Engaging American Indian/Alaska Native (AI/AN) Students with Participatory Bioexploration Assays[1]

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Abstract

American Indian and Alaska Native (AI/AN) students can experience a disconnect between their indigenous culture and the Eurocentric focus of U.S. science, technology, engineering, and mathematics (STEM) classrooms. As a result, some AI/AN students are less motivated to participate in educational activities that seem irrelevant or detached from their daily existence. An educational methodology utilizing AI/AN culturally-relevant medicinal plant knowledge as a foundation for inquiry-based bioexploratory lectures and laboratory experiments was tested for its potential to promote enhanced engagement in STEM instruction for AI/AN students. Workshop modules were held with 40 AI/AN high school student participants in Alaska and 12 middle and high school Lakota students and ten college Lakota students in North Dakota. The STROBE technique, an observational method previously validated to measure engagement in medical school lectures, was used to determine the level of engagement among students during the lecture, discussion, and laboratory portions of the workshops. From 1718 discrete student observations, students exhibited engagement behavior 1247 times, for an average of 72.5%. College students displayed higher levels of engagement (80.0% average) compared to high school students (70.3%). This research suggests that emphasizing traditional AI/AN culture in a participatory learning environment has the potential to enhance engagement of AI/AN students in STEM disciplines.

Keywords Science education, student engagement, Native American students, STEM, STROBE method, traditional ecological knowledge, inquiry-based learning

Introduction

American Indian and Alaska Native (AI/AN) students frequently struggle with standardized curricula in United States public classrooms, resulting in low levels of AI/AN student matriculation and achievement. AI/AN students are 73% more likely to be placed in special education programs (US National Caucus of State Legislators, 2008), and are 117% more likely to drop out before receiving a high school diploma compared to non-AI/AN students (McCarty, 2009). Only 64% of those students who do graduate pursue postsecondary education, perpetuating a severe underrepresentation of AI/AN students in the ranks of higher education (deVoe et al., 2008; Tynan and Loew, 2010).

There are a multitude of factors that may disadvantage AI/AN students, both at home and at school. Outside of class, students frequently face inadequate academic preparation, legal problems, acute and chronic health issues, behavioral issues, lack of parental support, teen pregnancy, poverty, substance abuse, and child care difficulties (Bowker, 1992; Demmert et al., 2006; Everett Jones et al., 2011; Faircloth and Tippeconnic, 2010; Ledlow, 1992; Swisher and Hoisch, 1992).

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Inside the classroom, a heightened focus on standardized tests, Eurocentric based curricula, and limited multicultural content, can fail to engage AI/AN students (Beaulieu et al., 2005; McCarty, 2009). In addition, traditional AI/AN students have little motivation to participate in educational activities that seem irrelevant to their own cultural practices and contributions to history. As Bradley and Reyes (2000) noted, "*schooling for Alaska Native students has been largely designed and implemented by non-Alaskans from the 'lower 48.' In most cases, the public school curriculum… does not reflect Native values, culture, or experiences.*" The lack of cultural appreciation and inclusion in school curricula is frequently compounded by teachers' lack of understanding about students' cultural background (Freng et al., 2006). Taken together, these factors tend to disconnect AI/AN students, creating a chasm between the experience of their own lived realities and the presented educational material. This paradox has led to a lack of engagement and motivation for AI/AN students in U.S. schools, which is a contributing reason why students in general drop out of school (Mac Iver and Mac Iver, 2009).

Alternative frameworks for re-engaging AI/AN students in school have been widely investigated, and evidence suggests that academic performance improves when AI/AN culture is incorporated into the classroom curriculum in meaningful ways. Educational programs where the values, ideas, social mores, and language of the respective communities are promoted and embraced, have been highlighted as a primary means of improving academic performance (Beaulieu et al., 2005; Guillory and Williams, 2014). Employing Native culture as a foundation of curriculum has the potential to connect a student's educational experience to his or her own lived reality, which is essential to enhance student success in the classroom (Agbo, 2001), while cultivating a sense of "place" that makes STEM curriculum more impactful (Nadelson et al., 2014).

Recently, a system of simple field bioassays was developed into an educational toolset that enables students to explore the bioactivity of extracts from culturally-familiar wild edible or medicinal plants. The assays evaluate plant potential to combat chronic and infectious human diseases, and require students to master basic biological and chemical laboratory principles in order to complete the assessments (Kellogg et al., 2010a). The purpose of this study was to ascertain the effects that participatory science curricula on student engagement in the classroom. Engagement of the AI/AN students was monitored and coded by trained observers using the STROBE method; an instrument previously validated as a means to objectively measure students' interest and attentiveness in medical school (O'Malley et al., 2003).

