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Landscaping Locally: Fostering Stewardship with Real Science in High School Curricula

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Abstract

The Igniting Streams of Learning in Science (ISLS) academy engages 11th and 12th grade students and their teachers in a year-long learning community (LC) experience. ISLS transforms attitudes about science in school curricula, local communities, college classrooms, and government agencies. The goals of ISLS are ambitious: 1) to increase student interest in teaching high school science, 2) to increase the number of students pursing Science, Technology, Engineering, and Math (STEM) majors in college, and 3) to connect students to their local environments using methods of scientific investigation. The ISLS Academy uses a four-part model that can be replicated. The model is centered on a twelve day summer institute: 1) pre-institute formation of seven member learning communities, 2) immersion of LC members in the summer institute where they are introduced to bio-monitoring protocols while being mentored by college professors, graduate students, and professional scientists from government agencies and private industry, 3) post-institute adaptation of protocols in the development of learning objects (LOs) (elements of a curriculum) to address local environmental issues, and 4) follow-up activities with LC members using their LOs in teaching peers and others. This paper is a mid-project report on a three-year program. It concerns fourteen school districts from urban, suburban and rural areas where students and teachers demonstrate the applicability of real science curricula across districts. By using "real science", i.e. the bio-monitoring protocols of the Ohio Environmental Protection Agency, students recognize that they themselves can use science to assess and improve the health of their local environments. The success and applicability of the ISLS program to other regions is dependent upon fostering ownership in the use of scientific protocols and methods of learning that invite all students to become citizen scientists. Results thus far indicate a high level of success in increasing student interest and understanding of science and in developing LOs that 1) are aligned with state science standards, 2) utilize current technologies already embraced by students, and 3) incorporate ecosystem approaches for addressing issues of local landscapes.

Keywords

Science education; learning communities; STEM education; biomonitoring; learning objects; action research model; wetland and stream education; wetland and stream protocols; learning technologies; citizen science

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INTRODUCTION

Recent advances in science, technology, engineering, and mathematics (STEM) throughout the world have been paralleled by a decrease in U.S. students successfully completing majors in STEM subjects. In 2008, we find ourselves looking at a nation threatened by a decline in science and innovation (National Academy of Sciences 2006) in large part because students do not want to study science. Educational research shows that students switch out of STEM majors not because they are incapable, but often because of a lack or loss of interest in science and a belief that other majors are more interesting (Seymour and Hewitt 1997). To reverse this trend, student interest in pursing STEM subjects needs to be cultivated and strengthened.

The experiential, learning-centered approach of environmental education provides an excellent platform for engaging students in learning science, in contrast to an educational norm today that de-emphasizes nature education (North American Association for Environmental Education 2000; Louv 2005). Ironically, degraded and highly modified urban environments provide excellent natural "laboratories" for engaging students in scientific studies of the environment. Degraded conditions are easy to document using standard scientific protocols. In addition, small scale changes proposed by students can often provide dramatic improvement in local environmental conditions that can be monitored by students.

The Igniting Streams of Learning in Science Academy (ISLS) grew out of this positive perspective about degraded environments. ISLS is named after the infamous burning of the Cuyahoga River in Cleveland, Ohio in 1969. The river fire sparked a revolution in scientific studies based on STEM applications that cleaned a river in record time, a clean-up that has made the Cuyahoga River an international model for river restoration (Ohio Environmental Protection Agency 2008a). In like manner, ISLS is designed from the best we know about learning in science education tailored to spark curiosity by guiding and fueling inquiry (Wieman 2007). Students learn that they can change even highly modified urban settings, by investigating, observing, formulating questions and hypotheses, making predictions designing effective ways of gathering data, interpreting results, and communicating findings. To do this, the ISLS model creates communities of investigators in local environments that transform classrooms into life-changing explorations. While using real science protocols, students become environmental stewards capable of understanding and improving their local landscapes.

