,845 teacher-participants, 100 administrator-participants, 308 museum educator-participants, and 172 university faculty-participants.

The contributions of TI over 6 years, 1999-2004

In their partial reconstruction of their activities since 1999, TI staff identified **193 activities and events** that they have undertaken on behalf of TI over the last 6 years. They documented about **1,200 hours of staff time**, or **8 person months,** devoted to this work.

Using TI records, we calculate that there have been at least **4,500 participants** at activities and events where they provided leadership during this period, and that this in turn has generated about **23,700 participant contact-hours** (about 67% of the contact hours are for teachers, 7% for district administrators, 22% for museum educators, and 4% for university faculty).

Cumulative participant contact-hours[13] at selected TI events and activities



[12] Participants are counted at each different event they attend. For most projects that we evaluate, the count of participants is typically higher than the number of individuals reached because some individuals attend more than one event. We would expect this to be true for TI as well.

[13] Contact-hours are calculated by multiplying the number of participants at an event by the average hours participants were engaged.

Ongoing professional development for TI staff. It is worth noting that in addition to the many contributions that TI staff make to science and mathematics education, they also stay current themselves through participation in activities such as attending UC Santa Cruz workshops on serving new teachers and training in dissemination of GEMS (Great Explorations in Math and Science) curriculum materials.

V. Limitations of the TI Programs

In this section we examine current limitations to the TI's ability to support improved science teaching. One involves concerns and hopes that surfaced through interviews with teachers who—while their experiences have been overwhelmingly positive—also have some ideas about how the TI could improve and "do more." Another concerns administrators' wishes for the TI to play an even stronger role in science improvement than they currently do. And the third results from ways in which the reality of the TI alumni's role as school leaders is not fully congruent with the TI's own theory of action.

Teachers' concerns and hopes

As noted above, our interviews were overwhelmingly positive. The few criticisms that did emerge arise, we think, because teachers are asking for more of what will help them in strengthening their teaching from a discipline-oriented perspective. These hopes underscore the observation that what the TI offers them is highly valuable and rarely supplied (if at all) by the education system.

More opportunities for seasoned teachers. TI alumni who are not participants in the New Teacher Program believe that the TI has become less focused on the needs of seasoned teachers since it shifted its emphasis to new teachers over the past five years. The intensive on-site programs are strong, these veterans say, but they are becoming limited in that the same programs are offered repeatedly. While the veteran teachers understand and support the TI's focus on new teachers, they need something more or different for themselves – deeper content, for example. Also, some of the alumni point out that the TI is a vitally important science resource for all teachers in the profession, not only new teachers, because the school system cannot support the content-related needs of teachers.

> *If you are just going to dedicate it to one group of [new] teachers, then I think you become more like an education department, rather than a science facility. We are all high school teachers. None of us have Ph.D.'s and we can always use more knowledge based, content based stuff. The Exploratorium is not stuck in the conservative educational system, which education really is. I just don't perceive the system as bringing all people up. (TI alumnus)*

Closer link between new teacher program and certification. At the same time that veteran teachers want more programming for them, a number of those we interviewed suggest that the TI expand its work with new teachers. One suggestion is to make the TI program into a certification-oriented program.

> *I think the Exploratorium mentoring program has to be worked into the credentialing system. You need to get your program to be the thing that would credential the teacher and so they are not doing one more thing in addition to BTSA. (TI alumnus)*

More outreach to schools and classrooms. Some teachers lament that the TI does not reach out to do more classroom-based support through demo lessons and co-teaching. One alumnus fantasizes that the TI would "come out and they will have new ideas and they will say, 'Oh, let's do this activity,' and they go with it and we let them lead." Another envisions a portable program that would bring materials and equipment, as well as expertise out to schools.

> *There would be somebody whose job it was as a guest science teacher. And a grade school teacher could hire them, or a science teacher who wanted something like liquid nitrogen (not something that I have available) or somebody to come and do experiments or demonstrations with equipment that I don't have…if they had like a little van that ran around San Mateo County that had some canned experiments or the cool equipment or something like that. (TI alumnus)*

Administrators' wishes for an even stronger role

In general, administrators have a desire that the TI act as an even stronger professional development provider, compensating for what districts are not able to offer to teachers. For example, some suggest that the TI could build science leadership capacity in their schools and districts. A LAUSD science administrator says:

> *If I were in charge I would expand it out. I would develop a leadership cadre within each of the local districts and send more teacher leaders up there, take the Inquiry institute, and then have the Exploratorium folks come down here and work with them on content. (District science administrator)*

Others suggest that the TI recruit more strategically and extensively (possibly using technology) so they can work with departments to have a broader impact and reach teachers in under-served areas.

