Screens-to-Nature: Opening Doors to Traditional Knowledge and Hands-on Science Education[1]

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Abstract

Science teachers continuously struggle to develop hands-on, stimulating pedagogical tools that capture the enthusiasm of their students, while simultaneously grappling with issues of cost-effectiveness and relevance to real-world situations. These constraints are particularly pronounced when educating indigenous students, who navigate daily between traditional and Western knowledge systems. An innovative "Screens-to-Nature" (STN) system, a portfolio of field-deployable bioassays and practical training, offers a well-designed alternative approach to transdisciplinary education, by immersing students in a guided approach to bioexploratory research. The STN bioassays simply and expediently give students the tools to detect bioactive, health-protecting properties present in local, indigenous plant materials, microbes, and fungi. The tests are reliable, accurate, low-cost, and relevant for multiple scientific disciplines. Students are transformed from observers into active researchers, able to observe and record their own uncharted scientific discoveries. Because the STN system can be implemented on traditionally-important medicinal herbs and foods, links between indigenous knowledge and Western science, as well as youth-to-elder communications, are fostered. Case studies from multiple global locations have provided positive insights as to how the STN system can stimulate the science education experience and provoke expanded science discovery.

Challenges for Science Educators

Teachers have voiced an increasing struggle to sustain students' attention and interest in science courses. Introductory science courses such as those found in high school and undergraduate curricula are challenged to motivate students for several reasons: they are usually 'required' rather than elective courses, class sizes can be large, and students tend to have negative preconceptions of science classes (Kern and Carpenter, 1984; Lila and Rogers, 1998). Students frequently criticize the impersonal lecture style in these courses, which discourages interaction between the students and professor (Seymour and Hewitt, 1997). Often there is a perceived disconnect between the material being taught in class and the

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'real-world,' further isolating students from learning (Bransford et al., 1999). This decline in student attitude has an impact on the retention and application of knowledge transferred in class (Henderleiter and Pringle, 1999), as students are only motivated to spend time to learn and to analyze problems they find interesting (Bransford et al., 1999). These results are all the more disturbing for university level courses, as the undergraduate years have been found to be a "filter point" in mathematics, science, and engineering classes, a critical time when negative experiences in classes can lead students to alter their career paths (Seymour and Hewitt, 1997).

As an added complication, the rapid advances of science that have occurred in the latter half of the 20th century have resulted in an eruption of interest in interdisciplinary research. Both life and physical sciences are becoming more dependent on each other (NRC 2003), and this intermingling of disciplinary tools is essential to identifying and understanding the mechanisms of the most pressing problems of the day (Jacobson and Robinson, 1990). The marked shift in real world research requirements necessitates a parallel shift in teaching strategy in order to ensure future scientists and members of society are able to participate in a broader, collective scientific discovery process (Godwin and Davis, 2005). While a transdisciplinary research approach is essential to progressive scientific discovery, individual disciplines have tended to move in the opposite direction, increasingly emphasizing the value of specialization, and developing very different philosophical outlooks and underlying paradigms (Jacobson and Robinson, 1990). Thus, modern teachers face a plethora of hazards and obstacles when they attempt to develop educational programs that reflect the current and future trends of scientific discovery.

If this is true for science students in industrialized countries, the situation is even more challenging for students from indigenous communities and from developing countries, as Western science concepts have frequently been imposed on top of indigenous knowledge systems during colonialism. Classroom globalization has precipitated a considerable increase in diversity of students in the classroom (Carter, 2008; Quigley, 2009). For example, a single classroom in Africa might contain both foreign exchange students and indigenous learners, or urban students mixing with students from rural areas, creating a learning environment comprised of multiple background and experience levels. Thus, educators have to recognize and adapt to the diversity of knowledge systems represented within one class. However, not enough attention has been paid to the complexity of indigenous students' learning methods, and the cultural conflicts that confront students between home and the classroom (Carter, 2008; Le Grange, 2007; Lee, 2001). Most formal science teaching is primarily based on Western science concepts, which have been accorded a superior position over indigenous knowledge systems (IKS) and thus tend to marginalize IKS' importance and contribution to science education (Maurial, 1999; Ntuli, 2002; Odora-Hoppers, 2002). The tension between the two knowledge systems alienates students both at home, contributing to the disappearance of IKS, and at school, resulting in underperformance in science education.

