

AUTHENTIC INQUIRIES INTO LOCAL ISSUES:

Increasing Engagement and Building a Sense of STEM Identity and Agency

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Around the nation, students are working with scientists, teachers, and community members to conduct scientific investigations and carry out engineering challenges related to issues that affect their communities, such as food deserts, urban heat islands, and water and air quality. Through such experiences, students come to understand the role that science, technology, engineering and mathematics (STEM) can play in improving people's lives—and how they themselves can contribute to those changes.

To share promising strategies in student-focused ITEST experiences with the ITEST community and the STEM education field, the ITEST program has called for reflection on best practices and lessons learned in response to the question, ***“What coherent sets of experiences effectively and efficiently support student competency (e.g., knowledge, skills), motivation, and persistence for productive participation in the STEM-related workforce of today or in the future?”*** We answer that question in this paper by focusing on ITEST projects



The Innovative Technology Experiences for Students and Teachers (ITEST) program was established by the National Science Foundation (NSF) to help ensure the breadth and depth of the science, technology, engineering, and mathematics (STEM) workforce, in direct response to concerns and projections about the growing demand for and current shortages of STEM professionals in the United States. The STEM Learning and Research (STELAR) Center at Education Development Center, Inc., in partnership with the Goodman Research Group, Inc., assists ITEST principal investigators (PIs) and evaluators to design, refine, and evaluate their ITEST projects and to effectively synthesize and disseminate project findings.



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that center on authentic inquiries into locally relevant issues.¹

Since its inception, the ITEST program has prioritized funding projects that are uniquely relevant to local contexts. Applied STEM inquiry experiences can foster a sense of agency by enabling students to select an issue to explore themselves. Youth can also participate in designing the investigative approach, and then use the resulting findings to design solutions to real problems. Such experiences may hold particular promise for drawing youth who may not be highly engaged in math and science at school, and for youth from groups that have been traditionally underrepresented in STEM careers.

From a review of over 200 publications related to approximately 110 ITEST projects, we identified a set of publications relating to 12 ITEST projects involving authentic inquiries into community-related issues or unique natural features of the local area.² Based on these publications,

we present the 12 projects below. First, we summarize the learning outcomes these projects targeted and the findings reported in the publications. We then discuss each project in more detail to illustrate approaches and strategies. A section on types of student involvement in these projects, from designer to analyst to reporter, follows. Lastly, although our focus is primarily on student learning, we briefly consider targeted outcomes for teachers.

A range of student learning outcomes targeted in authentic inquiry projects

Learning outcomes targeted in the featured projects include increases in content knowledge, interest, and engagement; attitudes regarding, awareness of, and interest in STEM pursuits; study and career plans; self-efficacy in STEM; and understanding of and appreciation for the value of STEM in one's daily life.

In at least three projects that engaged youth in local environmental investigations, student self-reports pointed to improved engagement with STEM and a deepening knowledge and understanding of the relevant STEM content (Blustein et al., 2013; Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Kissling & Calabrese Barton, 2013; Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013). In addition, two projects found that gains demonstrated by students during the project persisted more than a year later. In one project, students interviewed 12–18 months after the program reported that they continued to explore STEM

¹ This is one of two papers that responds to this question. [STEM Learning Games and Game Design in ITEST Projects](#) focuses on projects involving cyber-based learning experiences and “serious games.”

² For overviews of the characteristics of all ITEST projects drawn from program monitoring data, see the Data Briefs on the STELAR website (<http://stelar.edc.org/resources>). The projects included in this and related syntheses are the subset (approximately one-third) that have available publications on research.gov and the STELAR website.

fields (Blustein et al., 2013). In the other, researchers found that higher-order constructs related to student perceptions of STEM (e.g., as a career, as a way of making a difference in the world) were linked with student interest and aspirations with respect to STEM in a persistent way over time and that student understanding of the constructs persisted two years after their participation (Christensen, Knezek, Tyler-Wood, & Gibson, 2014).

Several projects reported that connections with real-world and locally relevant topics helped students develop a deeper understanding of STEM concepts. The team behind the [Environmental Science Information Technology Activities](#) project (2003-2006) aimed for local and personal relevance in part based on research demonstrating that adolescents can show increased understanding of STEM concepts in learning experiences they perceive as relevant (Cuff, Corazza, & Liang, 2007).