> *I imagine that they would get more bang for their buck if they worked with departments. (School administrator)*

> *If I had a choice of training 5 teachers at each of two schools versus 1 teacher at each of 10 schools, I would choose the 2 schools because the odds that a program is going to stick are greatly increased. Word of mouth leads to groups of teachers supporting each other. If you want something to happen, you need a bunch of people trained on the same thing. (County science administrator)*

> *It would be great if they could get to more rural areas because we don't have anything like that. Maybe running some TI [workshops] from satellite. People really trust the Exploratorium and think it is a tremendous resource. (County science administrator)*

A county administrator wants to tap the TI's expertise to better address needs of English language learners.

> *We are working with the Exploratorium on a new grant proposal that the state is providing. What we want to do is use their wonderful effective way of working with teachers and then build an English language piece onto that so it is more conscious and self-evident. (County science administrator)*

Underlying these suggestions, though, is a recognition that simply accomplishing what the TI does already is no small feat in these tight budgetary times.

> *Continue doing what they do, regardless of tight funding—don't change. (County science administrator)*

> *I don't think they charge nearly what they are worth. That's why I don't think they bring in the money to sustain an expansion. Their heart is in helping, not billing. (District science administrator)*

The unfulfilled potential of the TI's current strategy for "spreading" TI practice in the system

The TI has not adopted a strategy of trying to change "the system" by creating new curricula, getting involved in assessment, doing district planning, etc. They are not well positioned to do that and that is not their institutional strength. Rather, their strengths lie in promoting authentic science teaching and learning and in serving teachers as practitioners and professionals. And they tap their strengths to respond to changing conditions in the system—for example, to engineer offerings designed specifically for new teachers, and to refine activities so they meet teachers' greater needs to work with very heterogeneous classes and teach with greater sensitivity to standards.

However, there is one improvement function that TI staff believe their programs serve, but which in reality they serve very minimally or not at all—and that is to promote the "spread" of TI-based teaching strategies through the school- and district-based leadership of their alumni. The reality is that TI participants play much less of a professional leadership role in the system than TI staff (and we) expected.

While TI staff have engineered alumni leadership for their own programs, they have never aimed to engineer teacher leadership for and within schools and districts. Rather, TI staff have assumed and relied upon the existence of a "natural" process or context within the school system whereby TI teachers could put their knowledge and Exploratorium resources to use so that they spread beyond individual classrooms. For example, the Exploratorium thought that the department chair role would enable TI

alumni to engage in leadership activities such as demonstrating TI lessons and distributing materials, shaping curriculum to facilitate use of TI resources and methods, and fostering collaborative planning among science teachers. However, we learned from department chairs that the chair function is strongly circumscribed by the system's perspective and pressures; it is "all bureaucratic," as one person said. And TI alumni who serve as chairs do not, on their own, re-define the role as a professional leadership role for sharing practical knowledge and content. More generally speaking, while TI staff may regard alumni as leading teachers, the alumni themselves do not describe themselves this way. Thus, neither the mainstream system nor the Exploratorium engineers a leadership and dissemination function for departmental chairs or for alumni in other roles.

Similarly, we learned from alumni of different TI programs that teacher collaboration within and across schools happens far less than the TI expects. In fact, it is the rare department that supports teachers as members of professional learning communities. Rather, as we noted before, TI staff run into one another at the Exploratorium and other professional meetings.

In sum, the reality of the system is that it neither facilitates the spread of ideas through teacher leadership, nor does it support in-depth collegial reflection on practice. This reality can be seen as limiting the TI's contribution to improvement of science teaching beyond individual participants.

VI. Reflections and Implications

By all accounts, the Exploratorium's position outside the system enables it to make a vital contribution to teachers' learning and teaching of science. The Teacher Institute stands as a science-rich resource the system cannot provide for itself, but which the system needs.

