

# Center for Informal Learning and Schools

## Research and Education Activities, and Findings

### A. What have been your major research and education activities?

In 2002, the Center for Informal Learning and Schools was established as one of the National Science Foundation's 13 Centers for Learning and Teaching (CLT). Four cohorts were funded during the years 2000-2003: 2 in the first year, 5 in the second year, 3 in the third year, and 3 in the fourth year. The CLT initiative focused on the advanced preparation of science, technology, engineering, and mathematics (STEM) educators, as well as the establishment of meaningful partnerships among education stakeholders, especially Ph.D. granting institutions, school systems, and informal education centers. Its goals are to renew and diversify the cadre of leaders in STEM education; to increase the number of K-16 educators capable of delivering high-quality STEM instruction and assessment; and to conduct research into STEM education issues of national import.

The focus of the Center for Informal Learning and Schools (CILS) was to better understand how alliances between informal and formal educational opportunities, organizations, and systems could strengthen K-12 STEM education. Informal organizations included museums, zoos, aquaria, youth development organizations, and afterschool programs. Formal systems included K-12 schools and institutions of higher education. CILS offered graduate, postgraduate, and professional development programs at the Exploratorium, University of California Santa Cruz (UCSC), and King's College London (KCL). In addition to these formal programs and courses, a key CILS strategy was to convene leading researchers and informal educators, along with CILS faculty, students, and participants, at conferences organized to advance a research and practice agenda related to leveraging relationships between formal and informal systems and approaches to science education.

Details on project activities have been reported in prior annual reports. A summary of activities, and number of participants, includes the following:

January 2002	Start of CILS award
September 2002	Cohort I of informal practitioners begins 2 yr ILC program in SF (n=28)
October 2002	Recruitment and student selection process begins
Spring 2003	Cohort I of Science Fellows begins program at UCSC (n=6)
August 2003	First Bay Area Institute held at UCSC (n=60)
September 2003	Enrollment of first cohort of doctoral students (n=8)
September 2003	Enrollment of first cohort of postdoctoral fellows (n=6)
October 2003	Cohort II of informal practitioners begins 2 yr ILC program in SF (n=28)
March 2004	CILS Postdoctoral Symposium held in London
August 2004	Second Bay Area Institute held in San Francisco (n=170)
September 2004	Enrollment of second cohort of doctoral students (n=10)
September 2004	Enrollment of second cohort of postdoctoral fellows (n=2)
October 2004	Cohort III of informal practitioners begins 2 yr ILC program in SF (n=33)
July 2005	First CILS Summer School held in London
August 2005	Third Bay Area Institute held in San Francisco (n=197)
September 2005	Enrollment of third cohort of doctoral students (n=3)
September 2005	Enrollment of third cohort of postdoctoral fellows (n=5)
August 2006	LC Professional Development Design workshop
August 2006	Mini-BAI meets

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August 2006	Second CILS Summer School held in Santa Cruz
April 2007	LOST Opportunities Meeting held in San Francisco
August 2007	Third CILS Summer School held in Santa Cruz
August 2007	Fourth Bay Area Institute held in San Francisco (n=200)
2008-2009	Writing of LOST Opportunities volume & conference dissemination
March 2010	CAISE Inquiry Group publishes Making Science Matter
March 2011	Education Strand at Art as a Way of Knowing Conference held in SF
March 2011	Learning about Learning Summit held in San Francisco
June 2011	Making and Imagination Conversation held in San Francisco

Altogether, in these activities CILS supported the active participation of over 475 educators, scholars, and institutional leaders. These include:

- 21 Doctoral Students (14 graduated, 3 in progress, 4 left program)
- 16 Science Fellows
- 13 Post-Doctoral researchers
- 88 Informal Learning Certificate participants
- 337 Participants in the Bay Area Institute and other CILS convenings

In addition, over the last year CILS completed two other activities. These are:

CILS Director Bevan chaired a committee for the National Science Teachers Association to create a position statement on Informal Learning. This statement was a product of a group of 10 individuals, led by Bevan, and represents high level lessons learned through CILS and other efforts about the relationship between informal and formal science education. Key ideas include:

1. Learning is a process that develops across settings and timeframes, including in informal environments. There is no such thing as informal learning per se, but rather learning in informal environments.
2. There is clear evidence that learning science in informal environments can promote science learning and strengthen and enrich school science.
3. There is a need to expand opportunities for learning in informal environments.
4. Informal Learning Institutions can provide critical infrastructure support to the development of teacher content and pedagogy.
5. There is a need for new research and evaluation methodologies and new measurement strategies that can better capture the contributions to learning and public engagement with science made by informal learning environments.

The NSTA position statement includes declarations and recommendations encouraging stronger investment in the informal science education sector and stronger links between formal and informal settings and educators.

The second activity during the reporting period was the completion of the LOST Opportunities book, a collaboration among CILS, the LIFE Center, MetroMath, and CEMELA. The book's scheduled publication date is August 28, 2012.

### **B. What are your major findings from the activities identified above?**

CILS was primarily a training and development project (see Section C for further details).