Importantly, authentic inquiry experiences in ITEST projects have shown particular success with engaging students and teachers from groups underrepresented in STEM fields. Several projects that reported improvements in student engagement and learning serve low-income students and students from racial groups that are underrepresented in STEM fields (Kissling & Calabrese Barton, 2015; Malmberg & Maull, 2013; Rose & Calabrese Barton, 2012). One study that reported improvements in student dispositions toward science and technology found that the program had been more successful in fostering positive dispositions toward STEM among girls compared with boys. This project also saw a gender gap in dispositions toward technology disappear over the course of the project (Knezek, Christensen, & Tyler-Wood, 2011).³

Connections with real-world and locally relevant topics helped students develop a deeper understanding of STEM concepts.

³ For a fuller discussion of promising strategies for broadening participation particularly among students from groups underrepresented in STEM fields, see [Promising Approaches to Broadening Youth Participation in STEM](#).

This paper is based on a review of over 200 publications collected from research.gov and the STEM Learning and Research Center (STELAR) website, and of additional resources related to newer projects. The publications reviewed relate to approximately 110 of the 325 ITEST projects funded from the program's inception in 2003 to 2015. The publications originally appeared in sources from a wide range of disciplines (ranging from maritime technology to women's studies) and an array of formats (research journals, practitioner-focused magazines and newsletters, and conference presentations and posters). The publications reviewed also contain widely ranging levels of detail, and the connection to a given ITEST project may be direct or tenuous. Many include descriptions of project implementation or implementation plans. A smaller portion describe targeted outcomes, evaluation methods, and findings.

The variety of sources reflects the diversity of ITEST grantees' backgrounds, specialties, and professional communities, as well as the diversity of local contexts for which projects are designed. ITEST projects build on the strength found in bringing together diverse professionals in the goal of broadening participation in STEM careers, but this strength also presents challenges; because ITEST PIs come from a range of academic disciplines, the nonprofit sector, or formal or informal learning arenas, their work, and how they report on it, varies widely. By summarizing available publications, STELAR hopes to facilitate learning across the various professional communities that together comprise the ITEST community.



The technologies incorporated into the ITEST experience are real scientific tools used by scientists in their day-to-day work.

Approaches to locally relevant investigations

Two clear trends emerge in approaches to authentic and locally relevant STEM inquiry in ITEST-funded projects. One group of projects centers on *mapping activities*, while another involves types of *environmental monitoring*. Mapping and monitoring are both means of documenting and analyzing one's environment. In both cases, the technologies incorporated into the ITEST experience are real scientific tools used by scientists in their day-to-day work, rather than technologies designed for instructional purposes.

Mapping: Defining, understanding, and improving one's place

Mapping provides a new lens for defining one's place. From there, participants gain a new understanding, devise a plan for change, and share it with others. The primary technology tools ITEST projects use for mapping rely on Geographic Information Systems (GIS) and the Global Positioning System (GPS). Use of these systems was reported in several studies carried out within four ITEST projects. GIS integrates databases with geospatial maps to "layer" other types of data onto the maps; GPS pinpoints locations in time and space using information from a network of satellites. This satellite network, initially established by the U.S. Department of Defense, today supports myriad everyday uses, such as navigation systems in vehicles and mapping applications in smartphones.⁴

⁴ For more about GPS and related topics, see the U.S. government's official GPS webpage (<http://www.gps.gov/systems/gps/>).

Mapping urban heat islands in Michigan.

In the [GET City](#) (Green Energy Technology in the City) project (2007–2011), carried out in a Michigan Boys and Girls Club, urban minority students participating in afterschool clubs devised an approach for identifying urban heat islands. The students took responsibility for the design and direction of the project and conducted background research to understand the importance and consequences of urban heat islands (Calabrese Barton & Tan, 2010). After building an understanding of the issues generally and within their own community specifically, students went on to become "make a difference experts." Participants used what they had learned to make presentations to community leaders, write journalistic pieces about the issue, and work with their Boys and Girls Club to build a green roof. Through this experience, youth learned that they can effect change, using findings from inquiries they designed and conducted (Kissling & Calabrese Barton, 2015).

Mapping food deserts and developing hydroponic "vertical" gardening in Boston.