Methods

Subject and site selection

The study population consisted of 52 students from Alaska and North Dakota. More specifically, the study population included 40 high school AN students in Alaska, and 10 college students plus 12 middle school and high school AI students in North Dakota (Table 1). The study was conducted at summer science camps held at the University of Alaska at Fairbanks and the United Tribes Technical College in Bismarck, North Dakota.

IRB approval

Observational monitoring of student engagement behaviors was an uncomplicated and unobtrusive method of data collection, and thus was determined by the North Carolina State University (NCSU) Institutional Review Board of Human Subjects in Research (IRB) to be outside the requirement for regulation on human subject research. In addition, the NCSU IRB did not require informed consent, since no personal information was collected, students remained anonymous to the observers, and the research involved public behavior in a public school or college setting.

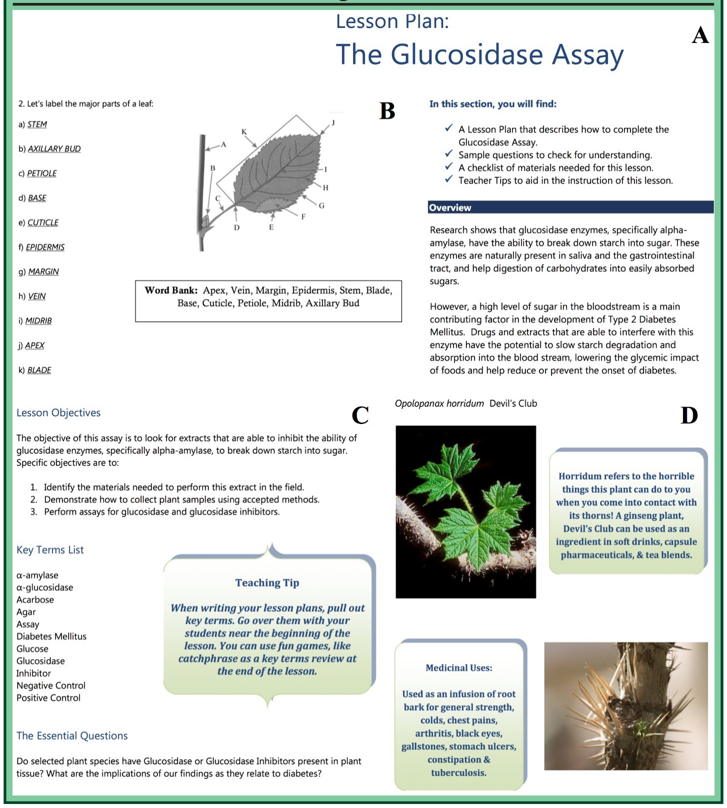
Field bioassays

The portfolio of field bioassays was previously developed as a research tool to investigate bioactive properties of wild indigenous plant material in a non-laboratory setting (Kellogg et al., 2010b). Assays created to screen for antioxidant and anti-glucosidase activities, helminthes lethality, wound healing, and protease inhibition were specifically selected in this study to be developed into classroom modules. Each of the selected bioassays addressed health concerns that were particularly relevant to the AI/AN students who participated in the exercises. The antioxidant screen is a colorimetric multi-well plate assay that investigates the quenching of free radicals. The ability to reduce oxidative radicals has been correlated with reduced incidence of chronic diseases, including cancer, type 2 diabetes, and heart disease. The enzyme-based anti-glucosidase screen investigates an extract's potential to reduce serum glucose levels, a biomarker of hyperglycemia and the development of insulin resistance. Cultures of the non-parasitic flatworm *Planaria spp*. treated with plant extracts can gauge worm lethality (an indication that the extract could be used to combat infections of other, closely related parasitic worms), or can demonstrate

Table 1. Location of participatory STEM workshops with Alaska and North Dakota students.

Workshop	Location	Students	School Level	Duration of Workshop	Elder Participation
AK1	Alaska	15	High school; at-risk youth	2 hours	Plant field collection
AK2	Alaska	12	High school; gifted youth	2 hours	Plant field collection
AK3	Alaska	13	High school; gifted youth	2 hours	Plant field collection
ND1	North Dakota	10	College	2 days	Plant field collection; discussion of plant uses
ND2	North Dakota	12	High school and middle school	2 days	Plant field collection; discussion of plant uses

Figure 1.



potential wound healing capabilities by allowing students to monitor the rate of tissue repair for injured flatworms. Proteases are essential tools for a number of infectious agents, including the human immunodeficiency virus (HIV); the protease bioassay investigates the extracts' potential inhibition of a non-pathogenic protease.

Also included were sections on lab safety, plant collection techniques, plant nomenclature and physiology, and notable medicinal plants of the region. Elders and schoolteachers in Anchorage and Fairbanks, AK, and Bismarck, ND assisted in the development and validation of these student activities and lesson plans, and teaching materials were revised according to the recommendations of the panels (Figure 1).