While laboratory sessions are usually an integral part of science courses, many curricula tend to take a pedantic approach involving 'cook-book' lists of tasks for students to follow ritualistically. Students are not engaged in thinking about the larger purposes of their investigation and of the sequence of tasks they need to pursue to achieve those ends (Hofstein and Lunetta, 2004). Classic laboratory experiments provide a great deal of control and reproducibility (Diamond, 1986), but can be reduced to a mechanistic abstraction, in stark contrast with everyday environments where contextual reasoning is often required. By limiting the hands-on education experience only to classic laboratory exercises, students are given little chance to translate their knowledge into real world situations (Resnick, 1987), which is central to indigenous knowledge systems. Though there has been a resurgence in the debate about the necessity to integrate IKS into science education (de Beer and Whitlock, 2009), there remain many unresolved questions - including resources, perceptions, policies, and indigenous rights – how IKS can find an equitable place in science teaching.

In this manuscript, an innovative "Screens-to-Nature" (STN) system is introduced as a conduit to direct, participatory science instruction, with the added advantage that students are able to make novel, undocumented discoveries with real-world applicability using resources that have cultural significance. The STN system, described below, centers around a core set of themes: bioexploration and its applications to plant biology, human health, biodiversity conservation, community frameworks, traditional ecological knowledge (TEK), and traditional medicine. Three case studies are provided from educational experiences in Africa, South America, and North America to illustrate how the STN system can help students to mediate between indigenous knowledge systems and science education.

Global Institute for BioExploration

Millions of people in developing countries die each year from infectious and chronic diseases. Unfortunately, the modern pharmaceutical industry has not focused on addressing the medical needs of developing countries, and available drugs are often costly and ineffective. The current drug development paradigm favors developed countries, and relies heavily on expensive, instrumentation-intensive proprietary technologies and patent protection to bring lucrative drugs to the market. This paradigm is rarely questioned, even for infectious tropical diseases not well served by it. In 2003, Rutgers University, in collaboration with University of Illinois in Urbana- Champaign, founded the Global Institute for BioExploration (GIBEX, see http://www.gibex.org) with a mission to enable and empower scientists from the developing world to carry out their own therapeutic lead discovery and to promote sustainable exploration of local biodiversity for products related to human health. North Carolina State University became part of the GIBEX team in 2008. GIBEX's approach to biodiscovery is based on a "Reversing the Flow" principle intended to bring simple pharmacological assays into developing countries, instead of removing biological materials from these countries to feed pharmaceutical discovery engines in developed countries. GIBEX works with universities and other research institutions in developing countries to equip local scientists and students with innovative, cost-effective, and portable pharmaceutical-discovery assays that can be directly deployed into forests, savannas, deserts, meadows, and marshes. Often, traditional knowledge can be used to zero-in on promising target endemic plants, useful for specific disease conditions. Seventeen developing countries have joined the GIBEX community since 2003, demonstrating a success of its mission. It is not surprising that, in contrast to conventional bioprospecting, GIBEX activities are enthusiastically and consistently supported by local universities, governments, and community leaders.