Empowering students to learn using a hands-on, field-centered approach is challenging in many urban school districts. Environmental education is too often equated with off-site field trips, highly specialized teachers with environmental experience, and wasting valuable time that should be spent on instruction to pass state-wide standardized science proficiency tests. In contrast, the ISLS model: 1) incorporates standard bio-monitoring protocols that can be applied to local rural, suburban, and urban school grounds, 2) provides intensive training to teachers AND their students so that teachers can see how students learn using the model, 3) emphasizes field experiences tied to state science standards, and 4) promotes collaborative, engaged learning.

This paper provides a description of the 2007 and 2008 ISLS STEM Academies and the ongoing ISLS program. ISLS is an experiment to integrate biomonitoring protocols used by government agencies into the curriculum of high schools. The paper describes the learning theory foundation of ISLS, the steps followed, and preliminary findings with emphasis on urban environments.

THE ISLS STEM ACADEMY

Funded by the Ohio Board of Regents (OBR) the ISLS Academy is part of an initiative to improve teacher capacity in STEM subjects. The goals of ISLS and the OBR initiative are to: (1) increase student interest in teaching high school science, and (2) increase the number of students pursing STEM majors in college. Academies were instructed by the OBR to include students who normally might not consider going to college (Ohio Board of Regents 2007). ISLS has a third goal: connect students to local environments, even modified and degraded urban environments, through scientific investigation.

ISLS integrates the knowledge of ecologists, science educators, and experts in learning theory from Hiram College, Kent State University, and the University of Akron in the formation of science teams modeled on scientific investigations. ISLS team members are at various levels of expertise, from novice high school students to advanced university professors. Teams meet for an extended period, in our case over 12 months (May through April). Teams learn and modify protocols for the investigation of a problem (June through December) and communicate findings to experts and the public (December through May), modeling the process of science. Although most financial support for this project was provided by the Ohio Board of Regents, non-financial support from administrators, teachers, and students at the level of the school district has ensured the continuation of the project beyond 12 months in many districts. Earning the respect and support of individuals responsible for supporting future investigations is also a reality of doing science. Just as in professional science, the emphasis is on learning, not on teaching scientific investigation.

The paradigmatic shift from instruction to learning (Barr and Tagg 1995; Bransford et al. 2000) reflects how people learn and how the curriculum can be made relevant (Weigel 2002). The ISLS model follows Seymour Sarason's definition of learning: "Learning is not a thing. Learning is a process that occurs in an interpersonal and group context, and it is always composed of an interaction of factors . . . motivation, cognition, emotion or affect, and attitude" (Siegel 1999; Sarason 2004). Experience in education (Dewey 1938) is not a new idea but it has taken decades of studies in neuroscience and the biology of learning to understand why experiential education works. David Kolb's (1983) cycle of experiential learning (experience, reflection, processing, application) continues to gain credibility with research (Zull 2002). Taking into account students' experiences, interests, and learning styles (e.g. visual, auditory, reading and kinesthetic styles) markedly increases their attention spans (Fleming 2006). Because learning is multidimensional and dynamic, understanding how people learn is important – from mirror neurons and the importance of modeling, to the critical importance of emotion to cognition and thus to learning (LeDoux 1998).

Employing experiential learning and critical thinking within a disciplinary context is central to helping students succeed in the sciences (Kronberg and Griffin 2000). Engaging in critical thinking can increase the use and understanding of science as it fosters enthusiasm in students who engage in collaborative activities that improve their ability to learn, retain, and use information (Nelson 1994). Science teachers can provide the path for improved performance by demonstrating how reading, questioning, understanding, and writing all have discipline-based expectations that go beyond general learning skills (Nelson 1994). With this in mind, the ISLS model was constructed with four steps: community formation, commitment, ownership, and sharing.