> *If I had to cut out all my other options for teacher training, I would still keep the Exploratorium because I know they can do almost anything . . . They are a big part of teacher support and since they are outside school they are not caught up in whatever issues are going on at the school. They are a separate place where teachers can get the support they need. (SFUSD science administrator)*

At the same time that the TI makes a vital contribution to system improvement, it does so not by working at the system level, but rather by working with individual classroom teachers and, to an increasing extent, with groups of teachers in a school/district setting. The TI works from a theory that the individual teacher is the key unit of change.

The role of the TI vis a vis the system

An obvious question deriving from the study is this: Would the Exploratorium have a broader impact if it altered its theory and strategy to work at the system level? Our reflections, based on our long-time study of the Exploratorium and other professional development programs and networks outside of schools, suggest that the answer is no. We see two reasons why changing the programmatic focus from teachers to schools and districts would be a mistake for the Exploratorium (and therefore for teachers, schools, and districts.) The first and most simple reason is that work at the system level is not the strength of this institution or of its staff. TI staff members know (and love) science first and foremost, and they know the teaching and learning of science. And while they are responsive to system needs and shifting demands on teachers, they are not equipped to catalyze or facilitate change at the direct system level.

The second is that, even if the staff were so inclined, a shift toward working at the level of the larger system could actually undermine the role that the TI plays in providing a *professional* perspective (rather than a system policy perspective) on improvement of teaching. The education system is essentially a series of loosely coupled institutions that, at every point, are shaped and governed by community expectations in the form of traditions and policies; and teachers are certainly part of the system. However, teachers are also part of a profession; and the profession is a social structure comprising membership defined by specialized knowledge and practices. As such, the profession

intersects and interacts with, but is not fully embedded in the school system. As shown in the conceptual framework shaping this report, the education system brings a set of perspectives to the question of what should be taught and learned in science; these perspectives are formed through a public policy-making process, which is appropriate for schools as public institutions. And the profession brings another set of perspectives to what should be taught and learned in science; these are derived from a different foundation, which is specialized knowledge of the disciplines and of how they are learned and can be taught. The school system, by its nature, does not have the capacity to promote a strongly discipline-based profession. Institutions such as the Exploratorium, therefore, play a critical role in shaping teaching and learning. Thus, the fact that the TI influences teachers in ways that help teachers teach authentic science *and* helps school administrators achieve their policy-oriented agenda does not mean the Exploratorium should start working at the system level. Rather, it means that the TI's discipline-based work with teachers is enabling those teachers to build classroom practice that is grounded in professional knowledge while being responsive to the demands of curriculum policy.

Enhancing the TI's contribution to strengthening science teaching

Given that the evidence points to the appropriateness of the TI role and its value as a source of professional development of teachers, the important questions are these: In what ways might the TI enhance its efficacy in fulfilling the functions for which it is best suited? How can the TI's work make a greater impact?

Here we offer a reflection from two perspectives, that of the system and that of the Exploratorium TI staff.

First, *the school system could likely make better use of the Exploratorium's strengths and the contributions of the TI*. Here we want to note again that we were surprised at the great extent to which some school and district leaders do tap the resources of the TI staff for teachers in their district. In other words, the system is currently making some use of the TI's assets and offerings in ways that extend the impact of TI work beyond the individuals who enroll in programs at the Exploratorium. It is also evident, however, that schools and districts could more strategically tap and benefit from the TI by, for example, encouraging TI alumni who are department heads to make more productive use of professional time for focusing on teaching and learning science; and tapping TI alumni for professional development leadership and encouraging them to facilitate spread of TI activities and resources.

Perhaps more importantly, *the TI could – within its own theory and set of values of respect for teachers – take a number of steps to deepen their work with teachers and extend their reach*. For example, they could take a more deliberate approach to engineering opportunities to serve teachers in school settings, and they could probably raise revenue from such a strand of work. Also, they could deliberately encourage TI alumni to define roles within their schools and districts in which they share more TI activities and resources with their colleagues. For example, the TI could hold monthly seminars for department chairs in the area, or promote the adaptation of such activities such as Teaching Boxes in departmental (or other school-based mentoring) settings.