The STN System

The central premise of the "Reversing the Flow" approach is the Screens-to-Nature" (STN) system, developed through collaborations between Rutgers University, North Carolina State University (NCSU), and the University of Illinois (UI). STN is comprised of a portfolio of field-deployable bioassays that allow students to explore the bioactivity, and potential human health ramifications, of natural plant extracts, while mastering basic biological and chemical principles. Currently, a score of individual STN assays have been designed to investigate the pharmaceutically-relevant activity of natural plant chemicals (such as biologically-active plant alkaloids, or anthocyanin pigments and related flavonoids) for human health protection. Relevant health targets include chronic and infectious disease agents (parasitic worms, protozoan pathogens, fungi, and bacteria), metabolic disorders (diabetes and obesity), and general health protection (via the antioxidant potential or anti-inflammatory properties of phytochemical constituents). The STN system engages students in 1) plant identification and field collections, 2) study of traditional, historic natural product use and ethnobotany, 3) vouchering and archiving, 4) computer-based data entry 5) extraction tactics, and 6) screening plant samples using biologically-relevant bioassays based on recognized, diagnostic chemical reactions or responses. All STN bioassays have been lab-validated, and are presented in tandem with a comprehensive field training manual which explains the set up, execution, and significance of each bioassay in the kit.

Illustration of an STN Assay

Bacterial infections, including Escherichia coli, cholera, typhoid, bacterial pneumonia, and campylobacter, are serious health hazards worldwide. The World Health Organization estimates that bacterial-related diarrhoeal diseases account for approximately 2,000,000 deaths per year, making bacteria one of the largest causes of infectious disease deaths worldwide (World Health Organization, 2009). One pertinent bioassay in the STN portfolio uses non-parasitic bacteria found in saliva samples as a simple model organism to gauge bacterial lethality when exposed to a plant's bioactive extracts. The oral bacteria, while non-lethal, provide a good indicator to screen for natural extracts that would be lethal to more infectious agents, and would therefore provide potential cures for diseases caused by bacteria.

The antibacterial STN assay process begins in the field, where students identify and collect plants in the wild. Both traditional ecological/medical knowledge (provided by elders and traditional healers) and/or ethnobotanical reference books can be used to zero in on prospective candidate plant species which might have efficacy in this bioassay. Each plant's location is recorded (using a portable GPS unit) and two small samples are taken: one for extraction and one for positive taxonomic identification and retention as a herbarium specimen. An extract can be prepared from any and all parts of the plant that may have medicinal value, including the leaves, bark, fruit, roots, or inflorescences. Extraction may be done in ways that mimic a traditional method of preparation (e.g. a poultice, tea infusion, or masticant), or pulverized in alcohol, a laboratory standard that extracts multiple compounds from the plant and creates a stable extract. Depending on the availability of candidate samples and the time allotted, several different plant extracts can be screened in a single assay run. The assay includes positive and negative controls. Extracts are used within 24-48 hours because the active principles may be sensitive to degradation.

The non-pathogenic bacteria are cultivated quickly on readily-available media (LB agar). The screening procedure involves plating a small sample of diluted saliva into each well of a 48-well plate (an easy way for an individual student to create a uniform inoculum), after which the plant extract is added to the culture. The plates are allowed to incubate overnight, and are then observed, ranked on a scale of 0 (bacteria cover the entire well surface, no antibacterial activity after treatment with the plant extract) to 3 (no noticeable growth of bacteria after treatment). Data, generated in duplicate assays, on the effectiveness of each plant extract is recorded in a computer-based database. Student teams are subsequently provided with potential strategies for further evaluation of plant extract bioactive potential, through laboratory-based bioassays, if warranted.

Other bioassays in the STN portfolio specifically evaluate the ability of plant extracts to regulate blood sugar levels in diabetic patients (by inhibiting key human enzymes that degrade starches into sugar), to inhibit microbial and parasitic infections (by inhibiting fungal or roundworm growth), to bolster immunity (through antioxidant action), or to inhibit viral infections (by breaking down proteins involved in viral replication), for example.