Training teams from North Carolina State University and Rutgers University conducted field bioassay workshops in cooperation with elders from the local native communities. These workshops featured elder-guided fieldwork to identify plants with medicinal value as recognized in traditional ecological medicine. These plants were highlighted in the prepared lesson plans, and students were tasked with employing the bioassay procedures to validate the bioactive potential of selected plants.

STROBE observational method

Engagement is the one of the essential elements in learning, signifying attention and interest in the material being presented, and is an indicator of student valuation of various learning activities (Deci and Ryan, 2000; Willms, 2003). In order to assess engagement levels, visible human behaviors (such as looking at the instructor, writing, reading classroom content, or performing lab experiments) were quantified and measured by external observers.

To measure in-class student engagement, the STROBE method – a validated classroom observational tool – was employed. STROBE allows a trained observer to gauge engagement without interfering with instructor activities (Kelly et al., 2010), and yields quantifiable data from randomized, discrete observations of individual students. While the lesson was in session, observers scanned the classroom every five minutes in a "STROBE cycle" which was repeated from 10 – 24 times, depending on the length of the workshop session. Due to the small number of participants in each section, it was possible to observe each student directly during the STROBE cycle, as opposed to a subset of students as is common in larger classes (O'Malley et al., 2003), and their activities were coded as described in Table 2.

The workshops began with introduction of instructors and the field bioassay system. Workbooks for the laboratory and discussion portions were distributed to students, and then necessary safety information for the

Table 2. Coding scheme for classroom STROBE observations.

Engaged Behavior		Disengaged Behavior	
On task: listening/watching/speaking	E1	Actively off task (e.g. talking)	D1
On task: writing or reading	E2	Passively off task (e.g. sleeping)	D2
On task: hands-on activity	E3		

Table 3. Sample instructional activities of one workshop and associated STROBE observational intervals.

STROBE Interval	Teacher Actions and Instructional Activities	Students Engaged	Students Disengaged
1	Introduction of instructors	7	8
2	Introduction to the bioassay process	8	7
3	Instruction on procedures for plant collection	11	4
4	Instruction on procedures for plant collection	13	2
5	Field collection of plant samples	10	5
6	Field collection of plant samples	15	0
7	Field collection of plant samples	15	0
8	Field collection of plant samples	14	1
9	Plant extraction procedure in student teams	12	3
10	Plant extraction procedure in student teams	14	1
11	Plant extraction procedure in student teams	8	7
12	Student groups begin to finish plant extraction procedures	6	9
13	Student groups begin to finish plant extraction procedures	5	10
14	Most groups finish plant extraction activity	4	11
15	One group finishing plant extraction activity	5	10
16	One group finishing plant extraction activity	7	8
17	Transition to discussion of extraction procedures with student groups reporting	12	3
18	Explanation of procedures for anti-oxidant assay	7	8
19	Instruction on weights and measures	11	4
20	Instruction on positive and negative controls	7	8
21	Student groups test plant extracts for anti-oxidant presence	3	12
22	Student groups test plant extracts for anti-oxidant presence	8	7
23	Student groups test plant extracts for anti-oxidant presence	11	4
24	Discussion of anti-oxidant properties of plants	11	4
Total observations		224	136

labs and instructions on field collection of plant material were given prior to moving outdoors. Plant specimens were identified, catalogued, and harvested together in the field, and brought back to the classroom for extraction and bioassaying. Lab experiments, involving groups of 2-3 students, involved preliminary extraction of the plant material, and colorimetric bioassays described in the workbooks. The lab period concluded with a summary of the results from each groups' experiments and a discussion of the findings and conclusions. The behaviors of each student were cataloged for each STROBE cycle as the workshop progressed. An example of the data collection, along with the classroom activities correlating to each STROBE cycle, is presented in Table 3.

Statistics

Statistical analysis was conducted using two-way ANOVA analysis as well as the student t-test (Prism 6.0, GraphPad Inc., La Jolla, CA), with statistical significance determined at the P <0.05 level.

Results and Discussion

Alaska Native Workshops

A two-hour bioassay workshop with 15 AN middle school and high school youth was held on the campus of the University of Alaska at Fairbanks (AK1). Two researchers collected STROBE observational data in this session and compared notes to reduce the potential for bias in the observations. The engagement of the 15 students is summarized in Figure 2. Student engagement rose during the first 50 minutes of the workshop session, peaking between 30 and 50 minutes (intervals 6 and 10). During this 20-minute period, students were immersed in the field collection and extraction portion of the workshop. Fieldwork was led by Alaskan Native elders to direct plant collecting, ethical practices of harvesting, and the benefits of plants that grew around the campus area. After collecting, the students began hands-on extraction of the plants they had obtained. The engagement of the students was evident in the rise of E3 engagement (hands on activity) during this time frame. The lowest engagement was during a period after the majority of groups had completed the extraction procedure and were waiting for the other groups to catch up before proceeding on to the next laboratory experiment (interval 13-16). Within a total of 360 student-observation points, students expressed engaged behaviors in 224 instances, yielding a 62% overall rate of engagement.

