The Confluence of STEM Education and Language Learning: Curriculum Integration to Benefit Language Learners

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THE CONFLUENCE OF STEM EDUCATION AND LANGUAGE LEARNING:
CURRICULUM INTEGRATION TO BENEFIT ENGLISH LEARNERS

by

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A capstone submitted in partial fulfillment of the requirements
for the degree of Master of Arts in English as a Second Language

Hamline University
St. Paul, Minnesota
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CHAPTER ONE: INTRODUCTION

My Background

I am an ESL teacher at a STEM elementary school located in a first-ring suburb of a major Midwestern metropolitan area whose student population has changed dramatically over the past two decades. The demographics have shifted from being homogeneously white to an extremely diverse population culturally, linguistically, and economically. Thirty-two percent of the students at our school are English learners, with a large Spanish-speaking first-language population. Additionally, 59% of students qualify for free or reduced cost lunch.

I find my job as an elementary ESL teacher both challenging and rewarding as it requires me to constantly reflect on and improve my instruction to meet the diverse linguistic and cultural backgrounds of my students. I recently completed a STEM certification from St. Catherine University. My final project was to adapt an engineering unit to meet the needs of ESL students. I wrote content and language objectives, added best practices for teaching ELs, and developed assessments for multiple modalities. This experience had a profound impact on my teaching practices in that it was taught in an integrated and engaging manner. I strongly believe that teaching ELs using an integrated, thematic, and project-based curriculum has a positive impact on student learning. While an integrated curriculum is proposed as a best practice for teaching ELs both STEM subjects and academic language, there exists several obstacles in implementing such an approach in elementary schools.

Many schools have a pre-established curriculum that teachers are mandated to follow. In other instances, teachers lack the necessary planning time to properly develop integrated units of
study according to best practices. Finally, many educators find lesson planning templates that integrate multiple subjects to be confusing, tedious, and unhelpful.

I also recently took part in an internship at the University of Minnesota in conjunction with the Mayo Clinic in a program called InSciEd Out. This innovative program links higher education and the science community with K-12 public schools. The University of Minnesota and the Mayo Clinic provide human, scientific, and technological support for K-12 students in their quest to implement authentic inquiry in the K-12 science classroom.

During the internship, I was able to participate as a learner and scientist. Our team of teachers made observations, developed novel questions, selected appropriate methods, conducted real experiments in the lab, and communicated our finding to real scientist at a poster session at the University of Minnesota. I saw science from the students’ perspective and this allowed me to see the integrated nature of scientific inquiry and the need for implementation of a project-based program model. Additionally, I saw the benefits firsthand of how partnerships with higher education will work for our K-12 students.

The STEM Crisis

A major initiative of the United States federal government is to increase the number of students pursuing advanced degrees in science, technology, engineering, and math (STEM). Clearly the jobs of the future are in these STEM fields, but projections indicate that the US will be unable to meet the demand with a supply of well-trained workers. In a recent international study of 15-year old students, the US ranked 28th in math literacy and 24th in science literacy. The US also ranks 20th among all nations in the proportion of 24-year olds who earn degrees in natural science or engineering (Kuenzi et al. 2006). Additionally, there exists a profound achievement gap between white and non-white students in US elementary assessments in STEM
areas, with non-white populations substantially underrepresented in STEM fields. More specifically, Minnesota holds the dubious distinction of having one of the largest discrepancies between low-income students and their higher-income peers in several measures of STEM-related academic performance (Wascalus, 2015).

In response to these worrying trends, the US government has championed several STEM initiatives. President Obama has identified three overarching priorities for STEM education: 1) improve students’ competencies in the STEM areas, 2) grow the number of students pursuing a post-secondary degree in the STEM areas, and 3) increase minority and female workers in these fields (Best Practices in Elementary STEM Programs, 2012). While these are worthy goals, there are limited data on the effectiveness of elementary STEM schools, particularly with regard to their ability to lower the achievement gap. Little research exists on specific curriculum designs that are effective for English Learners (ELs) at developing language proficiency and content knowledge in the STEM areas. ELs are the workforce of the future. They represent a huge demographic of the future workforce and have the added skill-set of being bilingual.

