IMPLEMENTING A CITIZEN SCIENCE PROJECT IN A

9-12 HIGH SCHOOL SCIENCE CLASSROOM

by

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DEDICATION

This work would not be accomplished without the assistance of my science professional learning committee (PLC), specifically my department chair, Matt Turner. Matt willingly and patiently reviewed formative assessments, project statements, Likert surveys and open-ended questionnaires. My final paper and presentation poster were proof-read and edited for fluency by both my daughter, a PhD student in avian ecology and my husband, a manager in the wood products industry. Lastly, my illustrious, energetic Advanced Placement (AP)® Environmental Science (APES) students who were willing, enthusiastic, and forthright in their participation in this new inquiry style of learning.

ABSTRACT

This classroom action research (AR) project explored the impacts of project-based learning on high school students critical thinking, decision-making, data collection and data analysis skills through the implementation of a citizen science project. AP® Environmental Science (APES) students co-developed a citizen science project that explored their local schoolyard biodiversity by designing and researching their own scientific investigative question. An evaluation of students changes in science self-efficacy, and attitudes toward science research and specific science tasks was tracked throughout the project. Pre- and post-Likert surveys, open-ended questions, field journals, focus group interviews, and a biological solutions science poster were employed as data collection tools. A mixed methodology (qualitative and quantitative) was used to analyze the data. These results showed that students made reasonable gains in data collection and analysis skills, critical thinking and decision-making abilities. Noticeable improvements were detected in student attitudes toward science and science self-efficacy. A discernable change was observed in the student's overall data and data analysis skills related to a field study.

INTRODUCTION & BACKGROUND

Project-based and guided inquiry learning have always been the foundation for my science classes. In the last few years, I have expanded to include case-study and phenomenon-based units with an emphasis on “sense of place”. A “sense of place” is a way for students to connect to science phenomena related to their current community or life experiences. For my classroom action research (AR) project, I wanted to explore how educators could address student designed place-based learning in an authentic and engaging manner. The National Resource Council (NRC) in developing the Next Generation Science Standards (NGSS) focused on students engaging in genuine scientific endeavors through education practices where teachers connect science to student’s interests, cultural backgrounds, and communities (NGSS Lead States, 2013). This is a daunting task but especially critical in an evolving 21st century world, where students must be able to critically reason through a plethora of information regarding critical environmental and scientific issues. A natural segue for exploring the problem-based inquiry model was the implementation of a citizen science project (CSP) in my AP® Environmental Science (APES) classroom.

My main focus question and sub-questions resulted from student pre-project interviews and an open-ended pre-project survey (Appendix A), which asked:

How does participation in a CSP in their local community impact student critical thinking and decision-making? To assess this overarching question, I analyzed several metrics of student learning:

1. How does student data collection and analysis skills change through participation in a CSP?
2. How do student attitudes towards science or science self-efficacy change throughout the CSP?
3. How does student interest in science tasks change throughout the CSP?
4. How does the implementation of a CSP impact me as a teacher in improving student engagement and student questioning skills?

During a CSP, students have the opportunity to work with scientists or experts on a local, regional, or global concern by collecting and analyzing data with their peers. Bonney, Cooper, Dickinson, Kelling, Phillips, Rosenberg & Shirk (2009) found that "Citizen science can provide insightful data to inform decisions, while also serving to enhance ecological awareness and foster environmental stewardship amongst participants" (as cited in Butera & Esser 2019, p.23). Students engaged in a self-designed CSP provide a unique bridge between the new NGSS standards, project-based learning and current citizen science models.

As noted by Becker-Klein, R., Peterman, K. and Stylinski (2016), in their study of embedded assessments of CSP, CSPs can be classified into one of three types: contributory, collaborative or co-created. A contributory CSP limits volunteers to data collection only, while a collaborative CSP expand volunteer contributions to data analysis results interpretation (Becker-Klein et al., 2016). For my classroom research project, I decided to implement a co-created CSP, where students are intricately involved in the CSP design, implementation and presentation. A co-created CSP allowed my students to design the project from defining their research questions to disseminating results and suggesting potential solutions.

Instructional Context

A co-created CSP best aligns with my school's, Spanaway Lake High School (SLHS), school improvement plan (SIP), which set a goal of implementing rigorous coursework that connect students to real-life learning experiences while simultaneously developing critical thinking skills appropriate for the 21st century (Spanaway Lake High School SIP, 2018). My specific teacher goal of practice involved improving student discourse through questioning techniques. NGSS science and engineering practice (SEP) standard #8 requires that student's engage in supporting claims by defending their evidence collected through their investigations through oral or written arguments. My APES classroom was a natural fit for implementation of a classroom AR project, as students are required to participate in a local community-based project focused on sustainability that helps students develop their leadership skills.

SLHS is one of three high schools in the Bethel School District #43 serving the community of Spanaway, Washington (a suburban area within rural Pierce County, Washington). According to the Office of Superintendent of Public Instruction (OSPI) in 2017-18, SLHS had 1,115 students with 48.4% female and 51.6% male, 42.4% low income, 14.1% special education and 3.7% 504's (health-related accommodations) represented by a diverse population as seen in Table 1 (OSPI, 2018). Montana State University's Institutional Review Board (IRB) determined that this research project was exempt from a full IRB review because it presented the lowest amount of risk to subjects, and data was reported without individual student identification (Appendix B).

CONCEPTUAL FRAMEWORK

This literature review will explore major themes, theories, methodologies and data analyses pertinent to my classroom research project focused on implementing a CSP within a formal high school science classroom. My project was adapted from analyses of many projects that focused on citizen science in high school classrooms (Bonney et al., 2009; Cohnstaedt, Ladner, Campbell, Busch & Barrera 2016; Crall, Newman, Stohlgren, Holfelder, Graham & Waller, 2011; Galloway, Tudor & Vander Haegen 2006; Hiller & Kitsantas, 2012 & 2016; Miller, 2018; O'Neill, 2016). Each of these projects provided a multitude of examples which addressed student science self-efficacy, observation and data collection skills and student preferred science tasks (i.e. microscope use, data analysis). Student science self-efficacy measures a student's belief in their ability to master science concepts or specific science tasks. Science tasks preferences measured student's interest in doing specific tasks such as, but not limited to: microscope work, chemical analysis, use of data probes, working with a scientist, reading scientific literature and outdoor field work. Though each author team explored a different phenomenon, common themes were noted, whereby each study used an experiential learning theory approach within an established curriculum to have students implement a CSP in collaboration with local scientists.

History of Experiential Learning

The work of Dewey, Lewin, and Piaget are a few of the original theorists exploring the concept of experiential learning theory (Kolb, 1984). In 1938, John Dewey in his book, *Environment and Education,* first proposed the idea of an experiential theory of learning, which describes melding students' previous life experiences and current knowledge to create new learning opportunities. Dewey's discussion of the need for an experiential learning theory connects with a modern movement aimed at providing students with a "sense of place" in their science classrooms:

> …It is his business to arrange for the kind of experiences which, while they do not repel the student, but rather engage his activities are, nevertheless, more than immediately enjoyable since they promote having desirable future experiences. Just as no man lives or dies to himself, so no experience lives and dies to itself. Wholly independent of desire or intent every experience lives on in further experiences. Hence the central problem of an education based upon experience is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences (p.35).

CSP's provide a unique opportunity for teachers to embrace the concept of experiential learning theory through integration of student classroom experiences with active science learning via real world investigations. It is this type of inquiry that can expand a student's knowledge beyond the typical classroom laboratory which could carry over to future experiences.

Kolb (1984) continues with this theme of "sense of place" in describing the role of an educator:

> …If the education process begins by bringing out the learner's beliefs and theories, examining and testing them, and then integrating the new, more refined ideas into the person's belief systems, the learning process will be facilitated. Piaget (see Elkind, 1970, Chapter 3) has identified two mechanisms by which new ideas are adopted by an individual-integration and substitution. Ideas that evolve through

> integration tend to become highly stable parts of the person's conception of the world. (p.28).

Since 2013 and the inception of the NGSS, science teachers have been motivated to bring a more authentic scientific experience into the classroom whether through more phenomenon-based inquiry experiences or student-designed investigations (NGSS Lead States, 2013). This re-focus of science education has also spurred research into how, where, and when students engage in authentic, real-life scientific experiences as well as a re-evaluation of the nature of science and its basic tenets. Keeping this in mind, I defer to Dewey's (1938) description of an educator pursuing this type of endeavor:

> …It thus becomes the office of the educator to select those things within the range of existing experience that have the promise and potentiality of presenting new problems which by stimulating new ways of observation and judgment will expand the area of further experience… (p.58).

It is with this premise that implementation of a CSP within an existing science curriculum would further students' scientific understanding of the world. Current literature shows that revised science curriculum should proceed with experiences afforded through citizen science projects. Gray, Nicosia, & Jordan (2012), proposed "learning communities that seek to engage successfully in such reform must forfeit some traditional ideas associated with both classroom instruction and citizen science projects and instead must reframe partnerships around the nature of science" (p.1). This focus on reframing the traditional science classroom to envelop nature of science tenets directly into three-dimensional science learning ties directly to one of the foci (student-designed investigations) of the NGSS standards (NGSS Leads States, 2013). The CSP, an experiential learning experience, will help students develop data collection and analysis skills, resulting in them using critical scientific thinking like a scientist while conducting an investigation of their design.

Citizen Science, Data Collection and Analysis Skills

Eberbach and Crowley (2009), found “systematic observation and comparison is a complex method used by biologists, yet one that is often misunderstood and treated as a simple skill by educators and others” (p.42). Their research into how students observe science and ultimately interpret evidence linked to scientific investigation is a critical piece to student learning that I implemented as a key phase in my project methodology. Eberbach and Crowley further found, “consequently children may be directed to observe, compare, and describe phenomena without meaningful disciplinary context and without gaining deeper scientific understanding” (p.42). This last statement highlights that only teaching observation skills is insufficient if there is not a direct and deeper connection to science understanding. Students’ data collection and analysis skills must connect to the main focus of their project and incorporate the use of critical thinking and decision-making skills. Keeping this is mind led to the development of two of my instruments: Citizen Science Questionnaire I (CSQI) (Appendix C) and Citizen Science Questionnaire Survey II (CSQSII) (Appendix D). CSQSII (Appendix D) was modified from another CSP (Lorenz, 2016) for relevancy to both our CSP and connections to our local community. In utilizing a previously published and peer-reviewed survey, I established a credible method, which accurately assessed student critical thinking skills, decision-making skills and science attitudes.