The second workshop took place with 12 AN high school students who had been classified as gifted by their local teachers (AK2). The field portion of the workshop was also led by Alaskan Native elders to guide the students in ethical plant collecting practices, and which plants have been used traditionally as medicines. The students demonstrated exceptionally high engagement behaviors during the first 75 min of the workshop, covering field collection, extraction of the plant material, and antioxidant bioassay screening (Figure 3). The students evidenced high levels of hands-on engagement through the elder-led plant collection (intervals 6-9), as well as through the plant extraction and assaying (observations

Figure 2. Workshop intervals of at-risk AN youth, Fairbanks, AK. Percent of students who were engaged in the lesson was measured using the STROBE method. Engaged students were categorized by the activity they were engaged in: listening/watching/speaking (E1,), writing or reading (E2,), and hands-on activity (E3,).

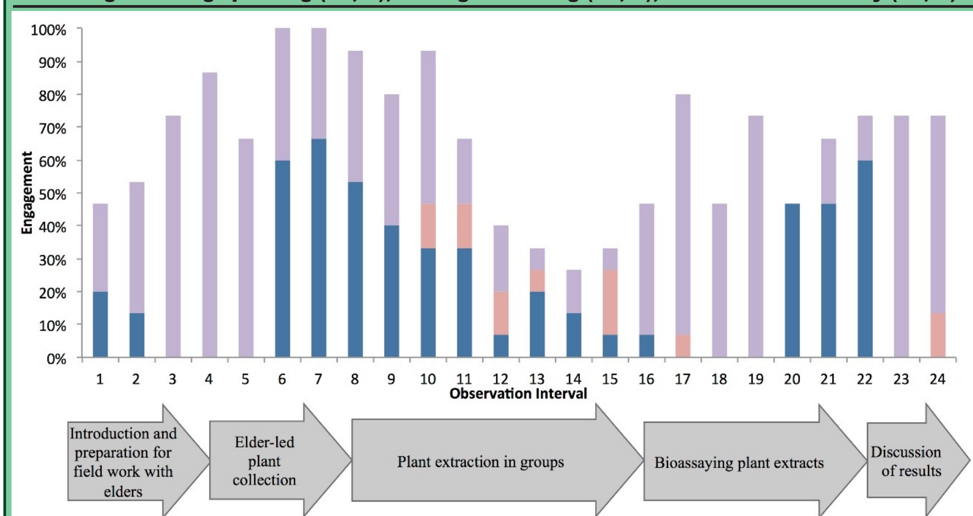
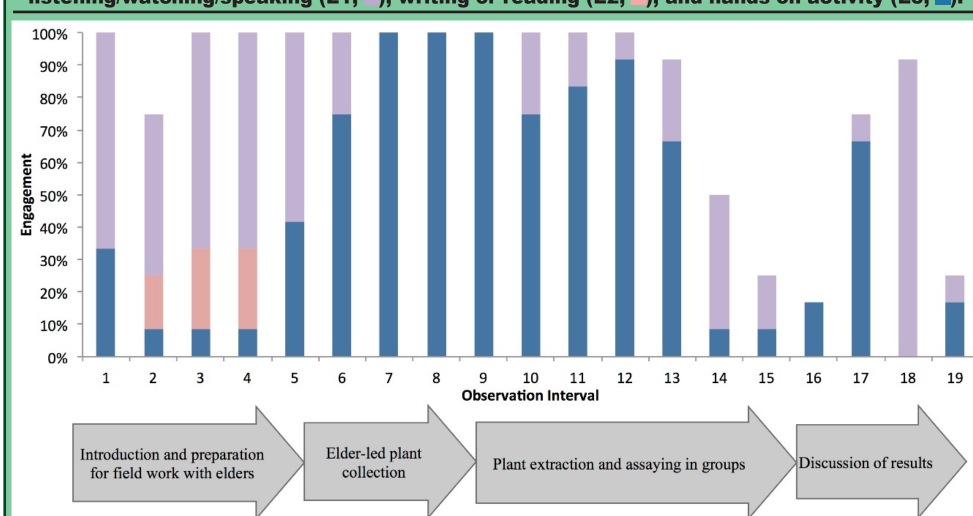


Figure 3. STROBE engagement intervals of gifted AN youth, Fairbanks, AK. Percent of students who were engaged in the lesson was measured using the STROBE method. Engaged students were categorized by the activity they were engaged in: listening/watching/speaking (E1,), writing or reading (E2,), and hands-on activity (E3,).