Unfortunately, the Common Core Standards are often interpreted by teachers and administrators alike as an itemized list of teaching topics to check off the list so students can pass a test. Too often teachers rely on rote learning to memorize facts in science. Unfortunately, children are left behind, the majority of them being students of color, many of whom speak a language other than English at home. Drew (2011) reported that approximately 40% of college students who declare science majors change them, often within the first year, because of low or failing grades in introductory science classes. This negative trend is amplified for women, African Americans, American Indians, and Latinos/Latinas who are already underrepresented in STEM (Herrera and Hurtado 2011).
Title I funds, ESL funds, and other sources are dedicated to the problem with specific guidelines and initiatives. These targeted services often pull the student out of their normal classroom environment and result in a school day with little focus, a fragmented approach to education. Traditional methods of lecture, teacher talk, rote learning, and memorization of facts is still the norm in many K-12 schools. In these schools, language learners are left juggling disconnected subjects with little chance to engage in authentic practice with the English language.

While the need for STEM education reform is widely recognized by educators and public policy experts, solutions are either vague or short-sighted. Instead of recommending an integrated approach based on the application of knowledge and language, content is most often presented in compartmentalized “silos.” This approach allows teachers to check off objectives from a list and plan in a cut-and-dry manner, but it does not factor the complexity of learning and the application of knowledge and skills (Dickstein, 2010).

**STEM and ESL**

The first challenge for any teacher is to engage learners in the subject matter and content. STEM content must be applicable to students’ lives, relevant, and engaging. We must utilize diverse teaching methodologies to cater to students’ multiple intelligences and learning styles. Additionally, STEM education must meet the needs of the ELs in the classroom with varying degrees of English language proficiency without watering-down the content. When we talk about the need for a more robust STEM education, we cannot simply continue to separate the curriculum into silos. STEM needs to integrate all of its disciplines, as well as the language structures needed to communicate in an academic manner (Dickstein, 2010).
While there exists substantial academic literature on STEM education, there are fewer resources and studies on teaching ELs and LEP students within a STEM education program model. Some articles discuss “modification” or “adaptations” to a STEM curriculum to better serve the needs of ELs; however, few articles propose that ESL best practices and STEM education are mutually beneficial programs. STEM inherently includes experiments, engineering design, visuals, realia, and technology. In my estimation, these components are perfect for teaching ELs because they bring the curriculum to life in a language-rich and contextualized environment. Conversely, teaching utilizing ESL methods and best practices enhances the learning of all students because it focuses attention on the academic English necessary to communicate effectively in these disciplines. There exists an incredible opportunity to simultaneously teach both STEM subjects and academic language to all students. These traditionally separate teaching areas actually have complementary, and mutually beneficial, planning practices and teaching methodologies.

Early findings suggest that high school students in Texas’ 51 inclusive STEM schools score higher on the state mathematics and science achievement tests, are less likely to be absent from school, and take more advanced courses than their peers in schools with similar demographics. This data is relatively recent and the schools were able to achieve these gains within their first three years of operation (National Research Council, 2011). While the data from Texas is intriguing, it only focuses on high school STEM schools. Creating the foundation to succeed in the STEM content areas, as well as sparking the desire to pursue higher education is laid during the elementary years. However, little data is available on the efficacy of implementing STEM programming at the elementary level.
Analysis Metro Area Elementary STEM Schools

We begin with an analysis of elementary STEM schools within a major metropolitan area compared with the average scores for the school districts in which they reside. These scores are also compared to the state averages. The elementary STEM schools selected had a substantial and statistically significant EL population of at least 10% of their overall school’s population. The metrics used are the state’s most recent data on high-stakes achievement tests for third through fifth grade students in the English language, reading, math, and science. A sample of elementary metro-area STEM schools with significant English learner populations was selected. Additionally, the overall data for these school districts was included in order to conduct a comparative analysis.