Advantages of the STN System as an Educational Tool

The assays that make up the STN system are designed to be simple and efficient, using a rigorously-tested, guided step-by-step approach to each experiment. In-field work is kept manageable by pre-measuring all main reagents to ensure reproducibility and standardization of the results. The tests rely upon visual indicators to qualitatively determine the bioactive potency (or, alternatively, the inactivity) of each extract. For example, viability, after exposure to a plant extract, of a model organism like a nematode is gauged by visually evaluating movement and appearance under magnification; in other cases, colorimetric chemical reactions mark the efficiency of the plant components to inhibit critical enzymes or disease pathogens. These design elements ensure that a broad spectrum of students can be engaged in the laboratory exercise, even when they lack previous laboratory experience. The bioassays are functional on a miniature scale, requiring as little as two grams of material for analysis and utilizing multi-well plates to increase efficiency, minimize costs, and allow multiple samples to be evaluated in a reasonable time frame.

The materials required for the extraction of plants and the set up and implementation of assays are generally inexpensive and readily-available, such as oatmeal and yeast used as growing media for worms or common agar and saliva to generate bacteria in the assay described above. Solvents used for bioassays are non-toxic, affordable, and easily accessible on a global scale. Students are engaged in a hands-on discovery process from the beginning to the conclusion of each STN experiment, actively collecting, extracting, assaying, and analyzing medicinal plants. Through directed study, students are introduced to modern research techniques such as pipetting, use of positive and negative controls, replication of experiments, preparing and using growth media, and analysis of experimental results. The hands-on attributes of the STN place the student in direct control of the research discovery process, conducting tests that, while based on previous research with plant extracts, have no predetermined outcome. Many of the candidate plants can be expected to demonstrate biological activity in some screens. Moreover, STN bioassays create a richer, more complete educational experience than the didactic exercises of many conventional labs by combining two differing styles of experimentation: the rigor and reproducibility of bench-top laboratory experiments and the larger context and applicability of fieldwork (Diamond, 1986).

The multi-disciplinary approach to the STN system blends several fields of science into a single educational experience, including such diverse topics as biochemistry, plant biology, organic chemistry, ecology, ethnoecology, indigenous knowledge, medicine, and human health. This web of interrelated science leads the students beyond the results to formulate more complicated questions and explorations, facilitating critical thinking and discussion from a single bioexploration lab experiment. The incorporation of fieldwork with the laboratory assays places the STN results in a real-world context, incorporating scientific theory into a contextual environment that is relevant and applicable to the students' life. This inquiry-based approach is essential for implementing state and federal science curriculum standards (Llewellyn, 2002; National Research Council, 1996).

Case Studies

To date, Rutgers, NCSU, and UI faculty and graduate students have conducted seven training courses over the past three years, with participating communities in Africa, South America, and the United States. In each case, the bioexploratory research experiences have proven to be invaluable learning tools for both educators and students.

Case Study 1 - Africa

Training sessions in Africa were conducted in Botswana (supported by GIBEX and the University of Botswana) and South Africa (supported by GIBEX and a grant from the Key International Science Capacity (KISC) initiative of the South African National Research Foundation), in Kenya (supported by GIBEX and the University of Nairobi, with the additional participation of students from Makerere University, Uganda) and in Tanzania (supported by GIBEX and a grant from the National Collegiate Inventors and Innovators Alliance, NCIIA). Local university professors, students, technicians, traditional healers, and local community members all participated in the training workshops. Each group entered into the workshop with different preconceived ideas as to how plant-based medicinal knowledge could be utilized effectively. Traditional medicine accounts for 80% of health care administered in Africa, 90% of which is plant-based (Kasilo et al., 2005). Traditional healers, confident in their remedies, were initially skeptical as to how science could add to their considerable practical knowledge, while, conversely, some participants from the university questioned the benefits of utilizing the TEK of local communities as the basis of investigative research.

The STN approach provided an excellent means to familiarize African students with science methods and to encourage receptivity of local people to the potential benefits of science-based examination of indigenous wild species. Despite their initial opinions, both healers and university members grew to acknowledge the strengths of a system combining STN assays with traditional knowledge. In Botswana, for example, community members and traditional healers taking part in the workshops voiced renewed pride as the results of the STN assays substantiated the traditional knowledge. All participants indicated that their experience with the STN assays increased their motivation to learn more about plant active chemistry and bioactivity, to conserve traditional knowledge, and to seek higher cooperation between traditional and modern healers. Levels of participation and interest grew substantially, and by the end of the seminar, many local people were bringing extra plants from their own backyards to be tested, merely curious to see if they "worked."