The integration of critical thinking and decision skills is supported in the Learning Science in Informal Environments (National Research Council, 2009) six strands of science learning (p.4), which students should be able to:

1. Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.
2. Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
3. Manipulate, test, explore, predict, question, observe, and make sense of natural and physical world.
4. Reflect on science as a way of knowing; on processes, concepts, institutions of science; and on their own process of learning about phenomena.
5. Participate in science activities and learning practices with others, using scientific language and tools.
6. Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

Strands #1, #4 and #6 correlate with focus sub-questions #2 and #3 in this work which emphasize science self-efficacy, science attitude, and science tasks (microscope use, chemical tests, etc.). Strands #1, #2, #4 and #5 directly relate to the CSP as an all-encompassing learning experience, while helping students reach the goals outlined in statements # 1, #2 and #4. Though the strands link together this classroom research project to established learning science standards it doesn't alleviate the need for proper assessment techniques to show successful implementation of the CSP.

The most valid and reliable method for assessing students' observation skills was to establish criteria and rubrics from which student work could be analyzed against a professional's standard survey protocol (Crall et al. 2011). Gray et al., 2012, found that "rubrics may play an important role in democratization of science since they have the ability to explicitly represent standards for what constitutes quality evidence to be used in decision making." (p.4). Multiple studies (Galloway, Tudor & Vander Haegen 2006;

Hiller & Kitsantas, 2012 & 2016; Lorenz, 2016) provided valid, reliable vetted assessments (surveys, questionnaires, rubrics and statistical analyses) for analyzing my focus research question and sub-questions. Hiller & Kitsantas (2012, 2016) and Gray et al. (2012) found that students' critical thinking, decision-making skills, and observation skills were directly linked to a students' intrinsic motivation, science self-efficacy and self-determination.

Citizen Science and Science Self-efficacy

Previous work has examined student attitudes towards science, a student's sense of place within a science classroom, and understanding of science practices following the implementation of a CSP in a high school biology class (Lorenz, 2016). Understanding student attitudes regarding scientists and science practices are directly related to my focus sub-questions #2 and #3 which examined student self-efficacy and science tasks. The latter was addressed previously in Lorenz's study of student understanding of the Next Generation Science Standards (NGSS) Science and Engineering Practices (SEPs). Working with 17 students and the teacher from a Yellowstone science class, Lorenz conducted a PhotoPoints study of Mammoth Hot Springs. Throughout the study students gathered photographic data, observed springs, and descriptively measured several variables (travertine growth, biofilm colors, flow velocity, presence of debris and facies classification). Lorenz designed a pre- and post-test method to collect information about students' sense of place, attitudes toward science, and understanding of science practices (Lorenz, 2016). A combination of qualitative and quantitative data was collected and used to summarize the findings, including the implementation of quantitative surveys and qualitative structured interviews. The interviews increased in complexity as the interviewee became more comfortable with the process, and “revealed rich insight into students’ sense of place, attitudes toward science, understanding of science practices, and nature of science, and impressions of citizen science” (Lorenz, 2016, p.iii).

For my study, one instrument, Science Motivation Questionnaire II (SMQII) (Appendix E), was chosen for assessing student science self-efficacy, intrinsic motivation and self-determination developed by Glynn, S.M., Brickman, P., Armstrong, N. and Taasoobshirazi, G. (2011). The SMQII was first developed and subsequently modified by Glynn, et. al, 2011, with 367 science college majors and 313 non-science college majors to explore five motivation components (Appendix E): intrinsic motivation, self-determination, self-efficacy, career motivation and grade motivation. Through this study (Glynn et. al, 2011) the construct validity of the questionnaire was determined through both exploratory and confirmatory factor analyses as noted in Glynn et al. “In earlier studies (Glynn, Taasoobshirazi & Brickman, 2007, 2009), the Science Motivation Questionnaire was found to have good content validity and criterion-related validity …” (p.2) This is a respected and vetted study with multiple Cronbach alpha indices (a reliability test showing correlation between Likert statements) and factor analysis that led to this surveys’ validity and reliability at assessing student science self-efficacy, attitudes and motivations towards science and science projects. These factors were the main reason for selecting this particular instrument as a data collection tool and subsequent analysis of sub-question #2, How do student attitudes towards science or science self-efficacy change throughout the CSP?

Citizen Science, Critical Thinking and Decision-making Skills

Cohnstaedt et al. (2016) engaged high school biology students in an inexpensive entomological study of mosquitoes as a CSP. This project met a main tenet of the NGSS by having students engage in authentic inquiry experience as noted in “Students are not only informed of the global problems in this lesson but are also educated and participate in a solution to the issue” (Cohnstaedt et al., 2016, p.318). Cohnstaedt et al. specifically recognized the link between student critical thinking skills and real-world scientific investigations, “This lesson emphasizes critical-thinking skills as students use data collected to assess personal risks from mosquito-borne diseases” (Cohnstaedt et al. p.318). The study’s emphasis on education, data collection linked to students’ personal experiences with mosquito related diseases or health concern impacting their community and proposing potential solutions helped guide methodology development in the current study.

Galloway, Tudor & Vander Haegen (2006) conducted a CSP across multiple grade levels, collecting biodiversity data on Oregon white oak trees in southwestern Washington. Their study had two foci: reliability and validity of student data in a CSP and student data interpretation. The results uncovered student data collection was reliable based on chi-square statistical analysis; however, there were issues with widespread reliability of the data collection. Younger students were more prone to include larger sized trees or rare species, which were known to be outside the sampling transect. The study provided insight to potential pitfalls of student data collectors, as well as their capabilities in contributing to real-world scientific investigations. This study also supported the use of industry-recognized sampling techniques associated with a forest biodiversity study, which were employed by students in this work. The Science Task Survey (STS) (Appendix F) was developed from skills assessed by this study with modifications from surveys from Lorenz (2016) and Hiller & Kitsantas (2012 & 2016) that conducted CSP in high school classrooms..

METHODOLOGY

This study explored how participation in a CSP changes a student's critical thinking, decision-making skills, data collection and analysis skills. It further explores how a student's science self-efficacy and attitude towards specific science tasks change in relation to a CSP. Through implementation of the CSP, I hope to show fellow educators (science team and statewide science fellows) that a CSP is a valid and reliable inquiry method for exploring phenomenon or case-study concepts while also engaging students in the scientific investigation of a local community issue. The local issue chosen by students for this CSP was a schoolyard plant biodiversity study (SBS). This CSP provides a connection to a global and regional environmental concern; the loss of plant biodiversity due to urbanization. In the current Pierce County planning document, our schoolyard is categorized as "educational zoning" without any reference to the plant biodiversity it contributes to the local watershed. This CSP presents an opportunity for my APES students to participate in data collection associated with a local issue, loss of plant biodiversity due to urbanization, while also contributing data to a global database, iNaturalist. This CSP would allow us to participate in both a national biodiversity data repository (iNaturalist), a regional BioBlitz project (Washington NatureMapping) and a local self-designed CSP to provide data to two entities: Pierce County Biodiversity planning network and Bethel school district facilities management director and long-term facilities planning committee.

iNaturalist is an open source data collection site that allows citizens to share biodiversity data with a larger audience while providing access to researchers, scientists and policy makers to a broad set of data. I established an account and set up a project (Spanaway Biodiversity Study) to contribute our plant biodiversity data so that our schoolyard plant biodiversity study (SBS) could be shared with the Global Biodiversity Information Facility via the iNaturalist website. Students collected both written and photographic data which was then uploaded to the site at the end of the project.

Currently the Washington Nature Mapping 2019 focus is on wildlife sightings; however, my APES students decided to maintain the information for later inclusion into this websites database as relevant wildlife habitat data. Students SBS data will be submitted during the public comment period for the Pierce County's Spanaway-Midland-Parkland 2019 draft land management development plan. Lastly the data will be utilized to prepare a facilities modification form to propose a change in current plant species diversity to the Bethel School District's facility director and long-term facility management planning committee. Within this same context, our school board's long-term facility committee needs to be informed about the current biodiversity of our schoolyard as they move forward with future construction, building modifications and other development. Without considering the biodiversity of the schoolyard, a significant wildlife corridor and habitat for native species could potentially be lost.

Currently the Spanaway-Parkland area is seeing an influx of development (including school construction, housing developments, single family homes and commercial businesses). Within this region there are limited areas that have a high biodiversity of native plants, with many areas limited to a few native species and several non-native or invasive species. The SBS is a starting point for our students to become active citizens in the studying of the local plant biodiversity while learning valuable scientific knowledge and skills.

Twenty-two AP® Environmental Science (APES) students participated in this classroom AR project. Table 1 shows the diversity of the APES class is similar to SLHS overall ethnic demographic, excluding Hispanic, Hawaiian-Pacific Islander, Native American and Mixed-race students.

Table 1
Student Ethnicity Percentage Comparison

Ethnicities	SLHS	Class
African American	16	13.6
Hispanic	19	.09
Hawaiian & Pacific Islander	5	.09
Asian	9	13.6
White	42	36.3
Mixed Race (one or more races)	7	22.7
Native American	2	0

Note. N=22, class demographics.

Excluding special education students (0%) and 504's (0.09%), my APES students are a fair representation of our student body at SLHS, with approximately 53% meeting the criteria for free-reduced lunch, nearly 45% from low income households. However, the class differs greatly from the school male to female ratio of 52:48 with a 36:64 ratio of male to female students..

Academically, the class is diverse, with four participating seniors taking multiple AP courses (three or more) and one sophomore enrolled in their first AP course. Some students are passionate about environmental issues, while others are dedicated to seeking a career in a science-related field. The class demographics provide a unique opportunity to see how a CSP impacts the science self-efficacy and attitude, critical thinking and data-analysis skills of typically under-represented groups in a higher-level science course. The majority of participating students have no prior field science experience, with a few experiencing some field science through informal settings (summer camps, Boy Scouts, Girl Scouts, etc.). None of the students, based on information gathered through informal conversations and an initial survey (Appendix A), have participated in a CSP prior to this class experience.

Treatment

The treatment began in mid-fall 2018 with an introduction to potential CSP's and selection of a project through an initial survey, initial focus group interview and informal conversations. The CSP was organized into four quarters of specific learning (Table 2) based on a model recommended by the *California Academy of Sciences* (2015) in their citizen science toolkit. This toolkit utilizes a progression of four activity tiers which I broke into explicit learning progressions. The progressions provided clear and concise goals for each quarter, while still allowing for organized data collection to occur throughout the project.