Research conducted as a part of the CILS doctoral programs included the following:

Name	Dissertation Advisor(s)	Dissertation Title
Tamara Ball	UCSC: G Wells	Explaining as Participation: A Multi-level Analysis of Learning Environments Designed to Support Scientific Argumentation
Rhiannon Crain	UCSC: T Ogawa, G Wells	Institutionalization in Action: Interactive Science Center Interactivity and Materiality from the Family Perspective
Jennifer DeWitt	KCL: J Osborne, J Hohenstein	Supporting Teachers on Science-Focused School Trips: Towards an Integrated Framework of Theory and Practice
Patrick Dowd	KCL: J Dillon, J Osborne	The Influence of Outdoor Science Educators' Teaching Identities on their Pedagogical Practice
Molly Loomis	UCSC: T Ogawa	Visitor Empowerment and the Authority of Science: Exploring Institutionalized Tensions in a Science Center
Megan Luce	UCSC: M Callanan	Mothers' Speech to Children in Conversations about Conflicting Evidence for Science-Related Claims
Ellen McCallie	KCL: J Osborne, J Hohenstein	Argumentation Among Publics and Scientists: A Study of Dialogue Events on Socio-Scientific Issues
Robin Meisner	KCL: J Osborne, C Heath	Encounters with Exhibits: A Study of Children's Activity at Interactive Exhibits in Three Museums
Jennifer Rigney	UCSC: M Callanan	Who Decides? Mothers' and Children's Beliefs about Food Choices.
Amy Dexter Roberts	UCSC: B Rogoff, M Callanan	Children's Reflections on Cultural Differences in Ways of Working Together
Debbie Siegel	UCSC: M Callanan	Parent-Child Interactions with Artifacts in Everyday Activities
Katie Silva	UCSC: B Rogoff	Teaching Children through 'Little Dramas': Opinions about Instructional Ribbing from Mexican-heritage and European American Mothers
Sandra Wever-Frerichs	KCL: J Dillon, J Osborne	The Role of Museums in the On-going Professional Development of Teachers
Mele Wheaton	UCSC: D Ash	Developing Connections to the Natural World: An Examination of High School Students' Environmental Identities in a Project-Based Conservation

**C. Describe the opportunities for training and development provided by your project.**

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CILS offered four different training opportunities, which have been described in detail in preceding annual reports and in the attached summative evaluation report:

(1) **The CILS PhD programs of study** at UCSC and KCL examined learning in general, and science learning in particular, with an emphasis on social and cultural contexts, scientific discourse and argumentation, and designs for learning in out-of-school settings. Programs in Education were offered at both UCSC and KCL (14 students enrolled) and programs in Developmental Psychology were offered at UCSC (7 students enrolled). Programs of study included both core departmental coursework and courses designed specifically for the CILS program. In addition to working with their primary advisors all CILS students worked with and learn from faculty and colleagues at CILS' partner institutions through the annual Bay Area Institute, monthly video-conference colloquia linking all three institutions, joint summer institutes, as well as individually planned opportunities.

**Doctoral Student Profile:** Molly Loomis, who is now the director of education at Echo Lake Aquarium and Science Center in Burlington, Vermont, was a doctoral student at UCSC in Education. Prior to becoming a CILS student, Molly had worked as an exhibit developer and museum educator at museums including the Montshire Museum of Science, Boston Museum of Science, the Bay Area Discovery Museum, and the Exploratorium. She had an EdM in Teaching and Learning from Harvard Graduate School of Education.

Molly was interested in exploring ways to broaden the museum audience to include more underrepresented minorities. Specifically, she wondered how the museum could be a bridge between certain social and linguistic minority students and classroom learning. Prior to joining CILS, Molly's definition of informal learning was strongly "tied to the environment." After a year of study at UCSC, Molly came to credit her study of socio-cultural theory for bringing to light a very different view of informal learning, as an instantiation of a theory that incorporates ideas such as social opportunity, choice, distributed cognition and understanding. Molly's dissertation was entitled, *Visitor Empowerment and the Authority of Science: Exploring Institutionalized Tensions in a Science Center*. The following is the abstract:

This research explored the relationships among societal, organizational, and visitor assumptions about learning in a science center. The study combined a sociocultural theory of learning with a constructivist theory of organizations to examine empirical links among the history of the Exploratorium (founded in 1969 and located in San Francisco, California), its organizational practices, and family activity at its exhibits. The study focused on three perspectives on science learning in a science center: (1) the societal perspective, which traced assumptions about science learning to the history of science centers; (2) the organizational perspective, which documented the ways that assumptions about science learning were manifested in historic museum exhibits; and (3) the family perspective, which documented the assumptions about science learning that characterized family activity at historic exhibits. All three perspectives uncovered a tension between the goals of supporting public empowerment on the one hand and preserving scientific authority on the other. Findings revealed this tension to be grounded in the social context of the organization's development, where ideas about promoting democracy and preserving the authority of science intersected. The tension was manifested in museum exhibits, which had as their task addressing the dual purposes of supporting all visitors, while also supporting committed visitors. The tension was also evident in the activity of families, who echoed sentiments about potential for their own empowerment but deferred to scientific authority. The study draws on critiques of a hidden curriculum in schools in order to explore the relationship between empowerment and authority in science centers, specifically as they are conveyed in the explicit and underlying missions of the Exploratorium. Findings suggest the need for science centers to engage in ongoing critical reflection and also lend empirical justification to the need for science centers to think in new and critical ways about whom they serve, as well as how and why they serve their audiences.

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Molly had a relatively clear sense of how being a part of CILS prepared her to be a leader in the field of informal science education. She believed the connections within UCSC and across the partner institutions and access to their assets and resources would help position her to be regarded as a credible and reliable source of knowledge in this domain. Further, specific to the UCSC campus, her connection to the CILS Science Fellows enabled her to deepen her own knowledge of the world of practicing sciences. Presenting at the BAI and other CILS sponsored events, particularly in the first few years of doctoral study, impressed Molly as key experiences in becoming a leader in the field.