Following the on-site training in Gabarone, the STN assays were introduced to students in a cell biology class at the University of Botswana (led by Dr. K. Marobela). Predominantly second-year medical students performed STN assays in the laboratory to determine the antibacterial, anti-parasitic, and enzyme-inhibitory activities of traditional plants. Two special lectures accompanied the STN laboratory module, covering drug discovery methodologies, natural products, and how to interpret and draw appropriate conclusions from the STN assays. Following the laboratory sessions, students (n=164) were surveyed to ascertain their perspectives of the impact of STN on classroom education. Eighty-one percent of students (n=133) completed the questionnaire, and responses were categorized to analyze the contribution of STN assays to student understanding, and interest level in medicinal plants and indigenous knowledge systems, as well as the suitability of utilizing STN to aid in integrating IKS into university science education.

Nearly three quarters of students (74%) responded that the STN system was beneficial in aiding their understanding of medicine-related scientific disciplines (Figure 1). The students felt that using the STN system in an educational setting gave them insights into the methodology of drug research and development, and how plants can be an important source of drugs (Table 1). As one student explained, "It has given me a clearer understanding how to tackle a problem through scientific methods. It has given me a greater appreciation for research in the field and how this can be used to solve health problems."

Using traditional medicinal plants as the foundation of the STN laboratories translated into an increased motivation to learn and research medicinal plants in 125 students (82%). Nearly 20% of the students felt engaged in exploring the link between indigenous knowledge and medicinal applications; 12% stated that the results made them rethink the value of IKS, while an additional 5% expressed excitement in the possibilities that IKS can provide solutions in investigating "everyday life issues" (Table 1). This is reflected in the student comments: "STN helped me to belief (sic) in many things I used to doubt in relation to traditional knowledge;" "It has shown me the concrete aspects of what I have believed all along that traditional knowledge can be coupled to modern technology for better and more efficient results." Virtually every student surveyed (94%) agreed that the STN system is a useful tool to bridge the gap between indigenous knowledge and biomedical science education.

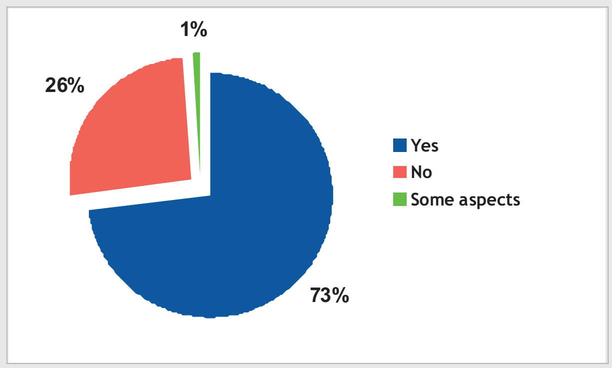

Figure 1. Student responses to "Has 'screens-to nature' (STN) plant testing contributed to your ability to understand aspects of science better?"

Table 1. Leading Responses of Students to Benefits of STN System in Science Education

Survey Response	% Student Response (n=84)
Plants have effects and can potentially contribute to human health	37
Insights into research/drug discovery/drug development	33
Insights into pharmacology/biochemistry/cell biology/medicine	13
Rethink the value of indigenous knowledge	12
Science can be combined with indigenous knowledge and everyday life issues	5

Case Study 2 – Ecuador

Ecuador was the initial test site for implementation of STN in South America (funded by GIBEX, and a targeted seed grant from the College of ACES, ACES Global Connect, University of Illinois, in support of joint projects in bioexploration). The project in Ecuador enjoyed a great degree of synergy by engaging government (Ministry of Environment), non-governmental organizations (NGOs), the University of San Francisco Quito (USFQ), and local ecotourism guides. The course was conducted in the Maquipucuna Foundation's ecological reserve north of Quito and incorporated two groups of students; one comprised of students and professors from USFQ and one made up of local guides, farmers, and park rangers.