Table 2
CSP Progression

General Activity	Project Progression	Timeline
Develop expertise	▪ Introduce the project ▪ Learn field sampling techniques ▪ Learn from field guides ▪ Observe and practice sketching, collecting data ▪ Write investigative question ▪ Work with a local expert	09/24-11/09
Contribute data	▪ Small group practice ▪ Design investigation ▪ Collect data	11/09-2/28
Make meaning	▪ Analyze data by identifying species, describing patterns and using graphs or statistics to look for trends ▪ Further investigation based on data collection and analysis	1/10-03/19
Share the work and Take action	▪ Complete Formal district documents (maps, plant proposals, maintenance plan) ▪ Reflect on experiences Present to other classes ▪ Collaborate with other classes (culinary, AP Biology) ▪ Talk with other scientists or conservation groups ▪ Share findings with stakeholders (School administration, District administration)	3/20-5/15

After selecting the SBS, instruction began on understanding the concept of biodiversity, native versus non-native plants, plant dichotomous key identification techniques, field observational skills and basic field sampling techniques. Lectures, classroom discussions, films and peer-reviewed literature readings on global, regional and local biodiversity-scales were integrated with field and classroom labs.

The SBS began with an introduction of the project, exploration of previous knowledge, and introduction of observation and sampling skills. Students learned basic sampling techniques (quadrat, basal-area, line transect) through individual labs and class activities (Appendix G). Students were presented with basic dichotomous key formation and terminology through class lectures and individual exploration of field application. Students were given standardized rubrics for analyzing critical thinking, decision-making, field journals (Appendix H), and science presentation posters. In addition to the rubrics, students were given standardized criteria for recording data (i.e. sketching, measuring, mapping).

Through schoolyard explorations and two field trips, students were taught basic field sketching techniques, dichotomous key usage and observation skills. In both the schoolyard explorations and field trips to Bresemann Forest (Spanaway, WA) and Pt. Defiance Park (Tacoma, WA), students were queried about the plants and other organisms they observed. The enquiry was used to assist students in eliciting traits that would help them identify unknown specimens. In both the schoolyard and local forest field studies, students learned collection techniques of physical specimens, documented conditions through videotaping and photography, and recorded relevant data in field journals (Appendix H). During the Pt. Defiance Park field trip, students worked with the Forest Ranger to explore an old-growth temperate coniferous forest in an urban setting with high public use.

After these initial outings, students began the CSP by writing individual investigative questions in their science journals. The students wrote their preferred study ideas on whiteboards, and subsequently formed collaborative field study groups based on major themes elicited from their investigative questions. Five major investigative questions were formulated (Table 3) under our overarching question: What is the biodiversity of our schoolyard and how does it compare to our local urban forest (Bresemann Forest)? During all of the activities, I served two roles: classroom facilitator and forest ecology expert.

Table 3
Students' Investigative Questions

Student Groups	Investigative Question
Group #1	What is the mycology of our schoolyard?
Group #2	What does the stem and root arrangement tell us about the health of our trees in our schoolyard? Does soil analysis help with this analysis?
Group #3	What is the number and type of non-native species in our schoolyard?
Group #4 A & #4 B	What is the number and species of shrubs and flowering shrubs in our schoolyard?
Group #5	What is the number and species of trees in our schoolyard?

Groups of four to six students chose one of the investigative questions from the five chosen by the whole class. Then each group designed their methodology by creating a schoolyard map which was used to established survey areas. After survey areas were determined, each group selected reliable and valid survey methods (transects, plots or whole area) appropriate to helping answer their respective investigative question. Over the next three to eight weeks, students collected data by recording information in their field journals, collecting physical specimens (plants, soil, fungi) and photographing specimen samples. Collected samples were analyzed for their soil chemical composition, and plant species were identified using a dichotomous key, website searches and/or literature search.

After analyzing their data from the three field schoolyard labs and Bresemann Forest fieldtrips, students determined that additional data, typically more plots, was needed prior to creating their formalized schoolyard biodiversity proposals (poster presentation). Through student discourse and a schoolyard walking tour, students decided on three focus areas for their final proposals in a poster presentation to improve biodiversity within their schoolyard. The focus of each poster was how the school could improve their backyard biodiversity, while also highlighting future learning opportunities or environmental issues. Students selected one of the three areas and researched plants, materials and connections to other learning. The three focus areas chosen were: dilapidated greenhouse and surrounding gravel area, small rectangle filled with weeds and a medium triangular area next to new construction overgrown with grasses, invasive plants and weeds. The result of student decision-making, critical thinking and data analysis was a formal electronic poster, which highlighted each student's suggestions for improving the schoolyard biodiversity to SLHS administration. From the individual proposal posters, the class choose three proposal posters to be included in the official facility modification form submitted to district. Three student speakers were also selected to present at an informal meeting with the SLHS Principal and other district representatives.

Instruments

The CSP began with an initial survey (Appendix A) to explore students' current understanding of the concept of a CSP and potential topics for exploration. Seven instruments (Table 4) were utilized to explore the project AR questions. The SMQII, CSQI, and STS pre-treatments were administered (late September to early October 2018) and were intended to address the first three focus questions (Table 4). The CSQSII were administered after the conclusion of the CSP in May 2019. Other employed instruments (lab activities, field journals, science journals, interviews) were utilized continuously throughout the eight-month project. The two long-term cumulative instruments were the schoolyard biodiversity posters and administration presentations which were only administered once, in May 2019.

Table 4
Triangulation of Data Sources and Focus Questions

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Main Focus: How does participation in a CSP in their local community impact student critical thinking and decision-making	CSQI	CSQSII	Focus Group Interviews & Schoolyard Biodiversity Science Poster
Sub-Question #1: How does student data collection and analysis skills improve through participation in a CSP?	CSQI	Field Journal	Focus Group Interviews & Schoolyard Biodiversity Science Poster
Sub-Question #2: How do student attitudes towards science or science self-efficacy change throughout the CSP?	SMQII	CSQSII	Focus Group Interviews
Sub-Question #3: How does student interest in science tasks change throughout the CSP?	STS	Field Journal	Focus Group Interviews
Sub-Question #4: How does this impact me as a teacher: student engagement and questioning?	CSQI	CSQSII	Focus Group Interviews

The SMQII (Appendix E) was modified from its original format due to its length (needed to be limited to one page) and so it could be administered multiple times. This resulted in an 18 Likert statement survey that could capture student’s science self-efficacy, self-determination and intrinsic motivation. The STS (Appendix F) and CSQI

(Appendix C) are original documents adapted from analyses focusing on self-efficacy and science task preferences (Lorenz (2016), Hiller & Kitsantas (2012, 2016), Galloway et al., 2006)). The STS explores 15 statements which directly relate to the general project focus, biodiversity of our schoolyard, and separate student preferences into six categories: Classroom Lab Activities, Field Lab Activities, Scientists' Work, Independent Research, Art as a Science Tool, and Community Related Projects. CSQI elicits students' critical thinking on the biodiversity of their schoolyard, connecting to multiple, foundational NGSS DCI's in life science and earth sciences. CSQI was the first questionnaire which attempted to analyze student decision-making skills related to investigative questions, design and implementation of a research study.

The CSQSII (Appendix D) is separated into three distinct areas: a nine statement Likert survey with explanation, 4 open-ended questions and 2 post-project questions. It provides insight into student research design (critical thinking and decision-making skills), and data collection and analysis skills through the open-ended questions. The nine statement Likert survey provides additional insight into student science self-efficacy and intrinsic motivation which correlates to their decision-making skills and ability to reason at a higher-level.

Three instruments (STS, CSQI, CSQSII) and the focused interviews (Appendix I) analyzed the effectiveness of my questioning skills in eliciting student thoughts and reasoning related to our CSP.

DATA AND ANALYSIS

Responses to the pre- and post-questions or statements from four instruments (Table 5) were used to provide insight into student scientific thinking and rationalization, the development of skill sets related to scientific data collection, and the ability of students to analyze data and develop an experimental design plan (Table 5). These instruments were a combination of Likert statements, Likert statements with a free-response and open-ended questions.

Table 5
Correlation of Student Frequency of Response on SMQII, STS, CSQI & CSQSII

Likert Survey Items or Survey or Questions	SMQII Items # 1, 3, 9, 12, 14, 15, 17, and 18			STS Items #7, 8, 9, 14, 15			CSQI #1, 3, 4, 6 & CSQSII #11	
	Student Responses Pre- and Post-Treatment							
	Rubric Score	*% f* Pre-	*% f* Post-	Rubric Score	*% f* Pre-	*% f* Post	*% f* Pre-	*% f* Post-
	5	33%	31%	5	43.24%	35%	N/A	N/A
	4	36%	35%	4	29.73%	28%	0%	9%
	3	24%	27%	3	18.92%	21%	13.6%	27.3%
	2	5%	4%	2	3.6%	8%	32.9%	37.5%
	1	0%	0%	1	0%	3%	53.4%	26.1%
	NA	3%	3%	NA	4.5%	5%	0	0

Note: *N=22*. NA=no answer or unclear and N/A = not applicable. Rubric scale 1 (lowest to 5 (highest). % *f*=percent of frequency of response.

CSQI questions 1 and 3, *studying a local problem will help me understand the work of scientists? Why? and What biological factors influence our local schoolyard? Community?*, correlated with all four questions of the self-efficacy, self-determination, and intrinsic motivation component of the SMQII. CSQI questions 4 and 7, *What type of data and data collection techniques are required to study our schoolyard biodiversity? and What is meant by high quality data in scientific research?*, correlated with STS questions 7, 8, 9, 14, and 15 linking students' interest in tasks related to conducting a field lab with a scientist while exploring a locally based environmental problem through scientific research.

The overlapping theme was a students' strong interest to study a local problem by working with a scientist while conducting a field investigation. Figure 1 shows the correlation of pre- and post-survey results for CSQI and CSQSII that evaluated student's understanding of local biodiversity problems or concerns and the data needed to answer an investigative question that would provide information for a student-proposed solution.