Table 1. Comparative Analysis Metropolitan Area Elementary STEM School Test Scores

<table>
<thead>
<tr>
<th>School</th>
<th>EL Population</th>
<th>EL Proficiency</th>
<th>Science ELs - 5th</th>
<th>State Reading EL Trend 3-5</th>
<th>State Math EL Trend 3-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birchbark STEM</td>
<td>32.30%</td>
<td>54.50%</td>
<td>32.30%</td>
<td>31%</td>
<td>46.80%</td>
</tr>
<tr>
<td>District 3rd-5th</td>
<td>34.00%</td>
<td>40.30%</td>
<td>28.20%</td>
<td>26%</td>
<td>40.40%</td>
</tr>
<tr>
<td>State Average ELs</td>
<td>8.30%</td>
<td>30.40%</td>
<td>15%</td>
<td>24%</td>
<td>24.50%</td>
</tr>
<tr>
<td>Carver STEAM</td>
<td>19.40%</td>
<td>41%</td>
<td>60%</td>
<td>45%</td>
<td>51%</td>
</tr>
<tr>
<td>District 3rd-5th</td>
<td>5.90%</td>
<td>32.10%</td>
<td>25.9%</td>
<td>20.00%</td>
<td>33.60%</td>
</tr>
<tr>
<td>State Average ELs</td>
<td>8.30%</td>
<td>30.40%</td>
<td>15%</td>
<td>24%</td>
<td>24.50%</td>
</tr>
<tr>
<td>Solar STEM</td>
<td>47.30%</td>
<td>15.60%</td>
<td>16.70%</td>
<td>29.60%</td>
<td>40.40%</td>
</tr>
<tr>
<td>District 3rd-5th</td>
<td>34.50%</td>
<td>12.10%</td>
<td>11.50%</td>
<td>19.90%</td>
<td>33.50%</td>
</tr>
<tr>
<td>State Average ELs</td>
<td>8.30%</td>
<td>30.40%</td>
<td>15%</td>
<td>24%</td>
<td>24.50%</td>
</tr>
<tr>
<td>River Bluff STEM</td>
<td>19.20%</td>
<td>42.30%</td>
<td>NA</td>
<td>45.70%</td>
<td>75.70%</td>
</tr>
<tr>
<td>District 3rd-4th</td>
<td>12.4%</td>
<td>32.5%</td>
<td>27.9%</td>
<td>44.9%</td>
<td></td>
</tr>
<tr>
<td>State Average ELs</td>
<td>8.30%</td>
<td>30.40%</td>
<td>24%</td>
<td>24.50%</td>
<td></td>
</tr>
</tbody>
</table>
The percentage of ELs proficient on the English language proficiency test, as well as state reading, math, and science tests is provided in Table 1. Each STEM school is compared to the district averages within which the school resides. It is important to note that proficiency on the English language test doesn’t necessarily indicate the school’s performance in teaching language. Language proficiency depends heavily on how long students have been in US schools. Having said that, nearly all STEM elementary schools in this metropolitan area outperformed both their district and state averages in virtually all categories. One could hypothesize that a STEM focus that utilizes a project-based and integrated curriculum has a positive impact on students’ language proficiency and content area knowledge in science, math, and literacy.

**Topic Statement and Research Questions**

I am investigating elementary STEM schools to analyze the efficacy of their program models for English learners in simultaneously developing students’ proficiency in academic language, science, and math. In doing so, I hope to identify curriculum, teaching methods, and forms of assessment to recommend to other elementary schools for teaching English learners language through the content area of science.

This research paper seeks to answer three central questions: 1) How can these various STEM disciplines be integrated in an effective and meaningful manner to improve both academic language and content area knowledge of ELs? 2) What lesson design format best prepares teachers to implement a project-based or integrated curriculum? 3) How can partnerships between higher education and K-12 public schools enrich students’ learning and promote authentic scientific inquiry?

What is the significance of the title “Confluence of STEM Education and Language Learning?” The work of an ESL teacher is collaborative, transformative, and ever-changing. The
goal of this paper is to integrate multiple disciplines in an authentic manner to benefit language learners. A unit on the quality of local watersheds is the foundation for the questions and curriculum developed within this capstone. An authentic issue and problem requires the confluence of many disciplines, ideas, and forms of communication to reach viable and sustaining solutions. Thus, a river and its tributaries are both the subject matter for the unit designed within this capstone, as well as a metaphor for the proposed pedagogical approach to learning and teaching.