The [Urban Ecological Challenges](#) project (2009–2014), a Boston University-run youth program, convened youth from under-resourced areas of the city to investigate and address issues in their own neighborhoods. The youth first mapped grocery store locations to identify "food deserts" within their communities, and also mapped vacant lots within the food deserts. Students then crafted a proposal for new grocery store locations. In a subsequent phase of the same project, students studied *hydroponics*, a resource-efficient approach to growing food that does not require access to land and, by being its own closed system, circumvents the deleterious effects of any

local soil contamination. Students built their own hydroponics systems, grew different types of produce, and sold it at local farmers markets. In both this project and the urban heat island project described above, students were encouraged to view themselves as agents of change, able to draw on relevant STEM experience, knowledge, practices, and tools to make change possible (Mark et al., 2013).

Incorporating Native knowledge into new mapping efforts in Alaska.

The University of Alaska Fairbanks, the Alaska Division of Geological & Geophysical Surveys, and the University of Wisconsin–Madison worked with Alaskan Native Elders in the [MapTEACH](#) project (2004–2008), which provided geospatial science and technology education for teachers and students that is directly applicable to understanding the local geographic context and problems. This project related Western science and information technology to traditional knowledge by including classroom modules in geology and geomorphology, topographic maps, remote sensing and aerial photography, GIS and GPS, and Native American cartography. In addition to giving students and teachers opportunities to work with these scientific tools, the project also aimed to develop a growing and sustainable rural economy (Olsen, Stevens, Craw, & Fenno, 2004; Stevens, Craw, & Olsen, 2005).

Mapping local trees in Maine and around the country.

A group of middle-schoolers in Maine used GPS and GIS tools to map and inventory trees surrounding their school in the [EcoScienceWorks](#) project (2009–2014). By analyzing their data, students could form hypotheses regarding how the construction of their school affected local tree growth



and habitats (Perkins, Hazelton, Erickson, & Allan, 2010). In the [Urban Ecology, Information Technology, and Inquiry Science for Students and Teachers](#) project (2005–2008), high school students in the Boston area used mapping technologies to investigate the trees in their community. They explored satellite images of a study site (typically, around a school) and collected data on the trees within that site. Students created memory maps and performed a schoolyard tree inventory to evaluate tree diameter at breast height as a measure of tree age. Students then made a grid of the site and collected data on trees within the grid. After teams examined their baseline reports, each developed a research question to investigate. In the last phase of the project, students shared results of their investigations with other participants and wrote letters to encourage tree plantings (Barnett et al., 2010). This approach combined local data with data from similar investigations in other places, empowering students not only to understand something new about where they themselves live, but also to share their understanding with others and see how the characteristics of their own environment figure into a national or global picture.

Students were encouraged to view themselves as agents of change, able to draw on relevant STEM experience, knowledge, practices, and tools to make change possible.



Mapping and paleontology in rural Montana.

Across a vast area in remote Northeastern Montana that encompasses three Native American reservations and has less than one middle school for every thousand square miles, the [Paleo Exploration Project](#) (2006–2010) offered summer field experiences that engaged participating middle school students in authentic scientific research and discovery. Using GIS, GPS, and Google Earth, participating students worked with teachers to map the occurrence of fossils in their local area and then used their mapping data to test hypotheses regarding relationships among fossils in time and space (Almquist, Stanley, Hendrix, 2007; Stanley & Almquist, 2008). The project also included field experiences during which participants dug for fossils. The scientific theme of this project—the geologic history and rich fossil record of Northeastern Montana—was selected to engage participants in a new perspective on their fossil-rich region and a sense of local geologic time. The project included teacher professional development for middle school science, math, and technology teachers on using geospatial techniques for

mapping fossils and on fossil excavation. Student survey data and exit interviews showed both increased self-efficacy in science and technology and increased interest in STEM careers (Almquist et al., 2010b).