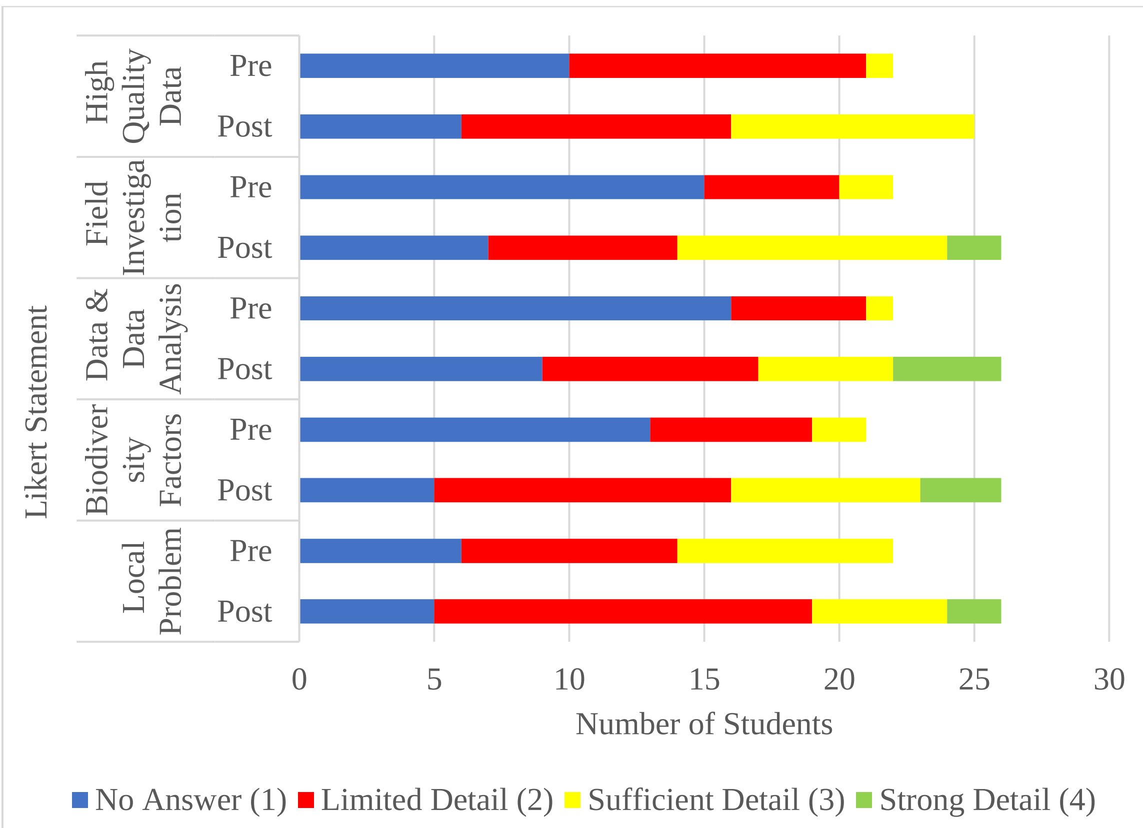

Figure 1. CSQI and CSQSII key items to CSP implementation, (*N*=22).

The pre- and post- CSQI key questions revealed student's understanding of what type of data to collect, data collection techniques and general scientific research methodology. Questions #1 and #2, *What factors influence biodiversity? or Why is* *studying a local problem important to science?*, summarized through the bottom two data sets showed that initially no students were able to give strong details such as specific local environmental problems or factors that were specific to our local area. After the CSP, some students (*n*=3) specifically noted a factor that was related to our SBS. An example from a student was the new portable construction at our high school as a factor influencing the biodiversity or distribution of plants within the schoolyard. Through interviews after the conclusion of the CSP, the number of students mentioning the new construction was higher (*n*=9) than indicated on the CSQI.

The last three subset of questions (data and analysis, field investigation and high-quality data) helped reveal student's understanding of what, where and why to collect data and the important components to ensure validity and reliability of a scientific investigation. The pre-survey questions revealed that many students (*n*=16) were unfamiliar with any type of field investigations, specifically what type of data to collect to answer their investigative questions. Sufficient detail was scored if a student indicated any type of relevant data collection: # of species, species distribution, etc. However, only 50% (*n*=10) were unfamiliar with the basic requirements for high quality data. For a student response to fall within the "sufficient detail" on the rubric they needed to mention at a minimum of three topics, investigative question, hypothesis, and multiple trials. (Figure 2).

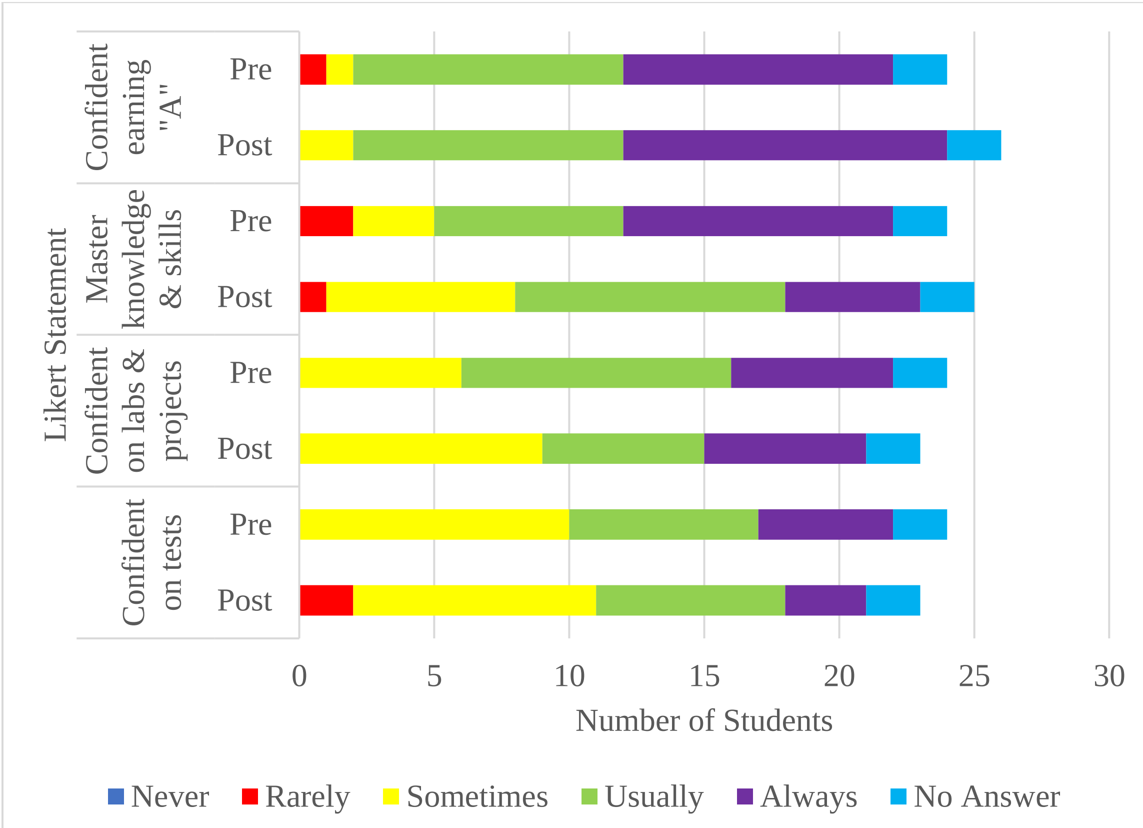

Figure 2. SMQII self-efficacy categorization statements, (*N*=22).

The SMQII four (#9,14,15,18) self-efficacy category questions (Figure 2) highlighted student's belief that they can be successful in a traditional science classroom. The two most relevant questions to this particular study were question #15, *I believe I can master science knowledge and skills,* and question #14, *I am confident I will do well on science labs and projects*. Each of these questions provides insight into a student's psyche regarding their ability to successfully complete an independent, field based CSP. Forty-eight percent of students initially responded that they usually can master science knowledge and skills whereas 38% believe they "always" master science knowledge and skills. There was no practical significance to classroom practices between the pre- and post-treatment for the students who "always" master science knowledge and skills;

however, the “usually” dropped by 50% shifting down towards “sometimes” or “rarely” after conclusion of the SBS.

Additional insight into student thinking was provided in the focus interviews (Appendix I) where students commented on their field experience, decision-making process and working on a local problem. The focused interviews included student comments such as, “We should do more outdoor field labs, but the math is difficult”; another student commented, “some stuff not into, like collecting samples or measuring trees.” Where students may have shown a shift from “strong interest” to “somewhat interest” or “rarely interested” on their SMQII, the interview showed the limitations in analyzing this type of question only within the context of a Likert statement.

SMQII statement #1 (Figure 3), *The science I learn is relevant to my life,#3, Learning science is interesting,* #12, *Learning science makes my life more meaningful, and #18, I am curious about discoveries in science, were found to be correlated as statements of intrinsic motivation regarding science education,* (Glynn, 2011). Initially, 52% (n=11) usually or always feel that science is relevant to their life or 42% (n=9) makes their life more meaningful. After the SBS, these numbers showed a drop of 28% to 23%, respectively.