Step 1 - Pre-Institute Formation of Learning Communities - April and May

The ISLS approach incorporates a model centered on mentoring of participants in the creation of learning communities (LCs) of five high school students, one near-peer (undergraduate), and one high school teacher supported by professional scientists, graduate students and professors (Figure 1). The LC provides the organizational structure where the best of what we know about learning (Dewey 1938; Bransford et al. 2000; Zull 2002; Wieman 2007) is put to the test as ten seven-person groups set out to learn together. Learning communities engage members in "integrative high-quality learning, collaborative knowledge construction; and skills and knowledge relevant to living in a complex, messy, diverse world" Lardner and Malnarich 2008). While LCs have increased in number and pedagogical sophistication over the last twenty years, support for learning communities dates to the 1930's. Advocates suggested that LCs were important for social and psychological growth and for curricular cohesion (Meiklejohn 1932). Taking these perspectives into account as well as the nature of scholarly communities that move science forward, we wanted to see how LCs would work with high school students and teachers. The theory and model for LCs used in ISLS is outlined at the Ohio Learning Network's Learning Communities Initiative Homepage (Ohio Learning Network 2007). By working in learning communities, students have the opportunity to identify and use their strengths while learning simultaneously from other strengths demonstrated by their LC peers. Teachers and undergraduates become peer-learners, especially in areas of technology where some high school students demonstrate extraordinary ability. The mentors of the high school students become models for learning how to use technology effectively.

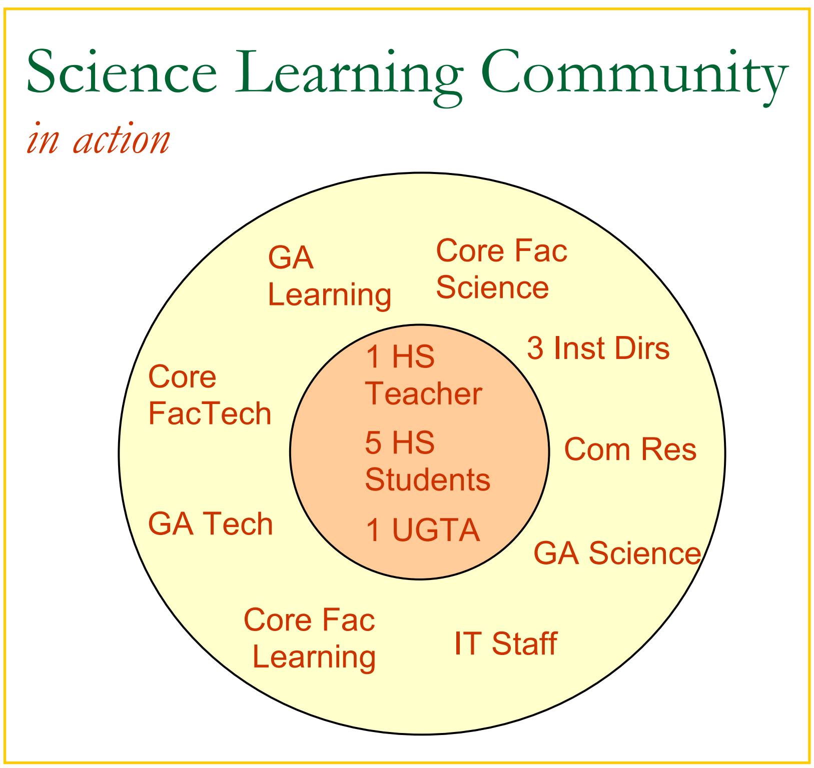

Figure 1. The Igniting Streams of Learning in Science Learning Community Model - Core participants (1 High School Teacher, 5 High School Students, 1 Undergraduate Teaching Assistant) - Supporting members from top (Core Science Faculty, 3 Institute Directors , Community Research Personnel, Graduate Assistant in Science, IT Staff, Core Learning Faculty, a Technology Graduate Assistant, Core Technology Faculty, and a Learning Graduate Assistant.

Selection of districts depends on identifying teachers who are committed to the project. An individual's willingness to embrace the LC model is more important to success than their familiarity or experience using either an LC model or bio-monitoring protocols. We found that most urban schools districts do not have these types of experiences. The LC concept is first introduced to teachers and administrators, who then select students.