As she stated to our external evaluator:

“I do feel connected to museums, and that is where all of this started for me. In the field of education right now, this theory-practice divide is so frustrating. I feel like I don’t want to be speaking to a small group of academics. I want to be impacting environments like museums and schools, and so working from within a museum might be a more effective way to do that. But I don’t see museums -- with the few exceptions -- as really being able to commit to research from within. I don’t see yet the ideal place that I would fit in, and yet I have hope that it will emerge somehow, that the field is changing and that more of a spectrum will open up. My work will be some combination of working closely with museums because I am still really tied to museums, even though I think informal learning is a process, not a setting specific thing. I imagine myself being very connected to museums but also having a significant component of my work being research. I am not sure what environment that will happen in best.”

**(2) The CILS Science Fellows Program** at UCSC was designed for doctoral students in the natural sciences, and led by CILS faculty from the Social Sciences, Natural Sciences and Engineering. The program created new a cadre of 16 scientists engaged and interested in understanding theory and practice in inquiry science teaching and learning in multiple contexts.

Science Fellows spent one quarter, during each of three years, in CILS related study, research, or practicum and were required to take the course Advanced Seminar in Science Education, co-taught by CILS faculty in the sciences and social sciences. Goals included the planning and designing learning activities that engage students in learning content through process; engaging and supporting all students in the processes of scientific inquiry; assessing student learning; and developing as a scientist educator. Final Projects required students to design, implement and assess an innovative science program in an informal or formal education setting. Projects included undergraduate science course and section revisions at UCSC, field guides for geology experiences, pre-service teacher recruitment events, and afterschool health education classes.

The following participants were enrolled in three cohorts of the program:

Name	Program of Study	Current Position
Kate Chabarek	Environmental Toxicology	Editor, Lore Editorial
David Cordes	Organic Chemistry	Assistant Professor, Chemistry, Pacific University
Brooke Crowley	Ecology & Environmental Biology	Assistant Professor, University of Cincinnati
Suzanne Langridge	Environmental Studies/EEB	Postdoctoral Fellow in Biology, Stanford University
Jennifer O’Leary	Ecology & Environmental Biology	Postdoctoral Fellow, Hopkins Marine Laboratory, Stanford University
Mira Patel	Chemistry	Scientist, Global Blood Therapeutics
Hoyt Peckham	Ecology & Environmental Biology	Director of Fisheries Science, Grupo Tortuguero de las Californias
Alexandra Racelis	Environmental Studies	Research Ecologist, USDA-ARS

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Marina Ramon	Marine Biology	Senior Program Manager, SACNAS (Advancing Hispanics, Chicanos and Native Americans in Science)
Juliana Rokosky Ron	Earth Sciences, MS	Middle School Science Teacher, The Nueva School in Hillsborough, CA
Yvonne Rodriguez	Physics	Director of Programs, The Society for the Advancement, Hispanics/Chicanos and Native Americans in Science (SACNAS)
Alexandra Rose	Ecology & Environmental Biology	Researcher, Lyon Lab
Christie Rowe	Earth and Planetary Sciences	Assistant Professor, Earth & Planetary Sciences, McGill University
Scott Seagroves	Astrophysics	Physics Lab Instructor, The College of St. Scholastica & Institute for Scientist and Engineer Educators, UCSC
Jennifer Small	Earth Sciences	Postdoctoral Researcher, Jet Propulsion Laboratory, NASA
Andi Stephens	Ocean Sciences	Fishery Resource Analysis and Monitoring (FRAM) Division, NOAA's Northwest Fisheries Science Center

Participants in the Science Fellows Program mastered core skills in their own scientific discipline and also learned about science education in informal settings as well as learning more generally. In several cases, participants reported how their experiences affected their work as graduate student instructors in undergraduate courses. Additionally, Science Fellows reported how informal learning intersected with their work in science disciplines.

**Science Fellow Profiles:** For example, Hoyt Peckham was a PhD candidate at UCSC in evolutionary biology and a member of the first cohort of CILS Science Fellows. Hoyt's research centered on coastal conservation, in particular he is interested in working with coastal communities on how to participate in the conservation of their coastal resources. Hoyt conducted scientific research (with loggerhead turtles) and also worked for a non profit organization called Blue Ocean Institute. His work with this organization centered on raising awareness of coastal dwellers in Mexico of their impact on marine resources. He was interested in CILS initially to help further his expertise in doing outreach, particularly extending informal learning strategies to his work with coastal communities.

An external evaluation found that Hoyt believed that CILS has added tremendous value to his own work and thinking.

*I think there is a huge role for informal learning and for lean and responsive non-profits to bring about this type of work. ... For the most part, [our outreach] has worked, but it is now really cool to look at some of the research, the learning science behind what we are trying to do, and to evaluate our efforts from that perspective. Another big piece that my involvement in CILS has enabled me to do is to figure out better ways of going about assessment. In the past, it has been very personal interactions and occasionally large scale. In the Cook Islands, we brought about some pretty big policy changes on the scale of the national government, but still it was hard to evaluate our progress, to identify what is working best and what is working less well and which sort of parts or facets of the project we are doing the best with and most cost effective.*

Hoyt was particularly interested in principles of teaching through inquiry, especially "conceptual antecedents" necessary for people to grasp a certain scientific concept.