10-15). Engagement began to wane 70 minutes into the session, during an instructor-led demonstration of *Planaria* worm dissection. Of a total 228 student-observation points, students were engaged in 186 instances, representing an 81.5 % overall engagement rate for all observations. The third Alaska workshop took place on the University of Alaska Fairbanks campus with 13 gifted AN high school students (AK3). Engagement was high (>70% student engagement) for the majority of the session, through the field collections, extraction, and bioassay protocols. The field work was led by AN elders from the community, and during the plant collection hands-on engagement (E3) was at 100%. Toward the end of the workshop, the students showed lower engagement as student groups finished up assay activities and had to wait for another experiment to begin. Of the 286 student observation points, engagement was recorded for 235 instances, yielding an 82.1% rate of engagement for all observations. North Dakota AI College Workshops

Ten AI college students participated in the field bioassay workshop at the United Tribes Technical College (UTTC) in Bismarck, North Dakota, which was run in an extended three-part format covering two days (ND1). The first session involved the description of relevant medicinal plants as part of their indigenous pharmacopeia, and then field collections of similar plant species. The initial discussion centered on similarities and differences between traditional native science methods and Western science approaches. Local community elders led the discussion on AI pharmacopeia and native scientific methods, and also directed students in the field while collecting plants. They guided the identification of beneficial plants that are traditionally incorporated in medicinal practices, and shared ethical and sustainable protocols for harvesting plants from the wild. Students were highly engaged during the discussion portion of the morning (observation 3-5) listening and speaking with the elders. The students transitioned to hands-on engagement as the workshop shifted to field collection of medicinal plants. Overall, from the 130 student-observation points of the first part of the workshop, students exhibited engagement 89% of the time (Figure 5 interval 1-12).

The following morning, students began the laboratory extraction of the plants collected during the previous day's session. Student engagement was observed in all students during the demonstration periods at the beginning of the workshop (observation 13-22, Figure 5), and while student groups were performing extractions, engagement remained relatively high. For the extraction, students were engaged 78.5% of the time from the 140 student-observation points (Figure 5, interval 13-22). The third session

Figure 4. Workshop observation intervals of gifted AN youth, Fairbanks, AK. Percent of students who were engaged in the lesson was measured using the STROBE method. Engaged students were categorized by the activity they were engaged in: listening/watching/speaking (E1, ■), writing or reading (E2, ■), and hands-on activity (E3, ■).

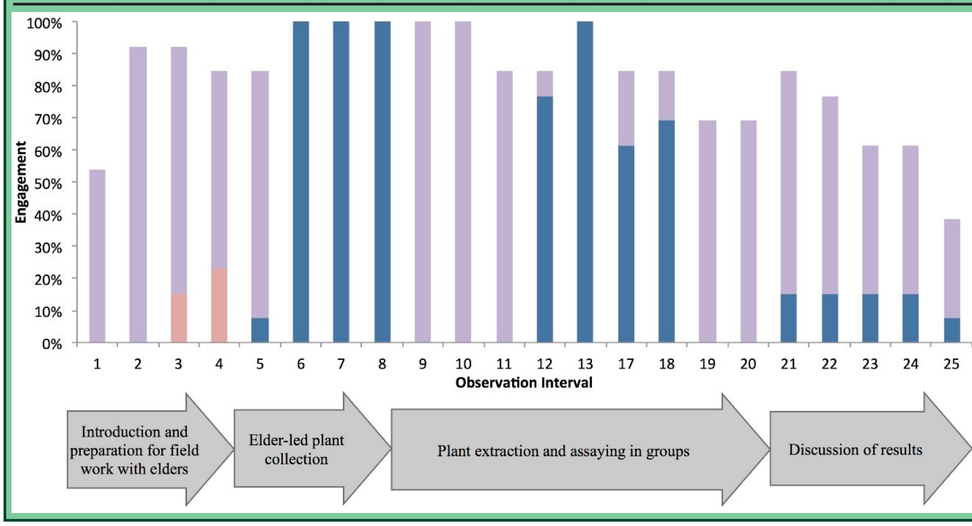
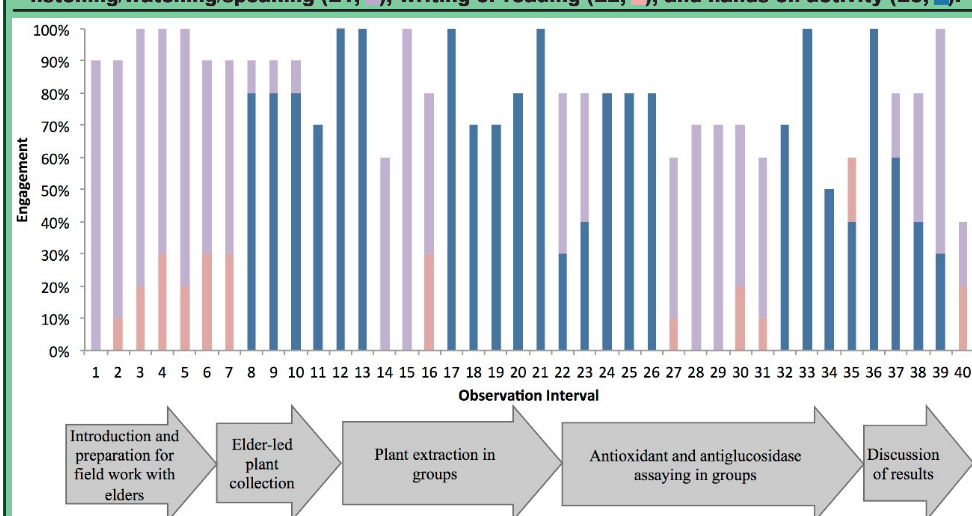