Monitoring the local environment

Several projects have addressed air and water quality issues by designing and implementing environmental monitoring programs in their communities. Interestingly, these efforts are not duplicating monitoring efforts already underway—student participants are often the first to take these water and air quality measurements and report them within their communities. Some project participants have shared their findings with local policymakers and the public, while another project provided its data to the National Weather Service. Monitoring projects can help build students' awareness of their local natural habitats even in urban centers where many residents don't have access to natural areas. For example, the [Curriculum and Community Enterprise for New York Harbor Restoration with New York City Public Schools](#) project, funded in 2014, engages large numbers of middle school students in research and investigations of local watersheds in New York City.⁵

In the [Environmental Science Information Technology Activities](#) project, based at the University of California–Berkeley, students in grades 9 and 10 engaged in locally focused environmental science research projects. Although a few of the student projects included investigations

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⁵ For more about the Curriculum and Community Enterprise for New York Harbor Restoration project, see the STELAR website (<http://stelar.edc.org/projects/19349/profile/curriculum-and-community-enterprise-new-york-harbor-restoration-new-york-city>).

on phenomena far from their own communities (e.g., a study that used samples collected from Lassen Volcanic National Park, over 200 miles away, and a study of water quality in Washington, D.C., schools that used mailed samples), most of the student projects featured local explorations of water quality, air quality, and air currents in local schools and parks (Adarkwa et al., 2005; Almendrala et al., 2006; Ararso et al., 2005; Ararso, Huang, Lau, & Le, 2006; Carter et al., 2005; Chan et al., 2004; Cuff & Corazza, 2006; Cuff et al., 2007; Cuff & Molinaro, 2004, 2005; Curry et al., 2006; Curry et al., 2007; Garcia, Bartelt, & Cuff, 2004; Guzman et al., 2006; Hua, Garduño, Mondragon, & Cuff, 2004). Students in this project were engaged in all phases of inquiry: defining problems and questions, designing approaches to the studies, and analysis and dissemination of findings. Like the heat island study in Michigan, involving students in sharing their study findings with the larger community can illustrate the importance of STEM for informing policy decisions that affect people's daily lives.

The above-mentioned [Urban Ecological Challenges](#) project also engaged youth in exploring how natural features of their environment influence air quality, noise, and temperature. Through an interview-based study of student outcomes, the project team demonstrated that participation changes how students view the natural environment and the role of science in their everyday lives. As one student said:

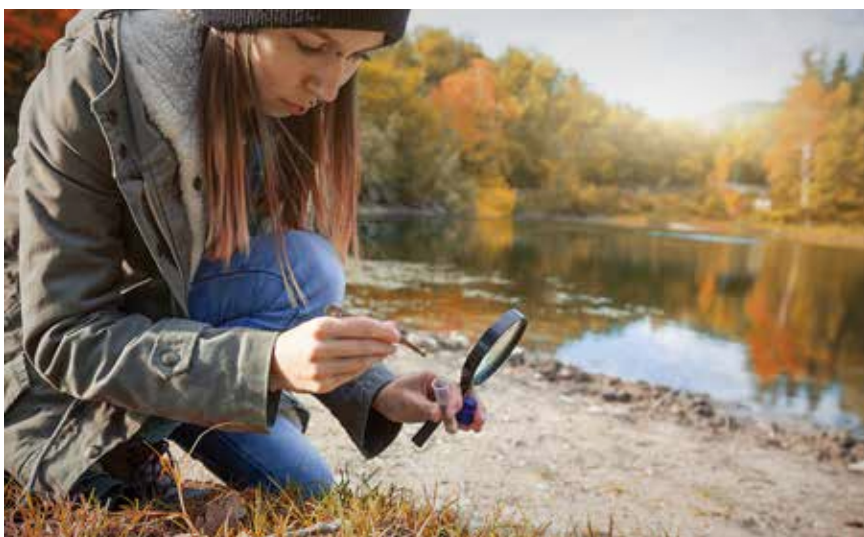
Science is everywhere. Like, science is everything. The littlest thing is scientific. I don't know. It was crazy to me, 'cause science to me was just earthy stuff like worms and ecosystem and all that. (Blustein et al., 2013, p. 53)

Water and air quality. In the [Student Enabled Network of Sensors for the Environment Using Innovative Technology](#) (SENSE IT) project (2008–2012), Clarkson University and The Beacon Institute for Rivers and Estuaries worked with teachers and students at Tech Valley High School in New York to support students in designing, developing, deploying, and testing sensors for measuring water quality in the Hudson. Using the sensors, the students then collected and analyzed data from their own water-monitoring network. The project aimed to increase engagement in STEM courses, awareness of STEM careers, and STEM career aspirations (Hotelling, Stolkin, Bonner, & Kirkey, 2008).