*I have learned how conveying necessary antecedents can bridge the gap that often exists between resource managers, say in this case biologists like myself who have a very broad perspective on status and abundance and all kinds of technical knowledge, and local resource users, in this case, how the fisherman have an incredible depth of knowledge that is very local and obviously not very academic. One of the things I am really excited about from CILS is that collaboration that develops through the BAI that is enabling me to take another look at the work we are doing to re-evaluate it and think, how can we do this better?*

*I can't think of anything [in CILS] that hasn't been influential. Just being in the same room with a bunch of social scientists is great. There is this osmotic process that happens, and so the seminar that we took last year got us reading about things that I would not normally read about that influenced what I was writing.*

*I would say my interaction with other science fellows is really cool, too, and feeling solidarity as physical and biological scientists. Then opening together to the social science perspective is really powerful; it has been fascinating for me to watch a chemist, a geologist and another ecologist, a mathematician go through that and watching how it has influenced their work is very cool.*

Christie Rowe was a doctoral student in geology at UCSC and also a member of the first cohort of CILS Fellows. Christie's focus for the Fellow's work was her teaching. Our external evaluators found that Christie felt that the most valuable aspect of being a CILS Fellow was access to people and ideas that could improve both her classroom and field-based teaching. As a very eager learner herself, she had little knowledge or understanding of what motivates other people, and how to best bring out what they know. Her interactions with CILS faculty, Fellows, post docs and graduate students helped her frame the course goals and strategies.

In particular, Christie expressed a desire to develop and teach a course that:

- integrates inquiry exercises to replace lectures where the content is appropriate
- gets students to create their own paths through the course material by integrating their personal interests
- develops meta-cognition in individuals and in the culture of the whole class
- develops a collaborative and helpful culture amongst the students
- creates authenticity of experience by integrating current literature in the field and by having students interact with active researchers
- integrates technology to enable reciprocal teaching and to extend the reach of student contributions

Christie reported that each of these goals has been developed as a result of her work in courses, seminars, and interactions with CILS' participants. Christie credits CILS for enabling her to think and talk in new ways about learning and teaching. She finds it difficult to imagine where she would be without having been a part of CILS, as she describes:

*Even without CILS I would still be teaching this class next winter, and I would have gone in and just marched through it and imitated my advisor's style as closely as possible, because I wouldn't have trusted myself to develop any new ideas or try anything that sounded a little risky. Now, learning about inquiry especially, but with the Exploratorium folks in particular, it has been really big in terms of not being afraid to go into a lesson and not have all of the students come out with the same experience. That is a big risk for an instructor to take.*

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Now, as a result of her courses and seminars, she feels confident that not only can she do it, but that it is worth doing – something that she admits has taken some time to believe. Now more than ever she bemoans the fact that so few instructors and professors examine their own teaching and strive to improve it.

**(3) The CILS Informal Learning Certificate (ILC) program** was designed for informal educators who work with outside educational agencies (such as schools and afterschool organizations) to strengthen science teaching and learning in their communities. The goal of the two-year program was for participants to design and lead stronger, more strategic programs that could build on the particular strengths and affordances of informal settings to support the needs and strengths of formal science teaching and learning. Participants attended a minimum of four workshops as well as the Bay Area Institutes. The workshops were led by faculty at the Exploratorium with guest faculty from UCSC and King's College London. Workshops addressed the topics of science inquiry, learning theory, school policy, and professional development design. Some 90 educators participated in the program.

The Informal Learning Certificate program helped begin building capacity of the broader field of informal science education. It contributed towards leadership development within the field and created a community of practice that appears poised to have an even greater impact on the field in the future. Because of the Informal Learning Certificate program there are now more people in the field with the interest, improved capacity, and propensity to deepen and strengthen informal education's connections with schools. With this hybrid leadership – people grounded in informal and school realities, policies and politics – this network of people is in a better position to navigate those two worlds because of their knowledge, understanding and experience.

**(4) The CILS Post-Doctoral Research Program.** Thirteen CILS postdoctoral researchers worked closely with CILS faculty and graduate students in research projects and courses. CILS Postdocs had doctoral degrees in Education (5), Psychology (5), Cultural Studies (2), and Linguistics (1). Postdocs led CILS colloquia, which were monthly video-conferences linking participants at the Exploratorium, UCSC, and King's College London. They also guest lectured in CILS courses.

**Postdoctoral Researcher Profile:** Postdoc Jill Hohenstein came to CILS with a doctorate in developmental psychology and an area of expertise in cognitive development, with a research focus on families, language, and conceptual development in science. She joined CILS as an opportunity to improve her knowledge of educational issues through work with both Maureen Callanan and Doris Ash, exploring the kinds of questions that parents ask children in the context of marine science exhibits. In general, Jill's work centered on learning more about how children come to know science outside of the classroom to help teachers understand this process better and make use of it in formal settings.

Jill reported to our external evaluator that the most valued benefit to being a part of CILS was the opportunity to communicate and share ideas and perspectives across departments and institutions. The Post Doc Symposium in London was particularly valuable, as an opportunity to hear different perspectives and ways of thinking about a common problem – something that is often hard to find within one's academic department.

Jill believes a major goal of CILS is to create a greater awareness among practitioners – both classroom- and museum-based – of how people learn, and that insights from informal settings can be useful in the classroom. While she acknowledges that the study of informal learning has been around a long time, ways of effectively utilizing informal learning strategies for education, have not. CILS thus provides an opportunity to bring together a diversity of ideas and methods to understand it in a deeper, more formalized way. As a result of her participation in CILS, Jill took a lecturer appointment at King's College London in 2004 where she continues to teach and pursue

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her research which examines how thought and language are interrelated in child and adult cognition. She was appointed senior lecturer in psychology of education in 2009.