Step 2 - The 12 Day Immersion Institute - Commitment to Learning – June

LCs are brought to campus and kept to a schedule of activities from 7:30 a.m. to 9:00 p.m. "Learning by doing" is the theme with activities designed to form sustainable LCs. LC members are faced with an overload of daily tasks including an introduction to Ohio Environmental Protection Agency (OEPA) and other bio-monitoring protocols. These provide the science platform for understanding aquatic resources.

The ISLS model incorporates what we know about the science of learning by providing access to the communication platforms used by today's students. Students and teachers are introduced to software programs for collection and analysis of data, presenting information, and transferring data immediately through smart phones and handheld devices. The incorporation of technology by students transforms learning from something that is not part of their daily lives to something that is central to their daily lives. Learning becomes associated with using technology. Students use handhelds and smart phones to answer questions posed by undergraduates about learning outcomes each day. Undergraduates and students explore ways to make OEPA datasheets smart phone accessible to eliminate paper forms. PowerPoint presentations demonstrating protocols are downloaded to handhelds so that material is accessible at all times.

Most schools find it difficult to keep up with technological applications, including Web 2.0, which has transformed the internet from a structure for streaming information from producers to consumers into one that provides interactive access to people and what they know (Brown and Adler 2008). In our cohort of 14 schools, for example, none had programs to integrate the technologies listed above into STEM curricula prior to participating in the ISLS STEM Academy, even though every school reported heavy use of these technologies by their students outside of the classroom. At a time when it is possible to stream information to and from students and teachers via the web at all times from any location, our traditional STEM curricula and teaching remain tied to a world view that celebrates the achievement of individuals, not the individual learning that is constructed from social interactions. Educators are beginning to realize that these same technologies are useful for social learning. We are beginning to see how understanding science comes from conversations about that content (Brown and Adler 2008). Web pages, blogs, wikis, YouTube, Flickr, and Facebook can be used to entice students to share what they have learned with others. Students use one or more of these technologies multiple times per hour to learn about the world when they are out of school and yet we bar them from using any of these technologies at all for their formal education. We need to keep pace with how students learn and how the curriculum can best be made relevant (Dewey 1938; Weigel 2002; Fink 2003). In ISLS we did this in part by using technology. Web pages, blogs, and Flickr, for example, were used to enhance the photo-documentation and description of bio-monitoring protocols learned by students throughout the institute. Using these tools, students practice communication skills while sharing what they are learning. Sharing becomes part of the learning.

Indeed, to succeed in the summer institute, LC members must share responsibilities, and often materials, using the internet. They must delegate and cooperate which leads to greater learning for individuals and for the group. A key component of the institute is mentoring by college professors, graduate students, and professional scientists from government agencies and private industry. Mentors introduce new protocols, technology, and learning theory and support LCs as they develop an idea for the final end product of the ISLS Academy, the learning object (LO). LOs are another name for class curricular or outreach materials developed by the LC. The last four days of the 12-day institute are spent brainstorming, exploring, and developing ideas for the LO. These learning outcomes are recorded along with other daily journal reflections about science, technology, and learning in the web-accessible journaling system.

Step 3 - Post Institute Summer Activities - Fostering Ownership - July and August

Following the institute, students and teachers meet to develop their LO. The challenge for each LC is to design a LO that is used in their school community. Each LC adapted the specific protocols that they judged would be most successful in their community or developed new approaches that captured the concepts of biomonitoring and promoting changes in attitudes about the environment. All LCs were asked to produce materials for posting on the web and on the ISLS Sakai learning site for others to use (Ohio Environmental Protection Agency 2008b). Examples of LOs include: 1) The BBC - Berkshire Biology Club - a Berkshire LC wetland and primary headwater habitat environmental education outreach program; 2) Kent Roosevelt High School - development of a new Environmental Science Curriculum for use in the high school designed and taught by the Kent LC; 3) Akron North - creation of a model small-scale house demonstrating green technology and ideas to showcase this model to students and members of their urban community.