In the [From Learning to Research: Developing Future Earth System Scientists and Professionals](#) project (2010–2014), students around the country engaged in the scientific process while deepening their knowledge and understanding of Earth's systems and processes. The project focused on providing supports to teachers, exposing students to climate science research, and using 21st century technologies to encourage collaboration among participants who are not co-located.

Participation changes how students view the natural environment and the role of science in their everyday lives.





Tribal community members visited the camp to share with the students the Tribe's stream restoration goals, Tribal stories, and historical events related to the creek.

One group of students explored ways to improve their environment through a revitalization project while carefully documenting their progress. By using [*Global Learning and Observation to Benefit the Environment \(GLOBE\)*](#) protocols to collect and visualize their data, students were able to see how modifying aspects of their environment helped to improve water quality. Students then participated in a virtual student conference, at which they shared before-and-after pictures of their communities and explained how their research led to them to improve their local environment (Malmberg & Maull, 2013).

Native American community resources. In the [*Back to the Earth*](#) project (2012–2016), Native American students learned the significance of local creeks to their tribe and its history while exploring creek restoration. The project incorporated interdisciplinary, place-based lessons on watershed, ecosystems, and natural resource management in a summer camp setting. Students spent time on the creeks, developing a sense of “membership” and connection to it through hiking, exploring, observing, and collecting data, along with their study of its historical

significance. Tribal community members visited the camp to share with the students the Tribe's stream restoration goals, Tribal stories, and historical events related to the creek. Students collected water-quality data in conjunction with demonstrations and discussions regarding the cause and effects of creek erosion. Using the data they had collected, students assessed the health of the creek, identified problems, and applied what they had learned to develop solutions. Students worked in teams to engineer restoration designs by building models of the creek. Teams then presented their completed stream restoration designs to members of their community (Navickis-Brasch et al., 2014).

Local energy use was the focus of at least one project in which teachers worked with students to collect and combine data in a spreadsheet to project how much electricity could be saved to both reduce costs and especially to reduce carbon dioxide released into the atmosphere by simply unplugging unused appliances in school and at home. This project, [*Middle Schoolers Out to Save the World*](#) (2013–2017) is a classroom based curriculum in which students participate in an out-of-school time program to monitor the energy used by home and school appliances and to assess standby power consumption. The project includes a year-end competition in which students collaboratively solve challenges designed by industry professionals. Using measures of dispositions toward STEM and interest in STEM careers, researchers studying outcomes of these student experiences concluded that several different kinds of hands-on STEM engagement activities are likely to foster or maintain positive STEM dispositions at the middle school level (Christensen, Knezek, & Tyler-Wood, 2015).

Breadth and depth of student roles and activities

Students took on a broad range of roles in the inquiry experiences described. In some cases, students engaged not only in experimentation and analysis but also in selecting topics for investigation and in developing research questions and designs. In some projects, students immersed themselves more deeply in the scientific process by sharing their findings with policymakers and the public, thereby drawing direct connections between their STEM inquiry and how their findings relate to people's everyday lives.

Identifying issues to study

In the [From Learning to Research](#) project described above, students in one region explored ecological features specific to their area and then pursued conversations with scientists specializing in these features before deciding which investigations to pursue (Malmberg & Maull, 2013).

Sharing findings for community impact

Students in several projects, including those that investigated urban heat islands, local tree populations, and food deserts, shared their findings with decision-makers in their communities. While some wrote letters or developed presentations, the students in the urban heat islands project ([GET City](#)) went further: they played the role of community science journalists, creating documentaries and conducting outreach to increase awareness of the

issue. The project team found that students developed a sense of agency in terms of their ability to not only understand the effect of urban heat islands but also raise others' awareness in relation to this issue (Calabrese Barton & Tan, 2010). The team also found that participants demonstrated increased interest in and awareness of STEM careers and placed greater value on science and technology for solving community problems (Calabrese Barton, Birmingham, Sato, Calabrese Barton, & Tan, 2013).

Conferences can provide another forum for dissemination of findings. In the [Learning to Research](#) project, students presented their work in a virtual student conference that brought together participants in multiple regions. In the [Environmental Science Information Technology Activities](#) project, students presented the research they had designed and conducted at student conferences.