Finally, it seems vitally important that *the TI find ways to expand its offerings for seasoned teachers* (while sustaining its work with new teachers). Teachers' workplace conditions are such that teachers have only rare opportunities to re-experience the joy of science and the excitement of teaching science in ways that reverberate in their classrooms. Revitalizing its programming in this way will enable the TI to better reflect its claim of supporting a professional "guild" that embraces and supports science teachers throughout their careers.

Appendix A
Evaluation Tasks and Data Sources

For this study we observed the TI's three core summer programs and conducted focus groups with participants; interviewed alumni teaching in San Mateo County schools; interviewed school, district and county administrators whose teachers have benefited from the TI; interviewed TI staff and attended a monthly staff meeting; and conducted analyses of TI records of staff activities. We carried out these tasks between summer 2003 and winter 2005.

Specifically, our study draws upon the following sources of information:

SUMMER 2003—emphasis on how the TI builds teacher commitment and supports professional community ("guild")

- Observations of TI Classic, Leadership and Alumni Institutes
- Focus groups with 55 Institute participants (22 teachers in the Classic Institute, 14 teachers in the Leadership Institute, and 19 teachers in the Alumni institute; 17 were current or former participants in the Beginning Teacher program)

SUMMER 2004—emphasis on impact/spread, focusing on San Mateo

- Focus groups with 12 San Mateo teachers in three TI summer programs

FALL 2004—emphasis on TI culture and accomplishments

- Observation of a Saturday workshop
- Focus group of TI leaders on their theory of action

WINTER-SPRING 2005—emphasis on context within which the TI works and its contributions to that context

- Documentation of TI staff outreach work to schools and others via staff interviews and analysis of database records
- Observation of TI staff meeting
- Interview with San Mateo County Science Supervisor
- Interviews with 8 San Mateo teachers, a mix of veteran TI alumni and former participants in the TI New Teacher Program
- Interviews with a principal and vice-principal at two schools identified by the TI as potentially highly impacted schools
- Interviews with 5 district administrators who have called upon the TI for support and who are familiar with their teachers' involvement with the TI (a Teacher on Special Assignment, Secondary Science Content Specialist, Secondary Science Advisor, Elementary Science Specialist [familiar with ExNet], and a Coordinator of Science Programs for a County Office of Education)

Appendix B
Additional Quotations

The additional quotations below relate to the following sections of our report:

The TI's core function: strengthening discipline-based professional knowledge and practice

They are amazingly responsive. Like today we did more on the arithmetic and I am sure that is in response to some of the comments that we made that we wanted. They worked really hard to listen to us and to modify what we do in the program. (TI New Teacher Program participant)

I am into the stage of my career where I am no longer struggling to build a curriculum. I have one. Now the challenge is to keep it fresh. You don't want to do the exact same thing every year, and I think they are useful and if I went more often, they could be more useful in that respect. Let's take a look at this thing, this experiment that you have been doing identically for the last 7 years now, how can we make that more interesting, how can we make that more accessible to the students and their own experiences? (TI New Teacher program alumnus)

I think if I could sum it up with one word, really, it would be quality, quality and quality, because nobody was ever condescending, and I mean just the quality and the depth that we experienced here was phenomenal. (TI New Teacher Program participant)

When you come here for the very first time and you look at the kind of exhibits that they have and the effort that they have put into, that it is just plain good science. Instead of like giving you this like McDonald's version… you have to learn it yourself because you learn better that way and if you watch kids coming through here and adults with their kids, you see the science happening. (TI alumnus)

Early in my career I did both the Exploratorium and the Tech Museum and so probably together they played [important roles] in terms of my just developing more of a lab based teaching approach. . . . I sort of dropped the Tech over time, because the Tech seemed to train more on how to teach, and the TI tended to also address your knowledge base and increasing your knowledge base in learning more in that sort of stuff. (TI alumnus)

It is connected consciousness, like there are things going on in everybody's minds and we are sharing them. . . . You have a little bit of separation anxiety for the last couple of days. (TI alumnus)

I go to these workshops and you see people who are 22 to 70, altogether in workshops and so that is kind of a neat cross-generational thing of teachers, so that is kind of interesting. (TI alumnus)