By involving students in curriculum design for their STEM classes, high school students become citizen scientists designing experiments, collecting and interpreting data, and disseminating what they know to the public. Rather than relying on the traditional Instructional Paradigm (Tagg and Ewell 2007) of lecturing to students in 50-minute periods that fit into a curriculum designed by others, the ISLS model requires groups of students and teachers and their university role models to develop individualized curricula tuned to the interests of students. The students and teachers become familiar with the goals of Ohio's Model Competency-Based Science Program by aligning their curriculum with these goals. In the learning paradigm (Tagg and Ewell 2007), students reflect on what they have learned as they create LOs. They begin to question why their own educational goals and those of their peers were or were not met.

The ISLS model connects students to local landscapes by supporting students in identifying and analyzing local environmental issues that they have the ability to change. For example, in learning about Primary Headwater Habitat protocols, an LC designed an LO to assess runoff from a new high school parking lot into a constructed stream, a process that could be easily repeated for runoff in any urban space. By working together to decide the "what, when, why, and how" of analysis and the resulting implications for correcting the problems documented by the LC, students learn basic STEM goals. Students come to recognize environmental issues 'at home' that had previously escaped them. The ISLS model also goes against the trend to structure learning into daily lesson plans with definitive learning outcomes determined ahead of time without student input and therefore often without student interest.

Step 4 - Follow-up Activities for Sharing Success - September through April

Bringing the LCs together for a day-long retreat in September is essential to maintaining momentum, especially when so many school activities co-opt students' time out of the classroom. In this retreat, LCs share their ideas and progress in developing their LOs. Then, in late October or early November, two directors and the graduate assistant specialist in documentation and evaluation make site visits to the schools. In January the LCs come together for another 1-day retreat to share results of LOs and to prepare for show-casing the results of their projects at a statewide conference. In 2008, groups attended the Ohio Digital Commons for Education (ODCE) conference held in Columbus, Ohio's capital. In April, LC members wrap-up the Academy and post their materials on the project web site and on the ISLS course site. We found that a single day or half-day spaced over a period of months is effective in sustaining LCs if all have a shared goal. In our case, the development of LOs for the ODCE conference provided a strong incentive. The educational value of the LC-developed LOs was affirmed by experts in learning, educational technology, and science attending the ODCE conference and in presentations in local communities. This affirmation helped students to realize their accomplishment (Figure 2).

Figure 2. Crestwood High School Students Kristen Egan, Hannah Orr and Evan Jarvi discussing their Learning Community designed Wetlands Learning Object with Chancellor Eric Fingerhut of the Ohio Board of Regents at the Ohio Digital Commons for Education March 2008.

ASSESSMENT AS AN EDUCATIONAL TOOL TO ENHANCE LEARNING

The ISLS Academy uses an Action Research (AR) model. AR is a dynamic, heuristic, and cyclical process created to involve the people who would be served by a change in the construction and implementation of that change (Lewin 1948). The cyclical process involves acting, observing, and reflecting on actions and their consequences and continuing the cycle, either changing the action or continuing on in the same direction. In short, AR is learning from mindful experience. While AR can be conducted by an individual who can choose to involve others as the research evolves, AR can also be a collaborative process where everyone becomes a researcher (Holly et al. 2009). One might think of AR as a process of *exaptation*, a word coined by the late Harvard scientist Stephen Jay Gould, to denote the creative process of taking something previously formed and using it in a new way (Gould and Vrba 1982). In ISLS, for example smart phones or handhelds can be used for recording data from stream monitoring. Participants also blue tooth journal entries to a central location, uses quite beyond those initially envisioned by teachers and high school students. The ISLS model is grounded by an experiential AR framework that evolves with the learning of the participants. The groups, times and methods of assessment used in ISLS 2007 demonstrate action research form of assessment and are summarized in Table 1.