This capstone will next review relevant studies and research on elementary STEM schools, best practices for teaching science and ESL, project-based learning, curriculum integration, culturally relevant instruction, and authentic methods of assessment. Chapter Three lays out the methodology for planning a fourth grade science unit that integrates the various STEM content areas with learning English, utilizes student projects and provides authentic methods of assessment. Chapter Four provides a curriculum planning template that more clearly draws a link between content and language objectives. Additionally, an integrated unit of study is laid out that provides a framework for teaching science and language using the aforementioned template. Chapter Five concludes the paper with reflections on the process of planning integrated units of study that push language to the forefront. Recommendations for future study and developments linking the areas of STEM and ESL are also proposed.
CHAPTER TWO: REVIEW OF RELEVANT LITERATURE

Introduction

This research paper seeks to answer three questions: 1) How are the various STEM disciplines integrated in an effective and meaningful manner to improve both academic language and content area knowledge of ELs? 2) What lesson design format best prepares teachers to implement a project-based or integrated curriculum? 3) How can partnerships with higher education promote and support authentic inquiry in the K-12 classroom?

The chapter that follows investigates previous research on teaching ESL through science content. The format of the chapter covers: 1) a philosophical framework for how children learn language and content simultaneously through curriculum integration, 2) a method of planning effective instruction that focuses on both target content and language skills, 3) methods of assessment that provide meaningful feedback to both the learner and the educator, and 4) innovated strategies to increase both student and teaching motivation.

Framework for an Integrated Approach to STEM Education

There is a growing body of research in science teaching and learning that maintains that language is essential for effective science learning. Language is necessary for students to describe their world, develop arguments, record their observations, and present their results. In addition to engaging in direct scientific investigations, students supplement and extend their learning by reading scientific books and articles, discussing research with peers, and writing in their own science journals. Language provides the necessary foundation to form ideas, theorize,
reflect, share, and debate with others, and communicate clearly with diverse audiences (Worth, 2006).

To keep from falling behind their English-speaking peers in academic content areas like science and social studies, ELs need to develop English language skills in the context of engaging content instruction. Content area instruction should provide a meaningful context for English language use, while advancing students’ knowledge and skill set in the content area (Lee, 2005).

The focus for curriculum and teacher preparation programs needs to include both science and language. Science and language complement each other perfectly. Science provides a meaningful context to practice communication and language with physical objects. Conversely, a focus on language in science improves students’ ability to articulate their ideas both orally and in written form. Thus, science and language instruction need to be taught in an integrated manner, not as isolated subjects. Inquiry-based science in particular is important for ELs because it provides real-life context and direct experience, and offers multiple opportunities to engage in meaningful and authentic language use. (Lee & Buxton, 2013) Teaching science organically lends itself to inquiry and using authentic materials, hands-on approaches, and visual representations. These strategies are also identified as best practices for teaching ELs (Buck, 2000).

Integration of subject areas is also instrumental in achieving a workable daily routine. Elementary teachers often find themselves trying to cram in science or social studies at the end of the day, after they have completed the mandated minutes of literacy and math in the morning. This framework ends up with teachers doing a little bit of everything that results in a lot of nothing (Worth, 2006). Putting science content at the core of the curriculum enables a teacher to
utilize the allotted literacy or math time to teach science in an integrated manner. The students are reading or writing about the central topic of science within their literacy block. Additionally, numerous topics in science provide an opportunity for real-life application of math skills.

Project-Based Learning

Project-based learning (PBL) places demands on learners and instructors that challenge traditional practices and school support structures. Learning from doing complex, challenging, and authentic projects requires resourcefulness and planning by the student, new forms of knowledge representations in school, expanded mechanisms for collaboration and communication, and support for reflection and authentic assessment. Project-based learning functions as a bridge between using English in class and using English in real-life situations outside of class. It does this by placing learners in situations that require authentic use of language in order to communicate (Bas, 2011).