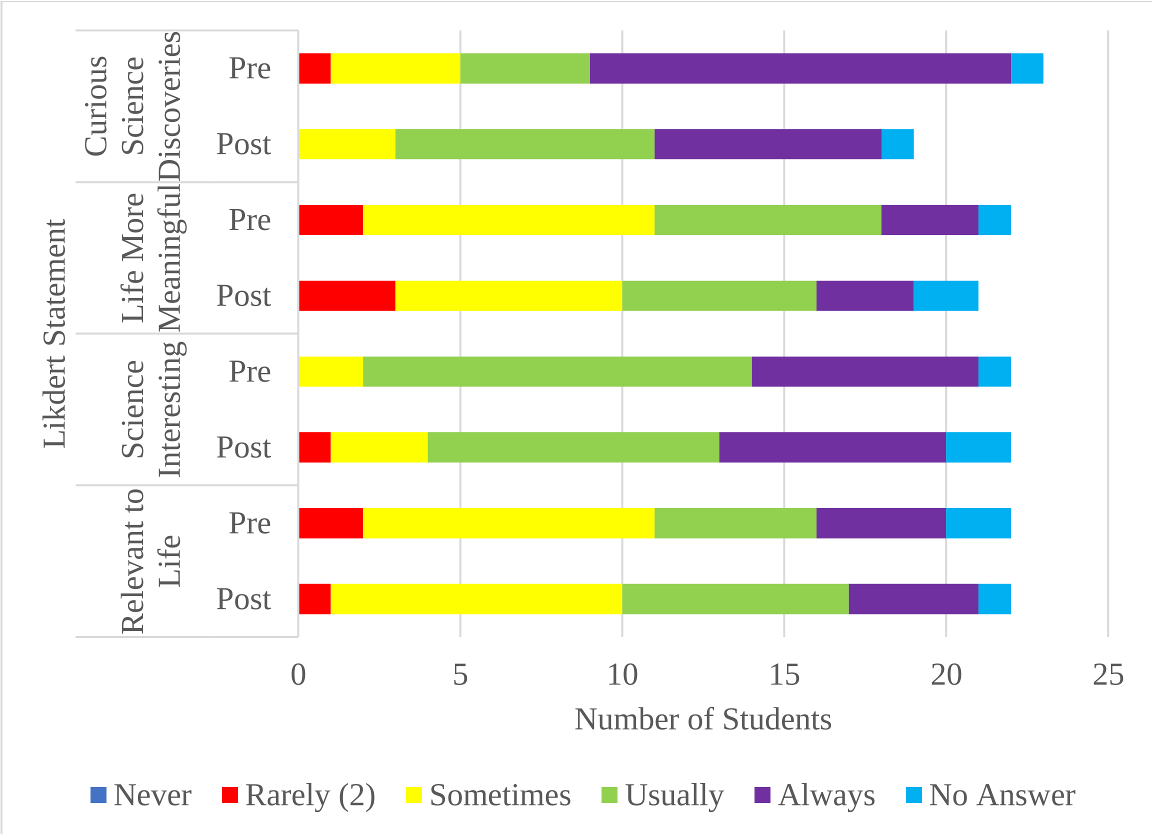

Figure 3. SMQII Intrinsic Motivation categorization statements.

Though we may have failed to make science a relevant topic in their previous classroom activities classroom, the results of many of the STS questions (Figure 4) show that students are interested in authentic, real-world science. More than fifty percent (*n*=14 to 16) of students were interested in working with a scientist either in data collection or exploring a topic. Students also had a strong interest in outdoor based labs (77%, *n*=17) compared to classroom labs (50%, *n*=11). After participating in the SBS, students showed an increase interest in classroom labs to 73% *(n*=16) as well as field labs (86%, *n*=19).

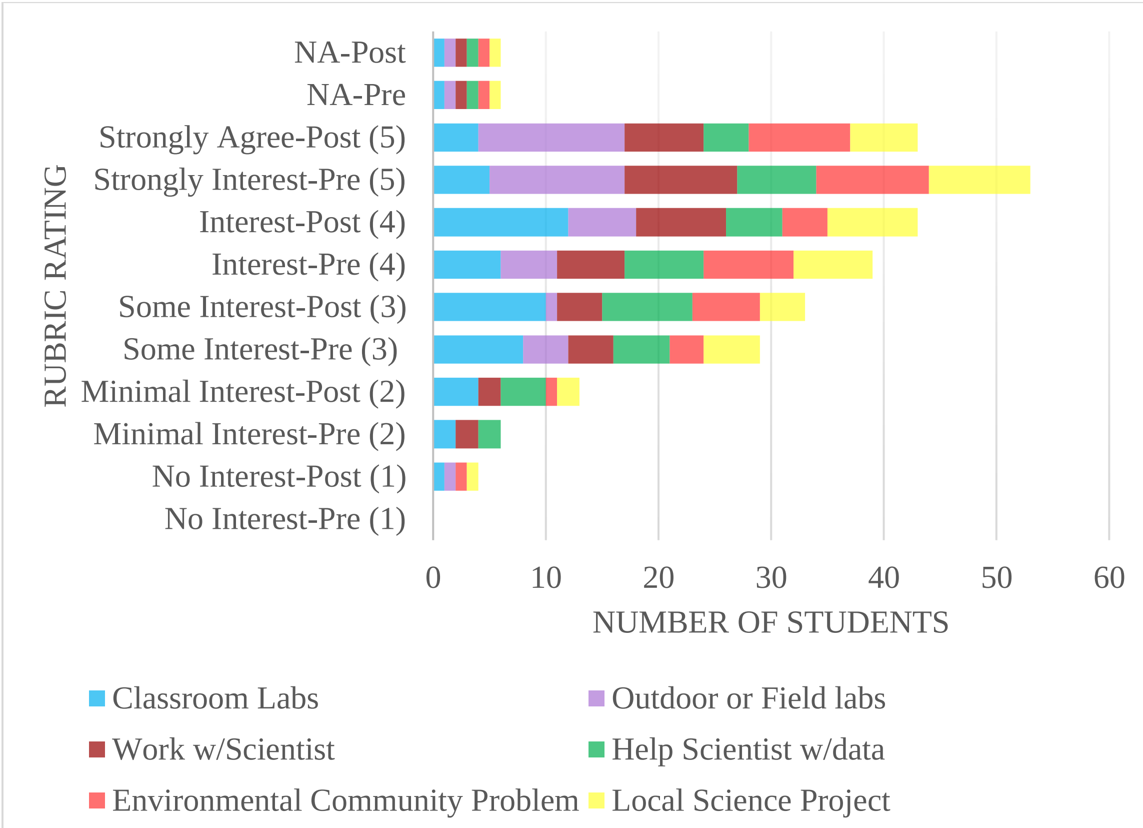

Figure 4. Science Task Survey (STS) key items for CSP, (*N*=22).

After concluding the SBS, two science tasks had the greatest downward shift from strong interest (rubric score 5) to minimal interest (rubric score 2) in regard to statements #8, *working with a scientist* and #14, *participating in an environmentally related community activity*. A practical significance was seen on the STS for tasks related to studying or working on a scientific project related to a local problem shifting. Here, the number of students indicating a strong interest (rubric score 5) changed from a post-treatment of 86% (*n*=19) to 68% (*n*=15) following the conclusion of the SBS (Figure 2).

Further insight into student thinking was revealed in focus group interviews (Appendix I), where some students (*n*=7) mentioned that "field work was challenging and difficult" as well as "data collection was difficult" or "weather was unpredictable." Other students who moved in a positive direction, commented that they “liked to get outside to do science and the classroom to look over results.”

Similar questions posed on the CSQI (Figure 1), *studying a local problem will help me understand the work of scientists? Why?*, initially revealed that 76% (n-=16) demonstrated knowledge of importance of how studying a local problem will help them understand a scientist’s work whereas, at the conclusion of the SBS, 85.7% demonstrated relevant understanding. Students responded with, “It will help because when we study a local problem we get an in depth look as to how scientist do and present work.” and “Large scale problems can often be better understood in a local context.” Or “making the problem more personal.”

The CSQI survey further elicited insight into students’ decision-making and their thoughts on conducting scientific research (Table 5). Open phenomenological coding (delineating themes for ordinal survey data) showed four major themes for question #3, *What factors do you think threaten the biodiversity within our schoolyard? Our local community?;* and included categories such as: pollution, construction (road building or homes), habitat destruction or human population. In the pollution category students mentioned air pollution (a topic not yet explored in class), cars, oil spills, and littering, showing that a few students were critically thinking about this question rather than giving a non-answer or generic response.

Field journal entries (Appendix H) showed that student’s level of science self-efficacy, critical-thinking, and decision-making skills were intertwined in their ability to record relevant scientific observations related to their investigative question. Initial field journals (October and November 2018) showed that 82% (*n*=18) needed improvement on organizing field data (basic data tables to recording information by transects or plots) with 14% (*n*=3) requiring additional training in abiotic and biotic information recording and 23% (*n*=5) on observational scientific details (drawing specimens, specific information on locations, etc.). Whereas the March 2019 field journal entries showed a marked increase in observational scientific details (mapping skills, data organization) to 72% (*n*=17). There was a practical significance from October 2018 to March 2019 with regards to student's knowledge, skills and dispositions as evaluated by the field journal rubric (Appendix J). This final field data collection showed that 77% of students displayed satisfactory (63%) or exemplary (24%) categorization of abiotic and biotic factors related to the SBS. Students were asked to record all biotic or abiotic data that was relevant to their investigative question (Table 3). No matter their question, though, students were asked to record date, time, details of location, organize by transect or plot, collect or photograph or sketch samples, notes regarding plant details to aide in identification, preliminary identification of specimens and draw a simple reference map showing plot or transect location with reference to a school feature. Data Collection skills showed a similar practical significance with 45% to 27% in the satisfactory or exemplary category by March 2019. Dispositions (distributions and level of observation detail) had the greatest increase over the course of the student, with 81% of students moving to the satisfactory (36%) or exemplary (45%) categories.

The initial school mapping (Figure 5) and sketching or recording of specimens (Appendix H) was completed by less than 50% of the students; however, by the end of the SBS more than 72% were providing maps of their study area with dimensions and reference points as well as specimen drawings and field identification of plants. .

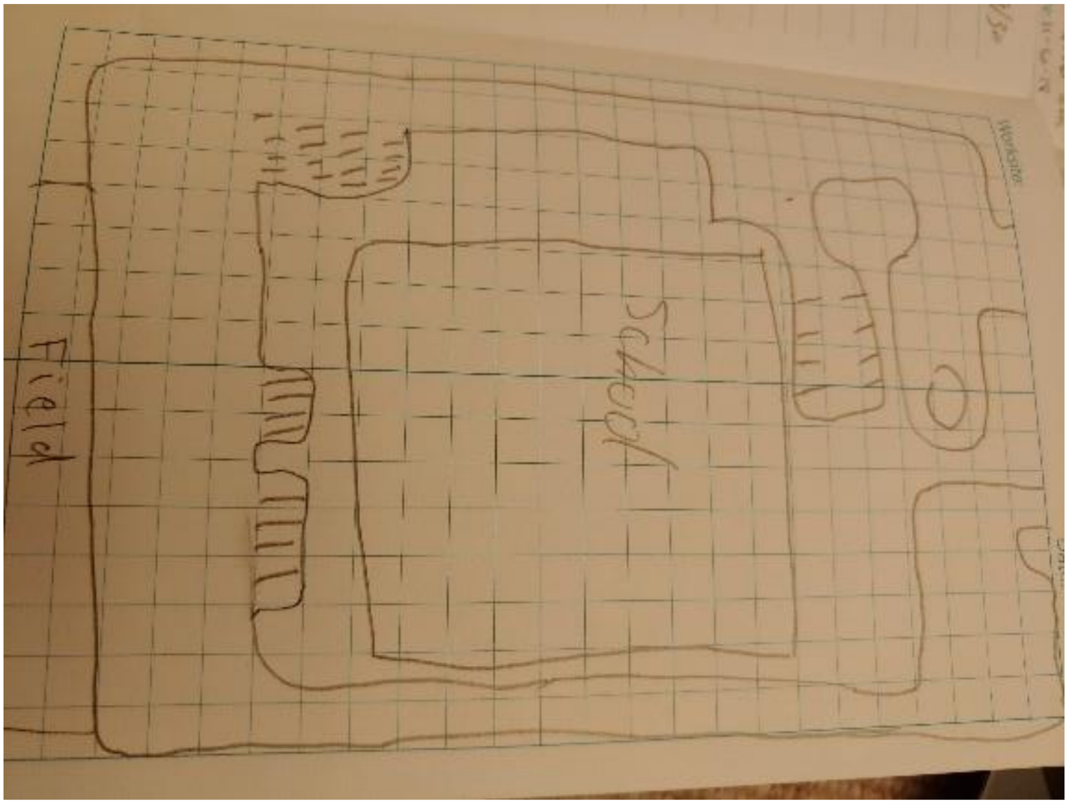

Figure 5. Initial student map.