With an AR approach to the ISLS Academy, heuristic assessment is built into every aspect of the model: in journals, photographs, focus groups, stream monitoring, creature and habitat identification, lab analysis, website and LO construction, presentation development, conversations among and between all members including field scientists and staff. In conversations at mealtime and in evening activities, one might be surprised to hear the "ah-ha" moments that arrive unannounced as people play table tennis or lift weights. From work at the Hiram College Field Station to LC members' foray into Cleveland and an urban entry into Lake Erie; from canoeing down the Cuyahoga River, or cookout with bonfire -- each activity is documented and becomes part of the evolving data base and story of ISLS. Capturing action for later reflection and for making connections is the challenge of AR and the learning paradigm; multiple and evolving methods are needed.

When	Method Used	Who
Pre institute Post institute Site visits Concluding session	Surveys	S,T,N,G,F,D
First and last day institute	Crest and tag lines	S,T,N
Daily during institute	Journals	S,T,D
Throughout academy	Pictures, videos	S,T,N,G,F,D
Daily during institute	Discussions	S,T,N,G,F,D,P
Throughout institute Site visits	Focus groups	S,T,N,G,D,A
Throughout institute At ODCE Local events	Presentations	S,T,N,G,F,D,A
Post institute	Case studies	T,G,D
During and after institute	Web sites	S,T,N
Summer institute to end	Learning objects	S,T,N,G,D
Throughout academy	Informal interviews	T,S,F,N,G,D
Throughout institute	18 science content metrics	S

Table 1. Methods of assessment and evaluation of learning including when methods involved different members of the ISLS Academy (Abbreviations: A= School Admin/Staff; D= Directors; F= Faculty; G= Graduate Assistants; N= Near Peer Mentors; P= Professional Scientists; S= High School Students; T= Teachers

To capture snapshots, including attitudes, observations, and reflections about doing science, we rely on journals as an action research tool. The journal serves as a memory bank and an evolving database that can be useful for all ISLS members regardless of role. Time is built into each day to "blue tooth" questions to students and to receive their responses. Responses often necessitate critical reflection; responses also provide a window into students' and teachers' perspectives. The journal is a place to keep ideas alive and growing and to assess understanding.

In 2007 and 2008 we assessed student achievement using eighteen separate metrics aligned to learning objectives. These metrics assessed student achievement and performance matched to the Ohio 11th and 12th grade science standards. Different metrics were used each year following the AR approach. Metrics for calculating grades included performance on completing protocols successfully, accurate data sheet entry, correct calculations on spreadsheets, presentations, assessments of written reports, on-line tests and quizzes, data sets, written reflections in daily journals, and contribution to the learning community as judged by near-peer mentors and teachers. The metrics used in 2007 were modified in 2008 to improve our understanding of student performance. We also assessed student attitudes about the effectiveness of the metrics through on-line journal questions. Metrics assessed real world skills that are used in scientific work outside of the STEM Academy. Emphasis was placed on group analysis and presentation of data in addition to the assessment of learning by individuals. The 18 metrics also took into account different learning styles with some assessments geared toward visual learners, others toward auditory learners, others towards those learners who like to read and others to kinesthetic learners. The metrics change to improve our understanding of learning.

Matching results on the science performance metrics with journal entries provides links between how students perform with their attitudes about learning associated with those tasks. Teacher interpretation of the links between student attitudes about science and student performance in doing science provides a critical action research tool for understanding how attitudes about science can affect performance in achieving proficiency in science subjects. Case studies are written at the end of the 12-day institute by each teacher. The case study provides a reflection on the learning by each LC member, a portrait of the LC, and a portrait of the teacher's own experience over the 12 days. The case study is a critical action research tool for capturing attitudes about learning and the environment, especially for urban students who had never been exposed to collecting data in the field. Multiple data sources provide plenty of snapshots – some literally – for constructing what happens to the LC and its members over time. These narratives, which often include pictures, are a way for us to learn far more about the LC members than we could without the perspective of the teacher who is an integral part of the LC. Preparing the case study is an integrative and reflective process of synthesizing, analyzing, portraying, and developing a critical perspective. The case studies are a tool for developing minds that watch themselves and others – enabling new depths of understanding. Case studies in ISLS are methodological tools that enhance the writer’s focus on learning and science.