### **D. Describe outreach activities your project has undertaken.**

The Bay Area Institute (BAI) brought together researchers, educators, and policymakers whose work focuses on how out-of-school-time learning can support and expand engagement and achievement in academic and career STEM pathways. Participants and presenters came primarily from the fields of developmental psychology, science education, museum learning, and organizational theory. Workshop topics included a rich mix of theory, research methods, program designs and practices, policy analysis, and professional development strategies, designed to engage questions and issues from both research and practice.

The following is a sample agenda from the BAI in 2007:

#### *Keynote Speakers*

- Culturally supportive learning environments for expanding STEM achievement (Kris Gutierrez, Professor of Social Research Methodology, UCLA)
- Learning in everyday settings (Shirley Brice Heath, Margery Bailey Professor of English and Dramatic Literature, Stanford University)
- Early interest as key predictor of later participation in STEM careers (Robert H. Tai, Assistant Professor Science Education, University of Virginia)

#### *Roundtable Discussions*

Two-part review and discussion of video data collected in home and out-of-school settings to consider the questions "what counts as everyday science?" and "what counts as everyday math?" Discussions led by teams of researchers from CEMELA, CILS, LIFE, and MetroMath.

#### *Poster Sessions*

Researchers, scientists, and educators involved in promoting out-of-school-time STEM learning activities will present current research projects and findings.

#### *Parallel Sessions*

Some two dozen workshops engaged participants in discussion of topics such as:

- Designing socially interactive exhibits in culturally diverse settings
- Supporting culturally-relevant STEM learning opportunities for indigenous populations
- Use of design-based research methodologies in informal settings
- Integrating argumentation and evidence in the museum experience
- Informal settings as sites for teacher preparation and development

In addition, a significant conference dissemination strategy was pursued with over 182 workshop sessions held during the period 2002-2012. See Appendix for a comprehensive list.

## **Contributions**

### **A. Contributions within the discipline:**

A key contribution to educational research was the development of a theoretical and empirical approach to understanding science learning in formal organizations, such as schools and museums. In particular, CILS was a leading force in the introduction of cultural historical activity theory into studies of learning in informal settings. While several scholars had been engaged in

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this work in prior years, the scope and reach of CILS made this body of work far more prominent, particularly to the field of practitioners through the ILC and the BAI.

For example, the work of Rodney Ogawa and his students (R. Crain, M. Loomis, T. Ball) developed an approach that integrated cultural historical activity theory and institutional theory in an analysis of the field of informal science centers (Ogawa, R. T., Crain, R., Loomis, M., & Ball, T. (2008). CHAT-IT: Toward conceptualizing learning in the context of formal organizations. *Education researcher*, 37(83-95).

The Callanan laboratory focused on non-formal and everyday interactions with science, such as in how families talk about scientific explanations and evidence. Parents with science-related educational backgrounds tended to discuss scientific evidence more consistently across the task than did parents without science-related educational backgrounds. These findings contribute to our theoretical understanding the social and cultural contributions to the development of children's scientific thinking.

Additionally, the publication of *Making Science Matters* (Bevan, B., Dillon, J., Hein, G. E., MacDonald, M., Michalchik, V., Miller, D., et al. (2010). *Making science matter: Collaborations between informal science education organizations and schools*. Washington DC: Center for Advancement of Informal Science Education) provides an important theoretical rationale for supporting and expanding collaborations between formal and informal science learning institutions.

The forthcoming (August, 2012) volume, *LOST Learning Opportunities*, sponsored by CILS, is an edited volume containing 13 papers and additional commentary that employ sociocultural and cultural historical approaches to researching learning in informal setting.

In addition, the Callanan laboratory's ongoing partnership with a children's science museum offers an effective model of how academia and museums can work together to benefit both research and practice.

### **B. Contributions to other disciplines:**

CILS UCSC made important contributions to the physical and natural sciences through the CILS Science Fellows Program. The CILS Science Fellows Program represented a working model of interdisciplinary education, promoting dialogue between natural and social scientists, and creating 'border-traders' (i.e. researchers who trade information across disciplinary borders as well as creating bridges between scientific knowledge and education). In addition, a collaboration between the CILS Science Fellows Program and the Professional Development Program of the Center for Adaptive Optics (CfAO) was institutionalized at UCSC under a new Institute for Scientists, Engineers, and Educators (ISEE). The ISEE helps perpetuate the ideas and development of graduate students in the physical and biological sciences, in engineering, and in science education through professional development training. The training is grounded in research-based education models. ISEE has received University wide, long-term support from the Vice Provost of Education, the Vice Provost of Undergraduate and Graduate Education, the Vice Provost of Research, the Dean of Physical and Biological Sciences, the Dean of Social Sciences, and the Dean of Engineering.

### **C. Contributions to human resource development:**

CILS made significant contributions to human resource development through its training and preparation of a cadre of doctoral students, postdoctoral researchers, and informal educators to take leadership in the field. As noted above, the program trained 13 postdoctoral researchers, 21 doctoral students in education or psychology, 16 doctoral students in the natural sciences, and 89 informal educators.

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The following list names CILS Postdoctoral Researchers and their current positions in the field.