The final schoolyard biodiversity posters also reflected student's critical thinking and decision-making skills as well as their preferences for certain science tasks and science self-efficacy. Fourteen students (59%, *N*=22) completed their project proposals within the initial timeframe. These 14 students provided an array of proposals representing each of the three areas. After completing data collection, students explored the schoolyard to determine areas where potential solutions to plant biodiversity could be implemented. There were simple proposals that focused on only one plant and didn't attempt to extend their learning to a new concept (pollinator) with little to no connection to the data from the SBS. Contrastingly, other students developed complex proposals which made clear connections to the SBS and potential future learning opportunities for students. The scoring rubric (Appendix J) for the posters revealed that 21% of the students developed a high-level proposal which provided a strong evaluation of the scientific data and justification for the way the dataset was interpreted. A smaller number of students (21%, *N*=22) were also able to develop strong proposals with a high level of critical thinking but were unable to make strong scientific connections or justifications for their data interpretation. Fifty percent of the students developed relatively simple proposals that showed some degree of critical thinking, but which lacked either an in-depth scientific analyses, justification or connection to the SBS. Finally, one student submitted a proposal that was well below grade level work, lacking scientific reasoning, proposal justification and strong scientific data analysis.

INTERPRETATION AND CONCLUSION

This classroom research study purpose was implementation of a CSP as an inquiry, project-based science teaching method. The main research question, How does participation in a CSP impact students critical thinking and decision-making skills?, initially showed students asking low level questions and resisting making their own decisions. Initial phenomenological open coding (answers organized by revealed themes) of the questions #2 and #3 on CSQI revealed that students were critically thinking about specific factors which influence biodiversity such as pollution, construction and habitat degradation; however, students weren’t able to delve into why the factors were important. The factors listed may have been influenced by the current unit of study (pollution and habitat degradation) rather than reflecting a strong critical thinking approach to the general concept of biodiversity and environmental factors. Focus student interviews (Appendix I) and post-survey questions (CSQSII, Appendix D) showed that students had a practical significant gain in this particular area with students providing specific examples, "new building construction specifically our new schoolyard portables" and "our biggest threat to the community is people and their lack of respect and littering". Through the implementation of the SBS, students were able to clearly make connections between their study, their community and the factors that influence the biodiversity within each area. When students are engaged in authentic real-life scientific experiences their learning moves beyond the abstract, rote memorization to relevant, experiential learning experiences as noted in Shah & Martinez, (2016): "Citizen science in the classroom instills community awareness, critical thinking, problem-solving and practical experience in students." (p. 21). Students demonstrated a greater community awareness in their responses to CSQII statement, *I feel connected to the natural surroundings in the place that I live*, with approximately 50% students responding with agree, somewhat agree or strongly agree. The STS also revealed that approximately 59% had an interest or strong interest in a local environmental problem. Most students specifically related a positive connection to their community by working on a CSP within their community, specifically their schoolyard.

As indicated in other studies (Gray et al., 2012), teaching both observational and sampling skills is critical to student's increased confidence in making decisions and critically thinking through the scientific investigative process. Decision-making skills revealed that students clearly understood the basic premise of the scientific investigation, but when queried with designing a field investigation the students were only able to provide a “skeleton” outline of the experimental design. Though field labs focused on written observations, survey skills, and protocols, student’s actions and journals indicated that about 82% (*N*=22) were initially using lower level questioning techniques and were hesitant to make decisions regarding which survey techniques to utilize or specific data to collect. However, after three field training labs focusing on these skills, more than 54% of students were able to determine why and what type of data to be collected and ask higher-level questions on subsequent field trips with science professionals. By the end of the SBS, the majority of students (54%) were able to make independent decisions regarding where to survey, appropriate survey techniques, and what data to collect or record. (Figure 1)

Data and data analysis skills, sub-question #1, improved by 36% in relation to student’s ability to provide strong data collection details (plot information, schematics, measurements, plant identification, further questions). Pre-treatment, students were prone to ask generic questions, state the obvious (take samples, measure) whereas, post-treatment, students were able to list specific data collection techniques (plot versus transect, plant identifying characteristics, proper sampling methodology). Through informal observations and field notebooks, students improved in their data analysis by being able to conduct both statistical analysis of data as well as interpretation of those numbers. This was evident in their final project proposal posters where the majority specifically noted the low schoolyard biodiversity as a factor to their proposed solution.

Sub-question #2, How do student attitudes towards science or science self-efficacy change throughout the CSP? is addressed through the SMQII and CSQSII. On the SMQI, there was a three percent downward shift in student response from “strongly agree” to lower categories (agree, somewhat agree, etc.) between the pre- and post-surveys. The STS revealed that at the beginning of the SBS students had a strong sense that they were capable of mastering science knowledge and skills; however, this sense of confidence dropped dramatically after the SBS. During focused interviews, students indicated that the content material and field work was more challenging than previous classes. Academically these students (59%, *N*=22) had taken advanced science courses (SLHS, n.d.) but few to no experiences with self-directed labs, multiple science topic interactions (biology with chemistry) or real-life science scenarios. This data is a possible indicator that on the pre-surveys students had an overconfidence regarding their ability to master science knowledge and skills, but those particular courses primarily focus on rote memorization rather than application of science skills.

In this study, students were tasked with making their own decisions on all aspects of this project, which differed greatly from previous science classroom experiences. If a student’s intrinsic motivation is high there is strong evidence that they are more likely to use higher critical thinking skills, have stronger decision-making skills and a high self-efficacy (James & Williams, 2017). This was evidenced by students through interviews and casual conversations that they felt more confident in their understanding of what a scientist does in the real-world and biodiversity and their schoolyard.

Sub-question #3, How does student interest in science tasks change throughout the CSP? addressed through the STS and focus interviews. Science task preferences changed significantly from a practical classroom application in three major areas: microscope use, field labs, classroom labs, studying a local problem or environmentally related project. The first two had a major shift from “no interest or minimal interest” to “interest or strong interest”. Student were completely fascinated with examining lichen, macroinvertebrates, water, air quality and soil samples through a dissecting and high-powered computerized microscope. For some students this was the first time utilizing either instrument.. A small proportion of students did display a major negative shift in their preference towards utilizing chemical analysis as a data collection tool, specifically a disinterest in analyzing water, air or soil samples. Many of these same students also indicated they liked collecting experimental datasets, but not analyzing them. The results may be directly correlated to their dislike for mathematical computation and writing intensive scientific reports. James & Williams (2017) found that “scaffolding the learning from the classroom to the field, and then back to the classroom results in memorable, comprehensive and long-term learning.” (p. 59), which was supported by student’s STS and open-ended survey questions indicating a greater preference for a combination of conducting field study then analyzing or discussing in the classroom. In the final project interviews and informal conversations expressed a desire to continue participating in field related labs especially those tied to their community.

The implementation of the SBS positively impacted my teaching, sub-question #4, in that it forced me to explore different ways to engage my students in scientific thinking, questioning techniques and reflection. The discourse varied depending on student interest in specific activities and the class as a whole. Three students indicated a disinterest in most environmental or field activities, which became a contentious point during some discussions. At times, management of their disinterest could have overrun the whole discourse process, but I found that if I could discover something they could engage in, said students would move beyond trying to disrupt the learning of others. I also found it beneficial to redirect students at times, as exemplified by the need to re-redirect one student who wanted to give her proposal presentation on ways to improve the local biodiversity of ladybugs and butterflies. By helping the student focus on her presentation idea during in-class discussions, I found she was not as negative about discussions related to data collection and/or complaining about necessary data analysis.

Overall, student feedback helped me see where questions required further clarification, better wording, and areas that required more structure or foundation prior to independent student learning or investigation.

VALUE

Currently the next steps are to develop a plan where students involved in an SBS are continually collecting and analyzing data. This will allow students to develop a reliable and valid dataset which can be incorporated into their final lab reports and presentations. Additional contacts with a local arborist, ecologist and district maintenance team will be sought out to provide more expert advice to help answer student questions. This research project is still relevant as a new inquiry approach to science learning and is very applicable to multiple classrooms and age groups. As this classroom research project continues to evolve throughout the semester, my support team will be able to assist with additional statistical analysis of data and serve as preliminary “fake community groups” for students to practice their presentations. Finally, I would recommend that anyone exploring the incorporation of an SBS consider a tighter timeframe with an established CSP (online or local) for their initial project. Students in their final CSQSII post-project questions 13-18 revealed that more structure within a narrower timeframe would be easier to comprehend. Students' reflections showed that they loved the inquiry and self-direction but would like to see more organization of the field labs with samples of science poster proposals. This last request will be easier as more CSP's are implemented in classrooms across the country and published in the scientific literature.