I found it really nice that one can just hang around with other teachers and so a lot of times, even if, a lot of times the conversation, if you get to know people, it will drift and so even though the institute has a particular topic that you are looking at, you can often discuss other things on your own time or at lunch or something like that and you can get ideas that way as well. (TI alumnus)

People come here and they fall in love with the program here and so they perpetuate it, so it wouldn't matter who maybe sometimes shuffles in and out, there are 20 years in this community and he knows what is going on here and who believe in it, who keep it going because it is good and anybody who looks at it is just going to sell itself, because it is that good. (TI alumnus)

I am not from this area, I feel really comfortable that I could email anybody here and ask them, hey, remember when you did this, what happened, I forgot exactly what went on here, and what was the thing you used? She would reply. I think we all feel like we are all good at what we do and we all get a response, we would find the time to respond. (TI alumnus)

[Are you sending people down to San Jose Tech or to other places in the same way that they go to TI?] *No, I am not as familiar with their program and we don't have the kind of same working relationship, but more importantly as long as they have spaces available at the Exploratorium, I would much rather send them there. (San Mateo County science administrator)*

Strengthening teachers' learning-from-practice within a professional guild of science teachers

I think regardless of whether they were there or not, I would be doing it. But I am not convinced that I would be doing it as effectively. The Exploratorium, when you go there, when you sit down with these other teachers, you just sit back and say, 'Wow, that will work in a classroom.' There are so many people there who have thought about these things and who have done lessons that you really do as a teacher, you just sit there and go, 'oh my god that will work.' (TI alumnus)

The fact that people from the Exploratorium know our classes and come into our schools, it is part of what makes them I think so valuable to us. They are not teaching theory the way this guy is and has been off of his yellow lecture notes for 100 years. (TI New Teacher Program participant)

To my mind, what they do so well, they think of what is an interesting topic and how can one teach that topic. Whether you are new or old, there are always twists on teaching the topic that you might not have thought about. (TI alumnus)

The Exploratorium gets the Big Idea out to teachers. They scaffold activities, which helps teachers get the concept down--why there is an effect, how to manipulate the materials…They're the best at it. (District science administrator)

What I learned from the Exploratorium was how to take just common run of the mill, very inexpensive stuff. I can think of a particular electrical activity with a few pie tins and pieces of Styrofoam, and you can go down to the drug store and spend ten bucks and have a whole class room work of it and that is not the best example I can think of, but things of that nature that are really easy to obtain and easy to implement. (TI New Teacher Program alumnus)

Having people that we know and can call and ask questions, having people resources [is great]. (TI New Teacher Program participant)

When I was a new teacher and I went to the Exploratorium, it was incredibly helpful, because this wasn't my area of expertise doing physics in high school, and it was really exciting to be there . . . . I worked with a mentor teacher at my school who was also involved with the Exploratorium and so I had this connection with my mentor teacher and the Exploratorium and so it provided this huge amount of support for doing labs and activities with high school kids. (TI alumnus)

Limitations of the TI programs

Any business sort of has to run itself and it is like you influence the professional organization, influences, who it can influence, but you are not going to get every individual, and so, I don't think you should do that. A lot of older teachers may not want the help and so there is really no point in

them trying to put a lot of effort into it. Out of a population out of 100, they might get 5 or something, who are still open to new ideas. (TI alumnus)

I think that [their focus on new teachers] is appropriate and considering the fact that funding is limited and that it really is a program to help teachers get started and create a philosophy and things like that, it is appropriate, but if they could expand it . . . . (TI alumnus)

They need more of something -- for lack of a better word-- something academic. You have to show all of these things, do all of these things, but then, what is the connector here, what is the thing that is going to be able to get your administrator off your back so that you can apply these things, you can meet the standards and do this and do that, and then yet still have fun and learn things and still have your students learn things. (TI alumnus)

I think I remember them telling me they are working on doing that more outreach, because they do so much with new teachers in San Francisco, but in the future, I would love to see that more in my area [Half Moon Bay]. All of the science teachers in my area, all 5 of them, will all be retiring, probably in the next 5 years. So there are going to be all of these new teachers and that is one thing that the Exploratorium does a wonderful job on -- supporting new teachers. (TI alumnus)