The cloud forest environment provided the project in Ecuador the ability to explore a region with very high biodiversity; the guides identified over a dozen plants with medicinal properties within the first half-mile of hiking. The STN system provided an excellent method for engaging students who had no scientific background (Figure 1). Combining a detailed manual with lectures in a guided lab approach empowered the students in their own learning experience, allowing them to independently carry out assays. One Ecuadorian educator remarked, "A brilliant project, very well done for being clear and simple … so that people without any scientific background can do it without [the training instructors]." Another elaborated that, by using the STN assays, "[the guides] realized they were capable to do some research … the assays and demonstrations … and visual aids and hands-on really helped re-enforce the assay."

Figure 2. In Ecuador, author Dr. Gili Joseph works with local guides on pipetting technique while screening plants for roundworm lethality.

Case Study 3 – North America

Finally, the STN system has been conducted with American Indian/Alaska Native partners in both Alaska (supported through the EPA STAR program, National Center for Environmental Research) and in North Dakota (funded through the USDA Tribal Colleges Research Grants Program). High school and elementary school teachers and students, and local residents from three distinct Alaska Native villages – Point Hope, Seldovia, and Akutan – participated, with additional involvement from the Alaska Native Tribal Health Consortium. United Tribes Technical College (UTTC) in Bismarck, North Dakota served as the hub for the STN training with participants from five tribes in the Dakotas. In these teaching sessions, both tribal elders and youth were engaged simultaneously in learning and applying the STN assay system to locally-important subsistence foods and indigenous herbs.

By linking elders, youth, and other community members in the laboratory exercises, the STN approach successfully integrated the traditional knowledge and modern scientific practices into a cohesive educational experience. In the Alaska cases, prior to working with STN materials, students conducted interviews with elders and other adults to gather local information on the use and importance of berries and other subsistence foods in the community past and present. Interaction between elders and younger community members generated enthusiasm for passing along traditions to the next generation, potentially helping to mitigate a trend in Native American tribes in which successive generations rapidly lose their traditional culture and knowledge (Tsuji, 1996). Elders in North Dakota led the plant collection and identification fieldwork, sharing their knowledge about the plants' medicinal value and place in local tribal culture with the students. The students had the opportunity to utilize the STN assay system to develop scientific support for their elders' traditional health claims for the plants. The students responded positively to this interdisciplinary scientific approach, saying the best parts of the project were "learning about traditional plants and the different uses for them," and "learn[ing] the properties of the [plants]." The STN bioassay kits were used by community teachers for follow-up investigations in the field with the same and different classes, which helped to reinforce the system and its integration into the curriculum.

Summary

Active student participation in science courses can greatly enhance the connection between the laboratory environment and the real world. Active learning scenarios enable instructors to substantially impact the attitude and interest of the students, and thus enhance their retention of material. The goal of these multidisciplinary laboratories is to heighten student engagement with the scientific material, translating into a feeling of "excitement" by the students. This is the single largest factor in improving student attitude towards labs (Basey et al., 2008), as well as towards science (Freedman, 1997). Students report higher feelings of confidence, interest, and enjoyment with the laboratory when they are participants (Henderleiter and Pringle, 1999; Kern and Carpenter, 1984). The advantages of applicable, hands-on laboratories go beyond a higher enjoyment of the subject matter; they are more effective in transmitting information to the students (Freedman, 1997), and catalyze significant improvement in student achievement on test scores compared to a standard laboratory (Rissing and Cogan, 2009).