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APPENDICES

APPENDIX A

OPEN-ENDED PRE-PROJECT SURVEY

Open-ended Citizen Science Questionnaire

Author: Paula Langager

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way

1. What does Citizen Science Project mean? What do you believe is meant by a Citizen Science Project?
2. If you could participate in a Citizen Science Project or Science Research Project, what topics would interest you?
3. If the project was limited to the following topics, which would you choose?
    a. Population Study
    b. Ecosystem Study
    c. Air Quality Study
    d. Plant Study
    e. Biome Study
    f. Lake Water Quality Study

APPENDIX B

INSTITUTIONAL REVIEW BOARD CERTIFICATION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects FWA 00000165

960 Technology Blvd. Room 127Chair: Mark Quinn

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MEMORANDUM

TO: Paula Langager and Walter Woolbaugh

FROM: Mark Quinn 1/(-a.Jc e-.+1
Chair, Institutional Rev Board for the Protection of Human Subjects

DATE: October 8, 2018

RE: "The Effect of Implementing a Citizen Science Project into a High School Science Classroom" [PL100818-EX]

The above research, described in your submission of October 7, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

x___________ Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

x___________ Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

b) (4)Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5)Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

_____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C

CITIZEN SCIENCE CRITICAL THINKING & DECISION-MAKING QUESTIONNAIRE I (CSQI)

Citizen Science Critical Thinking & Decision-Making Questionnaire I (CSQI)

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way.

1. Studying a local problem will help me understand the work of scientists? Why?
2. Why is biodiversity important and how can it be preserved?
3. What factors do you think threaten the biodiversity within our school yard? Our local community?
4. What type of data and data collection and analysis is needed to evaluate the biodiversity of our local schoolyard and the factors that influence the biodiversity?
5. What is the biodiversity (plants) index of our local school yard? How does this compare to the larger area (our community, the Clover Creek Watershed)?
6. How or what does our school yard biodiversity or habitat contribute to the native pollinators in the area? What type of data and data collection and analysis is needed to explore this question?
7. If you were to design a field investigation that explored the biodiversity of the habitat of our schoolyard, what question would you explore? What equipment would you need? Why would you explore that question?

APPENDIX D

CITIZEN SCIENCE ACTIVITY SURVEY II (CSQSII)

Citizen Science Project Questionnaire Survey (CSQSII)

Author: Paula M. Langager, Adapted from similar questionnaire in Lorenz, 2016.
Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way.

Rating Scale: 1 (Strongly Disagree), 2 (Somewhat Disagree), 3 (Disagree), 4 (Neutral), 5 (Agree), 6 (Somewhat Agree), 7 (Strongly Agree)

Statement	**Rating**
Science is important in my everyday life.	**1 2 3 4 5 6 7**
Please explain:	
I believe that I will use scientific knowledge and skills throughout my life.	**1 2 3 4 5 6 7**
Please explain:	
I believe science can be beneficial	**1 2 3 4 5 6 7**
Please explain:	
I believe science can be harmful.	**1 2 3 4 5 6 7**
Please explain:	
Only certain people are able to do science.	**1 2 3 4 5 6 7**
Please explain:	
Every question in science has been answered.	**1 2 3 4 5 6 7**
Please explain:	
I feel connected to the cultural heritage of the place I live: Cultural heritage: legacy of physical artifacts (structures, etc.) and intangible attributes (history, stories)	**1 2 3 4 5 6 7**
Please explain:	
I feel connected to the natural surroundings in the place that I live:	**1 2 3 4 5 6 7**
Please explain:	
I feel that the place I live has influenced my interests in life:	**1 2 3 4 5 6 7**
Please explain:	
Please rate on a scale of 1 (no understanding) to 7 (full understanding):	
When you read the phrase "scientific research," how much do you feel you understand it?	**1 2 3 4 5 6 7**

11. In a few sentences, describe what high quality data collection and analysis means to you:

Complete the following questions at the end of the project

12. In your own words, describe what it means to do scientific research:

Can you give an example from our Project?

13. List and describe what you believe are key scientific reasoning skills needed to conduct scientific research? Which of these scientific reasoning skills do you seeing being pertinent to our classroom research project?

13. Describe the components of a citizen science project (What is needed to conduct a citizen science project about our schoolyard biodiversity?):

What did you like about the project, and in what ways did it help you learn science?

What suggestions might you have for me should I do this project again?

APPENDIX E

SCIENCE MOTIVATION QUESTIONNAIRE II

& CATEGORIZATION SHEET

Science Motivation Questionnaire II*

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way

In order to better understand what you think and how you feel about your high school experience, please respond to each of the following statements from the perspective of "When I am in a high school science course…"

The science I learn is relevant to my life	N	R	S	U	A
I like to do better than other students on science tests	N	R	S	U	A
Learning science is interesting	N	R	S	U	A
Getting a good science grade is important to me	N	R	S	U	A
I put enough effort into learning science	N	R	S	U	A
I use strategies to learn science well	N	R	S	U	A
Learning science will help me get a good job	N	R	S	U	A
It is important that I get an "A" in science	N	R	S	U	A
I am confident I will do well on science tests	N	R	S	U	A
Knowing science will give me a career advantage	N	R	S	U	A
I spent a lot of time learning science	N	R	S	U	A
Learning science makes my life more meaningful	N	R	S	U	A
Understanding science will benefit me in my career	N	R	S	U	A
I am confident I will do well on science labs and projects	N	R	S	U	A
I believe I can master science knowledge and skills	N	R	S	U	A
I prepare well for science tests and labs	N	R	S	U	A
I am curious about discoveries in science	N	R	S	U	A
I believe I can earn a grade of "A in science	N	R	S	U	A

*Modified from Science Motivation Questionnaire II © Shawn M. Glynn 2011.

Science Motivation Questionnaire II (SMQ-II): Components

In order to better understand what you think and how you feel about your science courses, please respond to each of the following statements from the perspective of "When I am in a science course…"

Components (Scales) and Statements (Items)	Never 0	Rarely 1	Sometimes 2	Often 3	Always 4
Intrinsic Motivation					
01. The science I learn is relevant to my life.					
03. Learning science is interesting.					
12. Learning science makes my life more meaningful.					
17. I am curious about discoveries in science.					
19. I enjoy learning science.					
Self-Efficacy					
09. I am confident I will do well on science tests.					
14. I am confident I will do well on science labs and projects.					
15. I believe I can master science knowledge and skills.					
18. I believe I can earn a grade of "A" in science.					
21. I am sure I can understand science.					
Self-Determination					
05. I put enough effort into learning science.					
06. I use strategies to learn science well.					
11. I spend a lot of time learning science.					
16. I prepare well for science tests and labs.					
22. I study hard to learn science.					
Grade Motivation					
02. I like to do better than other students on science tests.					
04. Getting a good science grade is important to me.					
08. It is important that I get an "A" in science.					
20. I think about the grade I will get in science.					
24. Scoring high on science tests and labs matters to me.					
Career Motivation					
07. Learning science will help me get a good job.					
10. Knowing science will give me a career advantage.					
13. Understanding science will benefit me in my career.					
23. My career will involve science.					
25. I will use science problem-solving skills in my career.					

Note. The SMQ-II is copyrighted and registered. Go to **http://www.coe.uga.edu/smq/** for permission and directions to use it and its discipline-specific versions such as the Biology Motivation Questionnaire II (BMQ-II), Chemistry Motivation Questionnaire II (CMQ-II), and Physics Motivation Questionnaire II (PMQ-II) in which the words *biology*, *chemistry*, and *physics* are respectively substituted for the word *science*. Versions in other languages are also available.

APPENDIX F

SCIENCE TASK SURVEY

SCIENCE INTEREST TASK SURVEY

This survey is intended to serve as an instrument to measure students interests in particular science related tasks. Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way

Rating Scale:

1 – No Interest, 2 – Minimal Interest, 3- Some Interest, 4 – Interest, 5 – Strong Interest

Science Activity	Rating				
Using a microscope to look at specimens	1	2	3	4	5
Using a microscope to measure specimen samples	1	2	3	4	5
Collecting water, soil or air samples from different sites in the community	1	2	3	4	5
Analyzing water, soil or air samples through chemical analysis	1	2	3	4	5
Analyzing water, soil or air samples with electronic data probes	1	2	3	4	5
Classroom lab investigations	1	2	3	4	5
Outdoor or Field lab investigations	1	2	3	4	5
Working with a scientist to explore a topic	1	2	3	4	5
Helping a scientist collect data for a research question	1	2	3	4	5
Using art to explore an ecosystem and its interactions	1	2	3	4	5
Using art as a scientific data tool	1	2	3	4	5
Reading about science research	1	2	3	4	5
Working with a group to study a research question	1	2	3	4	5
Participating in an environmentally-related community activity	1	2	3	4	5
Studying or Working on science projects related to problems in my community	1	2	3	4	5

APPENDIX G

BIOLOGICAL POPULATION SAMPLING ACTIVITY

How Big is My Population?

Go to: http://mathbench.umd.edu/modules/env-science_sampling/page01.htm

Name: ____

1: **Counting Big Populations:** How do scientists estimate the size of a large population?

2: **Sampling on a grid:** To count the dandelions, we'll first create a grid, then use the computer's random number generator to tell us which grid squares to count. We'll do this 10 times, because, as you'll see, the counts in the different grid squares will vary a lot. After you count 10 squares, you'll use the average number per square to estimate the population of the entire lawn.

How many dandelions are there on the grid? ____________

3: **Scaling it Up:** What does it mean that we scaled it up?

4: **Keeping it Random:** Why is it important to ***randomly*** select segments to count?

5: **When Size Matters:** What is the simplest way to determine the appropriate sample size?

6: **Bare Bones Sampling:** What is the difference between measuring abundance versus Presence/absence?

7: **Collecting P/A Data:** *Counting Moss*.. How do we estimate sample size?

8: **Impervious Surface:** How do we estimate impervious surface? Explain.