CONCLUSION: LESSONS FROM THE IGNITING STREAMS OF LEARNING MODEL

Preliminary Findings

The ISLS approach to learning supports reforming science education from the bottom up: students and teachers learn more about science when provided the scaffolding for building their own curriculum using their own local environments as laboratories. Evidence from our first two years of data provides overwhelming support for this approach:

1) Student attitudes about doing, understanding, and communicating science can be dramatically transformed in 12 days as demonstrated by performance on group and individual assessments linked to analysis of journal entries.
2) Encouraging use of smart phones and handheld computers for learning can enhance student interest in doing science and improve the understanding of educators about student attitudes of doing science as seen in teacher comments in the case studies and by the analysis of student responses to questions written on paper versus those "texted" by them and downloaded over the internet.
3) Engaging students in developing their own learning objects can be effective in keeping students involved in teaching and learning activities as seen by their participation for at least ten months beyond the time when they received credit and a small stipend for their work.
4) Mentoring of students, teachers, and undergraduates in learning communities is effective in promoting individual achievement by high school learners as indicated through high scores using multiple modes of assessment.

5) Empowering students to learn in groups can increase their self-confidence and ability to communicate complex findings from scientific investigations as indicated through teacher responses on case studies, student responses on hand-written and electronic journal entries throughout the 12 months of the Academy, and by public presentations where students engage in conversations with experts on subjects ranging from environmental protocols and results to learning theory, technology, and teaching.

Challenges

Time and scheduling of classes poses challenges as the LCs go back into the school schedule. Time for meetings with all LC members is difficult to find, and 50-minute class periods leave little room for longer meetings with after-school schedules that include extra-curricular activities for some students and work for others.

The current education system values time spent on assessment often at the expense of time spent on learning by students. Because the assessment of curiosity and questioning is difficult, these essential steps are often eliminated from student laboratory and field programs. The ISLS program forces students to come up with the questions that students will investigate. This takes time, time that is not normally available in class. While the ISLS institute is a protected time (not leaving the institute or having visitors for 12 days), once the institute has concluded, the world rushes in. Although we address this during the institute, plans are often more difficult to actualize after the larger LC setting is concluded.

Paths and Obstacles to Sustainability

With competing priorities, the cultural shift from instruction to learning takes a longer term effort than even an intensive 12-day institute. The ISLS model addresses the central problems of engaging students in STEM subjects by inviting them to be partners in developing STEM LOs designed to improve their local landscapes. The intensive nature of ISLS, the expense of the intensive institute and the time commitment of teachers all pose challenges for the future.

Individual components of the program, however, can be adopted individually in any high school STEM classroom. Experiential learning can be the guiding principle for all STEM experiences. Mentoring can enhance critical thinking. Teachers can form learning communities to promote individual and group learning. Learning objects developed by students can promote ownership of learning. Local landscapes can be used as living laboratories to make learning relevant. Technology can connect learning to today's students. Simple STEM reform can begin by implementing just one.

What is the next priority for the ISLS program? We plan to develop simple STEM-derived bio-monitoring protocols specifically for urban landscapes where students and teachers in our most isolated urban settings can see for themselves that their work can improve their local environments and the larger world. For urban students, the changes we report may be especially important in fostering a desire to continue STEM education beyond high school. By surrendering one-sided control of science education and sharing our aspirations as well as our resources with students, they, too, understand the joy that comes from finding things out about the world. They become increasingly curious, and are driven to seek the result of their own investigation. We believe along with Louv (2005) that citizen scientists learn more from acting on their environments than from listening or reading about the environment trapped inside their classrooms and textbooks.

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