Name	Faculty Mentor	Current Position
Lucy Avraamidou	J. Osborne	Associate Professor of Science Education, University of Nicosia, Cyprus
Flavio Azevedo	J. Moschkovich	Assistant Professor, University of Massachusetts Amherst
Carol Brandt	D. Ash	Assistant Professor, Science Education, Temple University
Victoria Deneroff	R. Duschl	Assistant Professor of Middle Grades Education, Georgia College & State University
Jennifer Dyer-Seymour	M. Callanan	Associate Professor of Psychology, California State University, Monterey Bay
Jill Hohenstein	M. Callanan	Senior Lecturer in Psychology of Education, King's College London
Jane Lehr	J. Osborne	Associate Professor, Ethnic Studies, California Polytechnic State University
Rebeca Mejia-Arauz	B. Rogoff	Professor, Department of Psychology, Universidad ITESO
Leslie Moore	B. Rogoff	Assistant Professor, School of Teaching and Learning, Ohio State University
Lisa Szechter	M. Callanan	Assistant Professor, Department of Psychology, Tulane University
Anwar Tlili	J. Osborne	Lecturer, King's College London
Lynn Tran	J. Osborne	Research Specialist, Lawrence Hall of Science
Lara Triona	M. Callanan	Assistant Professor, California State University, Fresno

The above table illustrates that postdoctoral researchers have taken on faculty positions at a wide range of settings where they continue to pursue scholarly research in the domains of STEM learning and learning in informal environments. Based on a Google Scholar database search conducted in August of 2012, altogether, these CILS alumni have some 157 citations in the scholarly literature produced between 2002-2012.

CILS also supported leadership in the field of informal science education. The table below lists the ILC participants and their current positions.

Name	Cohort Year	Current Position
Barbara Addelson	2003	Science Education Consultant, Addelson Consulting
Andy Aichele	2002	Sr. Director for Exhibition and Volunteer Programs, COSI Columbus
Tamsin Astor-Jack	2003	Freelance Science Educator
Blair Baldwin	2004	Manager of PD and Distance Learning, Oregon Museum of Science and Industry
Rita Bell	2002	Director of Education Programs, Monterey Bay Aquarium
Anthony Bisulca	2003	Manager of Teacher Programs, Liberty Science Center
Colleen Blair	2002	Executive Vice President of Innovation, Fort Worth Museum of Science and History

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Judi Bowes	2004	Marketing Manager, Zoological Society Of San Diego
Kathleen Boyle	2003	Executive Director, Governor's Office of Student Achievement in Georgia
Karen Carroll	2003	Science Coach, California Science Center/UCLA
Marcia Carter	2004	Former Science Education Curator, Louisiana Art and Science Museum
Amelia Chapman	2004	Curator of Education, Pacific Asia Museum
Selena Connealy	2003	Consultant, Museum Education Group
Julie Cross-Steele	2002	Owner, Peas and Harmony Organic Food Gardens
Greg Danner	2004	Director of Programs and Exhibits, The Imaginarium
Karen Davies	2004	Head of Learning Resources, London Science Museum
Sam Dean	2002	ExNET Director, Exploratorium
Benjamin Dickow	2004	Director of Entree Initiative, CAISE
Kayla Dove	2003	Research Assistant, Education Development Center
Nina Drammissi	2002	Science Education Staff Developer, Reuben H. Fleet Science Center
Teresa Eastburn	2003	Manager of School & Public Programs with Spark UCAR Science Education, University Corporation for Atmospheric Research
Ramona Englebrecht	2002	Staff, Rochester Museum and Science Center
Aly Evans	2002	Senior Grants Coordinator, San Diego Association of Governments (SANDAG)
Brian Exton	2004	Science Education Specialist, Cedar Crest College
Anna Fitzpatrick	2003	Program Manager, Children's Museum of Pittsburgh
Robert Fox	2004	Unknown
Kathy French	2003	Education Coordinator, University of NE State Museum
Anjali Goel	2002	Asst Administrator, Science at the Academy of Natural Sciences
Dee Goldberg	2004	Coordinator for Science, Spring Branch Independent School District
Wendy Gram	2003	Chief of Education and Public Engagement, NEON, Inc.
Erin Graves	2004	Director of Programs, Catawba Science Center
Kurt Gross	2004	Principal Engineer, Channel Medsystems
Preeti Gupta	2002	Director of Youth Learning and Research, American Museum of Natural History
Gabby Hebert	2003	Director of Education, Phoenix Zoo
Ana Rosa Lopez Hernandez	2004	Staff, Museo Sol Del Nino A.C.
Mary Hobbs	2004	Coordinator for Science Initiatives, University of Texas at Austin
Susan Holmes	2002	Senior Museum Educator, Franklin Institute
Jennifer Hope	2004	Assistant Professor of Education, McKendree University
Ling Hsiao	2003	Educational Technology Coordinator, Museum of Science, Boston
Jim Jordan	2003	Senior Coordinator of Continuing Education, UM-St. Louis
Cheryl Lani Juarez	2004	Director of Professional Development, Miami Museum of Science
Thomas Keating	2002	Director of Instruction and Technology, San Carlos School District
Lesley Kennedy	2003	Program Manager, Teacher Enrichment at Museum of Science, Boston
Karen Knecht	2003	Director of Education and Exhibits, Da Vinci Discovery Center of Science and Technology
Claire Le Moine	2002	Science Education Coordinator, Explor@dome
Anson Lee	2002	Community Teacher Developer, Reuben H. Fleet Science Center
Isabel Leeder	2004	Curriculum Developer, Miami-Dade County Public Schools
Kristin Leigh	2003	Deputy Director, Explora
Linda Hagelin	2002	Educator Programs Staff, Monterey Bay Aquarium