Figure 5. STROBE engagement intervals during a three-part workshop involving AI college students from United Tribes Technical College, Bismarck, ND. Engaged students were categorized by the activity they were engaged in: listening/watching/speaking (E1, ■), writing or reading (E2, ■), and hands-on activity (E3, ■).



The third session of the workshop took place in the afternoon of the second workshop day. Engagement was lower overall in this session compared to the morning (Figure 5, interval 23-40), perhaps because this session addressed topics purely related to scientific methods and did not include discussions of the cultural aspects of the plants or bioassays. Students completed plant extraction and performed the antioxidant and antiglucosidase bioassays. Hands-on engagement was dominant during the bioassaying of the plant extracts (observations 24-26 and 32-35, Figure 5), when groups were actively conducting the two bioassays. The lowest engagement points (observations 34-35, Figure 5) occurred when student groups were completing the assays and awaiting further instruction or for other groups to complete their work. Of the 130 student-observation points, students were engaged in 97 instances, for an overall engagement rate of 74%.

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North Dakota AI High School and Middle School Workshops

A workshop geared towards high school and middle school students was provided as part of a science day camp sponsored by UTTC in Bismarck, ND (ND2). Twelve students participated in a weeklong science day camp, and received a monetary stipend for attending and participating in the entire camp, including the bioassay workshop. The workshop was divided into three sections spanning two days. The first portion of the workshop centered around collecting medicinal plants from the grounds around campus. Community elders participated in the discussion on AI ethnopharmacognosy, and also led students in the field while collecting plants. The elders guided students in the identification of medicinal plants and taught sustainable practices for harvesting plants. Students were moderately engaged during the discussion portion of the morning (observations 1-6 Figure 6) listening and speaking with the elders. The students' engagement increased and transitioned to hands-on participation as the workshop shifted to field collection of medicinal plants (observation 7-12). In general, participant engagement was high during this session (observations 1-13, Figure 6), exhibiting engagement behavior in 72.2% of the 104 student-observation points.

The second session, involving the extraction of plants and preparation of the extracts for bioassay analysis, was interrupted by a local television reporter and crew who visited the workshop to interview both participants and researchers for a local news feature. This provided a significant distraction during the extraction and analysis stage of the workshop, and was reflected in the lowest engagement scores of the three sessions (observations 14-17, Figure 6); of the 120 student-observation points, engagement behavior was recorded in only 58 instances, of 48.3% of the observations.

The third portion of the workshop took place on the second day of the camp. By this time, the students had become more familiar and more comfortable working with the presenters, and engagement was high during the assaying and data collection portions of the session (Observations 22-37, Figure 6). Students exhibited 100% engagement during four observations toward the end of the session, when the discussion turned to the incidence of type 2 diabetes among the participants' families, and how traditional medicinal plants can help mitigate the effects of the disease. A number of participants were interacting with the presenters, describing how their relatives suffered from diabetes. In 180 student-observation points, engagement was detected in 76.6% of the observations (Figure 6).

The average engagement of AI/AN students during each workshop interval (introduction, plant collection, extraction, bioassaying, and result discussion) is shown in Figure 7. Averages are compared between intervals (Figure 7A) or between workshops (Figure 7B). For the majority of the workshops, plant collecting was the most engaging activity for the students. Plant collecting incorporated both hands-on participation and cultural input from participating community elders, thus it is difficult to differentiate between the two effects on student engagement. The plant extraction, another intensive hands-on component, also evidenced high levels of engagement among the students. The exceptions to this, AK1, and ND2 (Figure 7B), are significantly lower, though this is due to unique circumstances that arose those two workshops (in AK1, the extraction period continued on while only one student group remained to complete the plant extraction, and so the other groups were idle and disengaged from the lesson; in ND2, the appearance

Figure 6. STROBE engagement intervals of a three-part workshop involving AI high school and middle students at the United Tribes Technical College, Bismarck, ND. Engaged students were categorized by the activity they were engaged in: listening/watching/speaking (E1, ■), writing or reading (E2, ■), and hands-on activity (E3, ■).