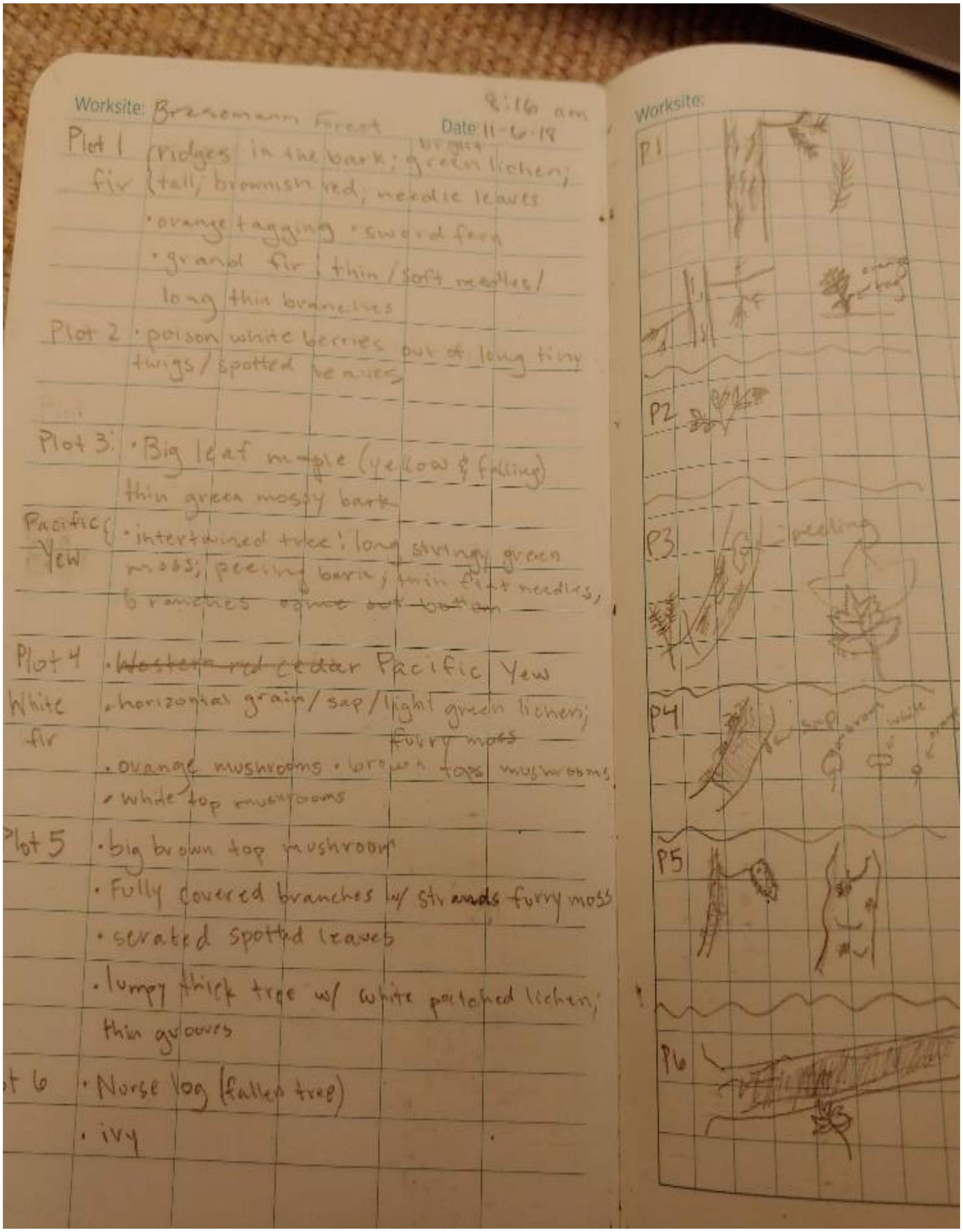
9: **Getting Fancy:** What are the *steps* for conducting a simple transect?

10: **Try a Transect:**

Summary: *Explain what you learned by doing this activity*

APPENDIX H

SAMPLE STUDENT FIELD JOURNAL



Worksite: Bresemann Forest   8:16 am   Date: 11-6-18

Plot 1 fir: ridges in the bark; bright green lichen; tall, brownish red, needle leaves

· orange tagging · sword fern

· grand fir; thin/soft needles/ long thin branches

Plot 2 · poison white berries out of long tiny twigs/spotted leaves

Plot 3: · Big leaf maple (yellow & falling) thin green mossy bark

Pacific Yew · intertwined tree; long stringy green moss; peeling bark; thin flat needles; ~~branches come out bottom~~

Plot 4 · ~~Western red cedar~~ Pacific Yew

White fir · horizontal grain/sap/light green lichen; ~~furry moss~~

· orange mushrooms · brown tops mushrooms

· white top mushrooms

Plot 5 · big brown top mushroom

· Fully covered branches w/ strands furry moss

· serrated spotted leaves

· lumpy thick tree w/ white patched lichen; thin grooves

t 6 · Nurse log (fallen tree)

· ivy

Worksite:

P1 orange tag

P2

P3 peeling

P4 sap brown white

P5

P6

APPENDIX I

FOCUS GROUP INTERVIEW QUESTIONS

Focus Group Interview Questions (March 2019)
Author: Paula M. Langager, Adapted from Miller, 2018 & Newman, 2018.
Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way.

Students asked if they could use a Likert scale of 1 to 5 to rate their responses during the interview and then offer elaboration.
Likert scale (determined by students): 1 – No affect, 2- some affect, 3- affected, 4- moderate affect, 5 – strong affect.

1. How do you think the schoolyard ecology field experience change your data collection skills?
    a. Follow-up: How does this differ from traditional science labs?
    b. Follow-up: Which has been more beneficial to increasing your data collection skills – field lab or traditional lab? Specific examples of labs? Why those labs?
2. Did the field ecology study change your science self-efficacy (your belief in your ability to do science)? If yes, how so?
    a. Follow-up: Why do you believe that?
3. How did participation in the schoolyard ecology field experience change your critical thinking skills?
    a. Follow-up: Why do you believe that?
    b. Follow-up: Would you have gained similar skills in a traditional lab?
        i. If so, which ones? Why?

4. Did our schoolyard field ecology study impact your attitude towards science? If so, how?
    a. Follow-up: How did this compare to the traditional labs?

APPENDIX J

RUBRICS

CSQI & CSQSII Rubric

Questions/Scale	1	2	3	4
Importance of biodiversity and its preservation	Unclear or Answer of "not sure"	Biodiversity mentioned in a general sense but lacks critical elements	Includes more specific examples of biodiversity importance and 1 or 2 preservation options	Detailed explanation of importance of biodiversity with more than 2 preservation options
Factors threatening our schoolyard? Our local community?	No factors listed or just a list of factors without explanation	1 factor listed for one category only with some explanation	2 to 3 factors listed from one category only with some explanation	3 or more factors for both with detailed explanations
Data and data analysis needed to evaluate biodiversity – schoolyard? Factors influencing biodiversity?	No tools, measurements, sampling techniques listed	1 type of tool, measurement, sampling technique mentioned, 1 factor that influences that collection	2 types of tools, measurements, sampling techniques, 2 factors that influence that collection	3 or more types of tools, measurements, sampling or analyzing techniques, 2 factors that influence
What is the biodiversity (plant) index of our local schoolyard?	Unsure or no answer	General answer without specific reference to plants within schoolyard	Answer includes plants in schoolyard alluding to their current percentages	Answer includes specific reference to number of plants and types of plants
Native pollinators and local schoolyard biodiversity (extension of learning to new area not covered in SBS)	Unsure or answer is unclear or off-topic	Alludes to native pollinators but missing strong connection	General examples related to native pollinators	Strong examples related to local biodiversity and native pollinators
Question & equipment to conduct biodiversity field investigation	No design proposal	Limited proposal with skeleton of ideas but lacks specifics	Proposal with some proposed measurement tools or potential questions	Strong proposal with question, measurement tools, and analysis techniques
Describe high quality data collection and analysis means to you (CSQSII-Question #11)	No answer or unsure or unclear	Mentions general scientific investigation but no specifics like variable, or controls or researchable question	Mentions specifics but only 1 or 2 of the following: variables, multiple trials, researchable question, hypothesis	Variables, control, interpretation related to question and hypothesis, multiple trials, peer reviewed

Field Notes/Field Book Scoring Rubric

	Needs Improvement (3)	**Satisfactory (4)**	**Exemplary (5)**	**Score**
Knowledge	Information recorded on materials is accurate; information recorded on relevant biotic or abiotic features is accurate	Information recorded on biotic species or abiotic factors, abundance of species and location is accurate within student's background; information recorded on spatial dimensions, distribution, and physical relationships is accurate within student's background;	Information recorded on biotic species or abiotic factors, abundance of species and location is consistently accurate; information recorded on spatial dimensions, distribution, and physical relationships of relevant abiotic or biotic features is consistently accurate	
Skills	Observations recorded completely within limits of student's background; required measurements are recorded; presentation of data is organized; graphical or pictorial representations is present;	Observations recorded feature relevant information on materials and relationships; accurate measurements are recorded; presentation of data is clear and well-organized; graphical or pictorial representations highlight relevant features	Observations recorded completely convey relevant features, materials, and relationships; measurements recorded consistently and accurately; presentation of data is clear, concise, and consistently well-organized; graphical or pictorial representations are representative, accurately scaled, with relevant features highlighted	
Dispositions	Observations reflect full participation in exercise; basic interpretation of field relations is provided; inclusion of relevant information	Distribution and detail of observations reflects exploration; attempt is made to interpret field relationships; inclusion of most highly relevant information	Distribution and detail of observations reflects optimal planning and execution; interpretation of field relations provides basis for continued inquiry; questions and/or predictions reflect reasonable hypothesis construction; inclusion of all relevant information; evaluate the accuracy and uncertainty of data within the detection limits of the equipment or observational technique	

Adapted from *Rubric for field notes/field books* created by Eric J. Pyle, Department of Geology & Environmental Science, James Madison University

Rubric for Science Poster

Criteria	1	2	3	4
Organization	• Clutter, no definitive sections, all over the place • Not all sections present	• No heading, but sectioned • Hard to follow, requires assistance • Missing parts • Obvious refinement required	• All present but unclear • Must reread for clarity • Some evidence of refinement	• Defined sections • Clear headings • Flows nicely to assist the reader without help • Finished product
Creativity	• Bland, no variability • No use of colour or diagrams • Boring to look at, does not catch your attention • Interest, motivation, effort and time obviously absent	• Very little use of colour or pictures but enough to engage and hold attention	• Some use of colour, diagrams, etc. • Will engage but will not stimulate	• Interesting, engaging, visually stimulating • Aesthetically appealing use of colour, diagrams and text • Interest, motivation, effort and time obviously present
Science Content and Literacy	• No analysis of science topic • No explanation • No science specific connection • No use of resources	• Poor explanation • Inaccurate science connection • Misinterprets the science • One resource for sure	• Adequate explanation • Science connection present but could be developed further • More than one resource present	• Appropriate dsl • Concept fully and properly explained • Insight present • Science specific connection made • Content is accurate, comprehensive and well supported • Excellent use of resources
Level and Difficulty of Understanding	• Task difficulty not suitable for grade level/not related to science (too easy) • Superficial/irrelevant task	• Explanation describes minimal level of validity • Needs serious refinement	• Task difficulty could be increased or developed • Some level of understanding shown	• Difficulty appropriate for grade level • Understanding present and apparent

Regina Public School, June 2003