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Chip Lindsey	2002	Executive Director, ScienceWorks Museum
Rick MacPherson	2003	Director of Conservation Programs, Coral Reef Alliance
Glenda McCarty	2004	Teaching Assistant, Doctoral Program at the University of Missouri–Saint Louis
Sue McWilliams	2004	Adjunct Faculty, Lewis and Clark College
Flavio Mendez	2004	Learning Center Senior Director, National Science Teachers Association
Diadre Metzler	2004	Education Director, San Joaquin River Parkway & Conservation Trust
Audrey Munoz	2002	Early Childhood Manager, Children's Discovery Museum of San Jose
Sara Nichol	2003	Staff, Phoenix Zoo
Jayshree Oberoi	2004	Teacher Services Supervisor, New England Aquarium
Kristen Parks	2003	Education Director, Discovery Science Place
Nicole Peisker	2002	Cultural Arts Developer, Children's Discovery Museum of San Jose
Colleen Pelak	2002	Fleet Inquiry Institute Project Director, Reuben H. Fleet Science Center
Lucinda Presley	2003	Education Consultant, The Leonardo in Utah
Wayne Ransom	2002	Retired
Anthony Richards	2004	Head of Gallery Programs, London Science Museum
Amy Roadarmel	2004	Director of Visual Arts, Cedarhurst Center for the Arts
Diana Robaina	2002	Supervisor of Programs and Special Projects, Ft Lauderdale Museum of Discovery and Science
Bill Rogers	2003	Staff, Buffalo Museum of Science
Kevin Rosenstein	2002	Unknown
Joel Rubin	2004	Teacher Resource Center, New England Aquarium
Amity Sandage	2002	Regional Coordinator, California Regional Environmental Education Community Network
Marcella Saoud	2004	Art Specialist, Taylor Elementary School
Lee Schmitt	2004	Faculty and Professional Development Coordinator, Hamline University
Maija Sedzielarz	2004	Senior Program Developer, Science Museum of Minnesota
Laura Shaffalo	2003	Museum Artist, Children's Museum of Pittsburgh
Karen Sherman	2002	Board Member, Arizona Museum for Youth
Frank Signorello	2002	Manager of STEM Initiatives, Girl Scouts of the USA
David Smith	2003	Director of Professional Development, Da Vinci Science Center
Judy Stanley	2003	Director of Education, LodeStar Astronomy Center
Carie Szalay	2004	Science Teacher, Springside School in Chestnut Hill
John Thacker	2004	Science Teacher, Covington HS in Covington, LA
Robin Thompson	2002	Staff, Ft Lauderdale Museum of Discovery and Science
Karen Wallace	2003	Director, Center for Science Learning, Buffalo Museum of Science
Carolyn Willard	2003	GEMS Network Director, Lawrence Hall of Science
Patrick Willis	2004	Science Instructor, Marylhurst University, Portland State University, Lewis and Clark College, and Faculty Member, Oregon State University Extension
Mary Ann Wojton	2002	Senior Director of Student and Teacher Programs, COSI Columbus
Sue Wu	2004	Senior Earth Science Educator, Oregon Museum of Science and Industry
Peter Yancone	2004	Director of Education, Maryland Science Center
Brigitte Zana	2002	Director for Development and Networks, Palais de la D�couverte

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The external evaluation of this program found that the program improved the infrastructure for informal science education. The program's major impacts fell into the following categories: personal and professional; programmatic (e.g., the number, quality, and reach of the participants' programs); institutional; and more broadly, impacts on the field.

### Personal and Professional:

- 92% said they became familiar with key research in the field that they didn't know about previously.
- 84% learned of research findings relevant to their own setting.
- 70% put research findings to work in their own setting.

### Programmatic:

- Nearly half the Informal Learning Certificate program graduates reported that the amount of work they do with teachers increased since they started the Informal Learning Certificate program.
- The Informal Learning Certificate program impacted participant's vision or goals for their work with teachers (54%); their priorities for their work with teachers (41%); and the ways they evaluate or assess their teacher programs (41%).

### Institutional:

- 55% said that the Informal Learning Certificate program contributed greatly to their abilities and confidence to take on leadership within their own department at their institution.
- 60% said that the Informal Learning Certificate program contributed greatly to their abilities and confidence to take on leadership in their own institution beyond their department.
- 76% of participants reported that the Informal Learning Certificate program program to a great or very great extent contributed to their leadership in collaboration or partnership with other museums.
- 80% said that they felt empowered to take on leadership designing and implementing partnerships with local schools.

Our external evaluation found that

"By taking advantage of the learning opportunities afforded them by the CILS program, participating informal science educators have grown intellectually and professionally. Our interviews and direct observations of programs suggest that they have become more sophisticated in their understanding about ways their work can contribute to informal and formal science education domains. Further, this group of leading educators has evolved into the beginnings of a strong professional network, reaching beyond the time-bound certificate program. They believe strongly in the potential of this group to improve their own work and the ways they connect with schools. CILS is thus strategically leveraging leading practitioners in the domain who are likely to stay in the field and move it forward, contributing to improvement of practice in future years."

### **D. Contributions to resources for research and education:**

The three major resources produced through the CILS grant include:

1. The 2010 report called Making Science Matter.
2. The 2012 edited volume called LOST Opportunities: Learning in Out-of-School Time
3. The 2007 Special Issue on Research on Learning Science in Informal Contexts by the International Journal of Science Education

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Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools was sponsored by the Center for the Advancement of Informal Science Education, and developed through the leadership of CILS Director Bevan who chaired the Inquiry Group that produced the report.