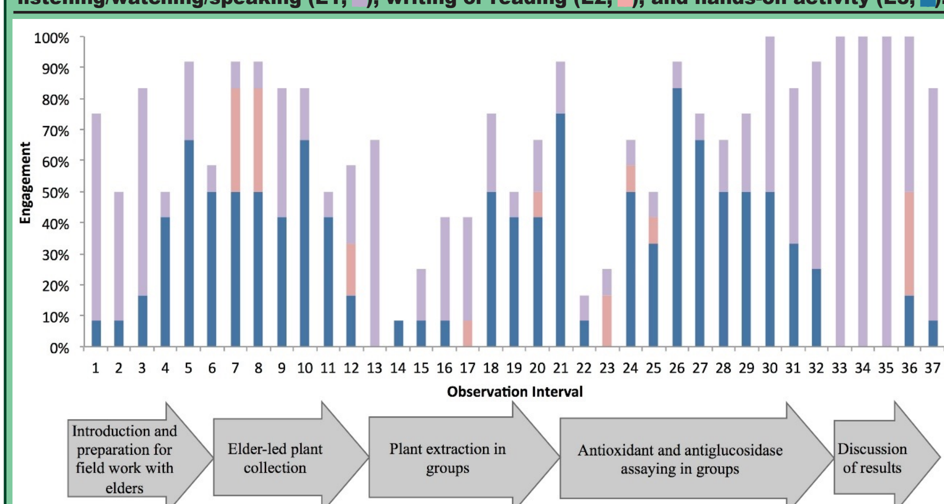
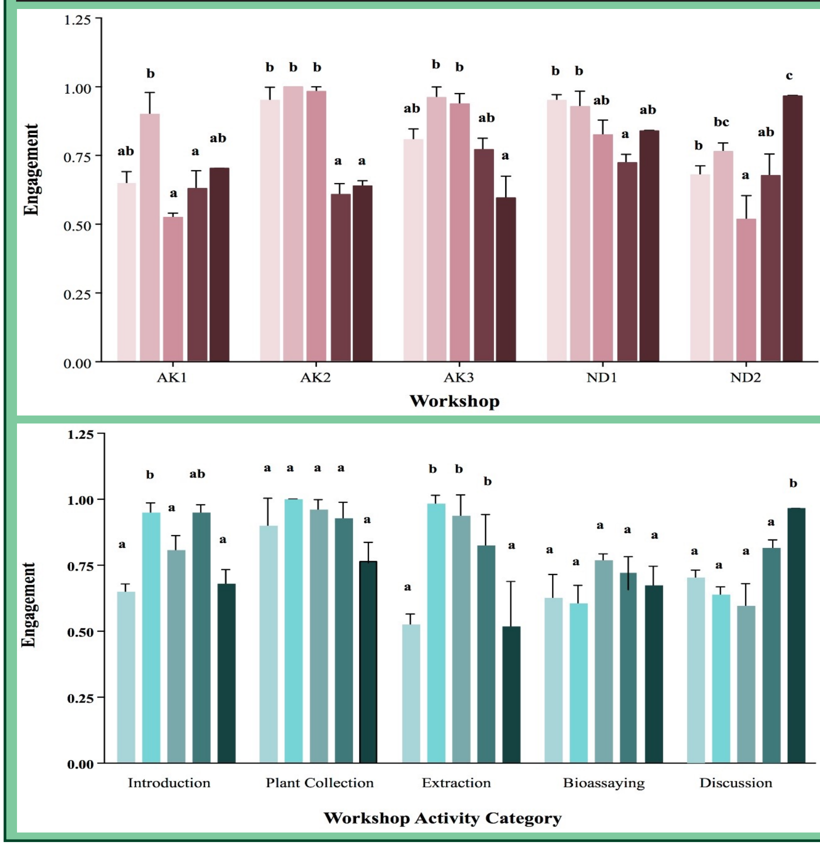


Figure 7. Average engagement of AI/AN students in Alaskan and North Dakotan workshops. (A) Averages compared across activities (- introduction - plant collection; - extraction; - bioassaying; - discussion of results). (B) Averages compared between workshops (- AK1 - AK2; - AK3; - ND1; - ND2). All values are expressed as the mean ± SEM of each observation window. Different letters designate significantly different values (P < 0.05).



of a television crew disrupted the workshop). Another trend across workshops was a drop-off in engagement throughout the discussion sections of each workshop (Figure 7B). This could be attributed to student fatigue after working through multiple hours of lessons and discussions and experiments. However, the second North Dakota workshop featured elders participating in the discussion section, interacting with the students on the medicinal plants and bioactivities that the students discovered, and how the traditional uses of the plants correspond to diseases that affect AI/AN communities. In this workshop, engagement was significantly higher than the other workshops (Figure 7B), and indeed was the highest participation section of the ND2 workshop (Figure 7A).