Using the STN system, teachers engage students by adding real-world context to the labs. Using a multidisciplinary, interactive approach, the STN assays expand scientific skills and concepts into directed field experiments that activate student attention and interest. Utilizing local indigenous wild plant species as the subjects for experimentation, including traditional extraction methods, and possibly relying on the expertise of engaged local healers or villagers to facilitate field collections infuses educational labs with a cultural context.

STN assay results invariably reinforce traditional medicinal uses for local plants, and provide an entrée for instructors to incorporate tribal histories and cultural practices into the classroom and field instruction. This context helps students realize the relevance of science principles (Medina-Jerez, 2008), and bridges the gap between the classroom and the real world (Anagnopoulos, 2006). The STN system is particularly relevant to indigenous students, as it mediates between their bifurcated knowledge systems (the Western-oriented classroom curriculum and indigenous knowledge at home), and efficaciously bolsters performance and decreases alienation from the learning process. Concepts of cross-over between science and culture have received greater attention in recent years, with several states incorporating the idea that cultural observations and traditional knowledge can play a part in scientific investigation and discovery into their educational rubrics and standards (AKDEED, 2009; NDDPI, 2006).

The STN approach has the potential to provide substantial benefits to students and school programs as compared to traditional lab exercises. The STN assays are inexpensive, readily deployable to the field or class laboratory, and implement modern laboratory techniques while encouraging a synergistic relationship with the traditional culture and knowledge of the students. Students have found this to be a great learning experience, saying, "I learn best when I get involved with hands on learning." "The screens were totally ingenious, sensible, and useful … [providing a] strong connection between local guides' knowledge and scientific tests," asserted another participant. In perhaps the best demonstration of the effectiveness of the STN system and its ability to engage students in science, two students from the Ecuador training course have initiated post-graduate research at the University of Illinois and Rutgers University, based upon traditional plants examined in the initial STN screening. Teachers have found it a useful resource, saying it provides, "so many great ideas for my classes," and, as one college instructor commented at the end of a STN workshop session, "I am excited to go further."

The positive feedback obtained by students, local school educators, and administrators during each of the previous Screens-to-Nature training sessions, and the post-instructional survey results from Botswana all highlight the potential of the assays to enhance secondary and university science, technology, engineering, and mathematics education. In order to more completely evaluate the effects that a hands-on curriculum utilizing the Screens-to-Nature system would have on student education, additional detailed analysis is essential. We are currently pursuing opportunities to conduct full-scale educational analysis of STN system to evaluate its impact in a teaching environment, including a control student group (tutored using traditional classroom laboratories), as well as methodical pre- and post-course analysis for both the test and control classes. This anticipated analysis will determine the statistical significance of the training on student performance or outlook as a result of a biodiscovery-based educational experience, as well as the potential for STN experiences to encourage post-secondary educational pursuits in science.

Literature Cited

Alaska Department of Education and Early Development. 2009. Alaska content standards, http://www.eed.state.ak.us/contentstandards/Science.html. Accessed: April 26, 2009.

Anagnopoulos, C. 2006. Lakota undergraduates as partners in aging research in American Indian communities. Educational Gerontology 32: 517-525.

Basey, J., L. Sackett, and N. Robinson. 2008. Optimal science lab design: Impacts of various components of lab design on students' attitudes toward lab. International Journal for the Scholarship of Teaching and Learning 2(1): 1-15.

Bransford, J., A.L. Brown, and R.R. Cocking. 1999. How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press.

Carter, L. 2008. Sociocultural influences on science education: Innovation for contemporary times. Science Education 92(1): 165-181.de Beer, J. and E. Whitlock. 2009. Indigenous knowledge in the life sciences classroom: Put on your de Bono hats. The American Biology Teacher 71(4): 209-216.

Diamond, J. 1986. Overview: Laboratory experiments, field experiments, and natural experiments. In J. Diamond and T.J. Case (eds.). Community Ecology. New York: Harper & Row.

Freedman, M.P. 1997. Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. Journal of Research in Science Teaching 34(4): 343-357.