As noted in Making Science Matter, the report intended to advance discussion about the value and nature of formal-informal collaborations through three actions:

1. Providing a rationale and theoretical basis for why the ISE and K–12 fields should care about and pursue such collaborations.
2. Reviewing examples of such collaborations, noting their documented outcomes, and identifying emergent themes or characteristics.
3. Identifying existing trends, gaps, and questions that would benefit from further experiments in both research and practice.

LOST Opportunities: Learning in Out-of-School Time is an edited volume published by Springer in 2012. The chapters are contributions from scholars participating in four NSF-funded Centers: CILS, the LIFE Center, MetroMath, and CEMELA. This volume is divided into three sections:

1. What Counts as Math and Science
2. Understanding How and Why People Learn Across Settings as an Educational Equity Strategy
3. STEM in the Organized Out-of-School Time Setting

The volume examines how science and mathematics are experienced in everyday and out-of-school-time (OST) settings. The chapters in this volume include studies of everyday and situated processes that facilitate science and mathematics learning. They also feature new theoretical and empirical frameworks for studying learning pathways that span both in- and out-of-school time and settings. Contributors also examine structured OST programs in which everyday and situated modes of learning are leveraged in support of more disciplined practices and conceptions of science and mathematics. The studies look closely at cultural and developmental issues related to learners and communities of learners, as well as institutional and policy dimensions of supporting learning in OST. Underpinning much of this work is a leading focus on educational equity—a desire to foster more socially supportive and intellectually engaging science and mathematics learning opportunities for youth from historically non-dominant communities.

Additionally, cross-institutional teams produced six position papers addressing key issues related to the focus of CILS. These papers were:

Bevan, B., & Semper, R. J. (2006, January). Mapping informal science institutions onto the science education landscape, from <http://cils.exploratorium.edu/cils/resource.php?resourceID=1276>

Dillon, J. (2006, January). Outdoor education, from <http://cils.exploratorium.edu/cils/resource.php?resourceID=1277>

Hohenstein, J. (2006, January). Discussing the role of conversation in learning at informal science institutions, from <http://cils.exploratorium.edu/cils/resource.php?resourceID=1278>

Hsi, S. (2006, January). Digital learning and play: A synthesis and elaboration from a CILS Bay Area Institute roundtable, from <http://cils.exploratorium.edu/cils/resource.php?resourceID=1274>

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Ogawa, R.T., Crain, R., Loomis, M., Ball, T., and Kim, R. (2006, January) Linking socio-cultural theories of learning with an institutional theory of organizations: Implications for theory, practice, and collaboration, from <http://cils.exploratorium.edu/cils/resource.php?resourceID=1275>

Osborne, J. (2006, January). Communicating science: Roundtable Summary, from <http://cils.exploratorium.edu/cils/page.php?ID=15>

### **E. Contributions beyond science and engineering:**

CILS has also made long-term contributions to the development and direction of programs at the key partner institutions. For example, at the Exploratorium CILS led to a new focus on working with afterschool organizations, including the creation of a research and practice agenda. The Exploratorium became a founding member of the Coalition for Science Afterschool. CILS was awarded an NSF grant to conduct the research and evaluation of the Academies for Young Scientists program (DRL-0639656). CILS created a statewide network of afterschool tinkering programs. Additionally, a major legacy of CILS has been a focus on the integration and relationship of research and practice. CILS received an NSF grant to create a website for informal educators that provides access to current education research resources (Relating Research to Practice; DRL-1049817), two other related NSF grants are currently pending and expected to start in the fall of 2012. CILS also launched a new program of research of science learning in afterschool settings, hiring postdoctoral researcher Dr Shirin Vossoughi to lead this work.

In London, involvement in CILS has had a major influence on the composition, focus and outputs of the Department of Education and Professional Studies at KCL. Dr Anwar Tlili's involvement has led to the creation of a new MA Education in Arts and Cultural Settings and his appointment as a permanent member of staff; Dr Heather King continues to work at King's as a Research Associate; Dr Jennifer DeWitt continues to work at King's as a Research Associate. KCL is preparing to offer a new bachelors degree in Science Engagement and Communication from September 2013 led by Professor Justin Dillon. In terms of research involvement, KCL has taken part in several related research projects under the European Union's Framework Programmes including the Permanent European Research Centre for Informal Learning (PENCIL) and Towards Women in Science and Technology (TWIST). More recently King's has worked in partnership with the Exploratorium and the University of Washington on an NSF grant, Relating Research to Practice.

KCL developed a number of collaborations, both formal and informal, with museums and other museums including collaborative doctoral studentships with the Natural History Museum, London, Royal Botanic Gardens, Kew and Imperial College's Reach Out lab. King's staff are involved in leadership positions in professional organizations including Ecsite and the Visitor Studies Group.

At UCSC, the Education Department continues to attract PhD students with interests in science education outside the confines of K-12 education. UCSC has one third year student, who was not funded by CILS but works on linking planetarium experiences with science education in community colleges. UCSC continues to explore the possibility of establishing an academic program to provide advanced preparation (and perhaps a graduate degree) for informal science educators. The budgetary situation in UC has slowed this process.

The UCSC Science Fellows Program was joined with a similar program supported by the Center for Adaptive Optics (CfAO), another NSF-funded center. The two programs became the Institute for Scientists and Engineer Educators, which prepares PhD students in the sciences and engineering to teach science. ISEE is funded in part by UCSC and CILS PI Rodney Ogawa and Associate Professor of Education Jerome Shaw remain actively involved with this effort.