Summary

Maintaining student engagement in lectures and labs is a constant struggle for educators, This challenge is made greater when there is a disconnect between the aspirations and attitudes of the learners and the content to be learned. This study indicates that these youth can be more engaged by western science education when culturally relevant, experimental, and hands-on methods are used. Engagement heightens the connection between students and the learning environment, and has been shown to be a powerful motivator for students actively interacting and participating in the educational process (Deci and Ryan, 2000; Willms, 2003). College students displayed generally higher levels of engagement (80.0% average) compared to high school students (70.3%) ($p < 0.05$), though the reasons why this occurred are beyond the scope of this current study.

These educational modules, based upon field bioassays, incorporate several methods that have proven effective in classrooms regardless of student demographic makeup. The system utilized in this study presented a novel bioexploration scenarios to AI/AN students using inquiry-based approaches to STEM laboratory instruction, which has been shown to engage and motivate students at all levels by providing novel problem solving opportunities (Ahlfeldt et al., 2005; Anagnopoulos, 2006; Kelly et al., 2010). The method also used physical movement in the classroom, through plant collection and bench-top extraction and bioassay experimentation, and movement has been shown to boost engagement and increase comprehension simultaneously (dePorter et al., 1999). From Figure 7, plant collection and extraction yielded high levels of engagement from students in all workshops. In addition, hands-on engagement levels increased substantially during the field collection, plant extraction, and bioassay portions of the workshops, reinforcing the notion that the participatory nature of these modules has promise to engage students in the material being delivered by the instructor.

The potential efficacy of this system of bioassays in engaging AI/AN students could also be attributed to the method's similarities with traditional forms of AI/AN education. Native educational systems were based upon generations of accumulated knowledge about the natural world, and had evolved into a complex experiential process, which included learning by doing, watching, listening, and experimenting under the mentorship of elders community members (Hall, 1996). The studied bioassay laboratory and lecture system, akin to traditional learning methodologies, emphasized hands-on learning in a participatory format that featured environmental knowledge as a focal point of the educational process (Guillory and Williams, 2014). Hands-on activities have demonstrated higher interest levels from students (Kellogg et al., 2010a), and this is another aspect of the bioassay system that aided in higher engagement levels during the field collection, extraction, and bioassaying portions of the workshops. Taken together, the structure of this culturally-based educational system helped to incorporate learning structures that were familiar to the students from their lives beyond the classroom.

In addition, by focusing on AI/AN traditional medicinal plants and diseases (like diabetes and metabolic syndrome) that constitute a major public health concern in the communities, the method highlighted here incorporated crucial elements of the students' realities outside the classroom into the formal educational structure. This is a key element in effective education with AI/AN students in order to maximize student success (Agbo, 2001). Utilizing aspects of the students' lives also provided opportunities to talk about themselves and relate the content to their personal lives and interests, which has been shown to allow students to personalize learning and make meaningful connections from the lesson using their own words and be an essential part of learning (Marzano et al., 2009). The incorporation of culturally relevant information – traditional medicinal plants, harvesting practices, and health concerns within the AN or AI community – that heightened engagement with the students during discussions. This was evident in the discussion section of the second North Dakota workshop (ND2), where elders participated in the final discussion of medicinal plants and diseases that affect AI/AN communities, where the engagement was significantly higher than other workshops.

In order to more completely evaluate the effects that a hands-on bioassay curriculum emphasizing AI/AN culture and values would have on student engagement, additional studies are essential. The majority of published studies on student engagement rely upon student self-reporting (Ahlfeldt et al., 2005; Appleton et al., 2006) rather than direct recordings during the class session by an impartial observer. Thus, there are no quantifiable results available to compare the quantified engagement rates observed in this study to other similar educational situations.

We are currently pursuing opportunities to evaluate the impact this curriculum has on student retention, including a control student group (one experiencing standard classroom educational curriculum), as well as pre- and post-course analysis for both the test and control classes. This proposed analysis will determine the significance of the curriculum not only on student engagement but on student performance and retention, as well as the potential for culturally-sensitive educational experiences like those presented here to encourage post-secondary educational pursuits in STEM disciplines.

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