Godwin, H.A. and B.L. Davis. 2005. Teaching undergraduates at the interface of chemistry and biology: Challenges and opportunities. Nature Chemical Biology 1(4): 176-179.

Henderleiter, J. and D.L. Pringle. 1999. Effects of context-based laboratory experiments on attitudes of analytical chemistry students. Journal of Chemical Education 76(1): 100-106.

Hofstein, A. and V.N. Lunetta. 2004. The laboratory in science education: Foundations for the 21st century. Science Education 88: 28-54.

Jacobson, S.K. and J.G. Robinson. 1990. Training the new conservationist: Cross-disciplinary education in the 1990s. Environmental Conservation 17(4): 319-327.

Kasilo, O.M.J., E. Soumbey-Alley, C. Wambebe, and R. Chatora. 2005. Regional Overview: African Region. In G. Bodeker, C.K. Ong, C. Grundy, G. Burford, and K. Shein (eds.). WHO Global Atlas of Traditional, Complementary, and Alternative Medicine. Kobe, Japan: World Health Organization.

Kern, E.L. and J.R. Carpenter. 1984. Enhancement of student values, interests, and attitudes in earth science through a field-oriented approach. Journal of Geological Education 32: 299-305.

Le Grange, L. 2007. Integrating Western and indigenous knowledge systems: The basis for effective science education in South Africa. International Review of Education 53: 577-591.

Lee, O. 2001. Culture and language in science education: What do we know and what do we need to know? Journal of Research in Science Teaching 38: 499-501.

Lila, M.A. and R.B. Rogers. 1998. The game show challenge: Catalyst for student participation in plant propagation. HortTechnology 8(2): 238-241.

Llewellyn, D.J. 2002. Inquire within: Implementing inquiry based science standards, Thousand Oaks, CA: Corwin Press, Inc.

Maurial, M. 1999. Indigenous knowledge and Western knowledge: A continuum between conflict and dialogue. In L. Semali and J. Kincheloe (eds.). What is Indigenous Knowledge? Voices from the Academy. New York: Falmer Press.

Medina-Jerez, W. 2008. Between local culture and school science: The case of provincial and urban students from eastern Columbia. Research in Science Education 38: 189-212.

National Research Council. 1996. National Science Education Standards. City: National Academy Press: Washington D.C.

National Research Council Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century. 2003. BIO 2010: Transforming undergraduate education for future research biologists, Washington, D.C.: National Academies Press.

North Dakota Department of Public Instruction. 2006. North Dakota Curriculum Content Standards, http://www.dpi.state.nd.us/standard/content.shtm. Accessed: April 29, 2009.

Ntuli, P.P. 2002. Indigenous knowledge systems and the African renaissance. In C.A. Odora-Hoppers, (ed.), Indigenous Knowledge and the Integration of Knowledge Systems. Cape Town, South Africa: New Africa Books.

Odora-Hoppers, C.A. 2002. Indigenous Knowledge and the Integration of Knowledge Systems, Cape Town, South Africa: New Africa Books.

Quigley, C. 2009. Globalization and science education: The implications for indigenous knowledge systems. International Education Studies 2(1): 76-88.

Resnick, L.B. 1987. The 1987 Presidential address: Learning in school and out. Educational Researcher 16(9): 13-20-54.

Rissing, S.W. and J.G. Cogan. 2009. Can an inquiry approach improve college student learning in a teaching laboratory? CBE-Life Science Education 8: 55-61.

Seymour, E. and N.M. Hewitt. 1997. Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview Press.

Tsuji, L.J.S. 1996. Loss of Cree traditional ecological knowledge in the western James Bay region of northern Ontario, Canada: A case study of the sharp-tailed grouse, Tympanuchus phasianellus phasianellus. The Canadian Journal of Native Studies 16(2): 283-292.

World Health Organization. 2009. Diarrhoel Diseases, http://www.who.int/vaccine_research/diseases/diarrhoeal/en/. Accessed: February 20, 2010.