Designing solutions based on scientific findings

In several projects, students took action based on the findings of their scientific investigations. As mentioned above, Boston-area residents who had performed an analysis of food deserts in their communities undertook hydroponic gardening. Selling their resulting produce at local farmers markets enabled participating youth to talk with market-goers about the advantages of hydroponics for urban agriculture (Mark et al., 2013; Zhang & Barnett, 2013). Similarly, in the creek restoration project, students drew on their findings to design restoration plans using clay models.



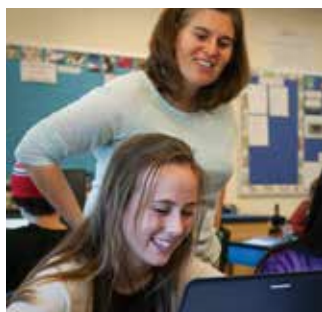
Boston-area residents who had performed an analysis of food deserts in their communities undertook hydroponic gardening.



Offering stipends for participation

Particularly in out-of-school-time programs, it can be difficult for youth to consistently participate due to inadequate transportation options and other afterschool commitments, such as part-time jobs or caring for family members. Stipends can help offset these other demands and show youth that their contributions are valued. Several projects addressed the competing demands on young people by paying them for their scientific work in the projects. In the [Paleo Exploration Project](#), a group of students were offered paid summer internships to continue with the project's fossil-mapping research. Among these interns, the project team saw outcomes similar to those of regular participants; in addition, the interns showed increased knowledge of the science inquiry process and procedures (Almquist, Estrada, Hanfling, & Stanley, 2010a). The [Urban Ecological Challenges](#) project similarly paid youth a stipend for participating in its summer program (Blustein et al., 2013).

Project teams aim to ignite not only students' but also *teachers'* excitement for inquiry experiences.



Goals for teacher participation

While some of the student experiences described above take place outside of school—during weekends or summers, or through a local community center—others are integrated into the classroom curriculum and involve classroom teachers from a range of STEM subjects. Projects that involve teachers (e.g., the [Paleo Exploration Project](#), [MapTEACH](#)) have substantial professional development components to help teachers build the

technical competence to ably facilitate such experiences (Almquist et al., 2007; Olsen et al., 2004; Stanley & Almquist, 2008; Stevens et al., 2005). Targeted outcomes for teachers in authentic inquiry projects typically overlap with those for students. Project teams aim to ignite not only students' but also *teachers'* excitement for inquiry experiences—and to enable teachers, too, to view themselves as capable of using STEM tools and practices as powerful means of effecting change or catalyzing new perspectives.

Looking ahead

ITEST projects strive to use real-world problems to highlight the value of science in shaping our everyday lives. The publications included in this summary suggest that locally relevant, authentic investigations are important for fostering interest in STEM and STEM careers. For example, the middle school students in Maine who mapped trees in their schoolyard and used GIS data to explore how their schoolyard construction impinged on the tree habitat showed a statistically significant increase in spatial awareness (Perkins et al., 2010). More research is needed to understand more thoroughly the mechanisms that connect this particular type of project design with ITEST program goals. Such research could help uncover a set of design principles for using local investigations to build interest in STEM and STEM careers and to improve learning outcomes for participating students.

Projects included in this synthesis

(listed in order of appearance):

1. [GET City](#)
(2007–2011; DRL-0737642)
2. [Urban Ecological Challenges](#)
(2009–2014; DRL-0833624)
3. [MapTEACH](#)
(2004–2008; DRL-0322958;
DRL-0322980; DRL-0323191)
4. [EcoScienceWorks](#)
(2009–2014; DRL-0525221)
5. [Urban Ecology, Information Technology, and Inquiry Science for Students and Teachers](#)
(2005–2008; DRL-0525040)
6. [Paleo Exploration Project](#)
(2006–2010; DRL-0624590)
7. [Curriculum and Community Enterprise for New York Harbor Restoration with New York City Public Schools](#)
(2014–2017; DRL-1440869)
8. [Environmental Science Information Technology Activities](#)
(2003–2006; DRL-323178)
9. [Student Enabled Network of Sensors for the Environment Using Innovative Technology](#)
(2008–2012; DRL-0833440)
10. [From Learning to Research: Developing Future Earth System Scientists and Professionals](#)
(2010–2014; DR-L0929725)
11. [Back to the Earth](#)
(2012–2016; DRL-1139657)
12. [Middle Schoolers out to Save the World](#)
(2013–2017; DRL-1312168)

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