Features of PBL, according to Phyllis (1991) Blumenfeld:

1. Questions that are anchored in real-world problems and ideally use multiple content areas.
2. Opportunities for students to make active investigations that enable them to learn concepts, apply information, and represent their knowledge in a variety of ways.
3. Collaboration among students, teachers, and others in the community so that knowledge can be shared and distributed between members of the learning community.
4. Use of cognitive tools in learning environments that support students in the representation of their ideas (p. 377).
Lesson Preparation: Understanding by Design (UbD)

The UbD framework was originally developed by Grant Wiggins and Jay McTighe. The authors are two experts in the field of curriculum, assessment, and teaching for understanding. The UbD model offers a three-stage, backward design process for curriculum planning that includes a template and set of design tools that embody the process. The three stages can be summarized as: the outcomes, the assessments, and the learning plan. A central aspect in UbD framework is alignment (i.e., all three stages must clearly align not only to standards, but also to one another). Following this logic, the content and understanding planned in Stage 1 must be what is assessed in Stage 2 and taught in Stage 3 (Wiggins & McTinghe, 2011).

While the UbD lesson plan template does an excellent job of planning curriculum using standards and benchmarks, the format does not clearly align these benchmarks to their corresponding language objectives. Backwards design in an effective model but there is a gap in the research and methods on aligning content objectives clearly with language objectives so all students are able to access content and effectively communicate on assessments and performance tasks. Teachers, especially those without a background in linguistics and second language acquisition, have difficulty identifying the language structures necessary to explicitly teach students in order to produce the academic English necessary to express themselves effectively in class and on performance indicators.

The chapters that follow modify the UbD template in order to more clearly make the connections between the STEM benchmark content objectives and their corresponding language objectives. Additionally, each performance task or method of assessment will clearly address both the content area knowledge and an aspect of the English language.
Standards: Linking the Common Core and Language Objectives

The Common Core State Standards (CCSS) were initially released in 2010. By 2015, 42 states and the District of Columbia had adopted both the literacy and math standards (Common Core State Standards, 2015). These standards require an unprecedented emphasis on developing the academic language of each content area. Therefore, the new standards present both opportunity and challenge. Academic language is more clearly articulated in the standards and aligned with content standards. However, without the proper language supports, ELs will fall further behind their native English-speaking peers. What is needed is targeted language instruction through content that will accelerate both the content knowledge and language skills of ELs. In diverse classrooms with large numbers of English learners and others who struggle with the language and literacy demands associated with the rigorous curriculum and standards, the teaching may be even more focused on disconnected pieces than in non-diverse classrooms with high percentages of proficient English speakers (Zwiers & O’Hara, 2014).

The WIDA language proficiency standards attempt to guide mainstream and language teachers in preparing ELs to succeed in all modalities of language including listening, speaking, reading, and writing. The standards are a framework that give teachers the understanding and resources to differentiate language instruction to meet the demands of the rigorous content standards. A central aspect of the WIDA standards framework is its direct link to state content standards.

A report conducted by the Wisconsin Center for Education Research conducted a study on the alignment of the Common Core Standards adopted by South Dakota with the WIDA’s language proficiency standards. Findings from this study generally suggest that there is strong

The standards developed by WIDA are based largely on the CCSS and the Next Generation Science Standards (NGSS). The WIDA does not provide English language development (ELD) standards for all standards found in the CCSS. However, it does contain a diverse sample of fleshe-out ELD standards that serve as models for how to differentiate and scaffold instruction for ELs in the various content areas. WIDA breaks down each standard by domain and level. Additionally, the standards delineate the features of academic language including vocabulary usage, language forms and conventions, and linguistic complexity (WIDA, 2012).

Sheltered Instruction

Sheltered Instruction has become a popular approach for teaching English in the content areas. The major components of sheltered instruction include defined content and language objectives, appropriate content for age and background, supplementary materials, adaptation of content for student proficiency levels, and meaningful activities that integrate concepts (Vogt & Echevarria, 2008). With regard to lesson planning, teachers utilize a backward design approach to insure that the instruction gives the students the tools they need to be successful on the final performance assessment. Educators assess both the content and language objectives for the unit and plan instruction that allows students to clearly articulate their ideas in both oral and written form.

However, many researchers such as Jeff Zweirs and Susan O’Hara (2014) argue that a sheltered instruction model is not enough to ensure that ELs will make the necessary growth to
catch up to their native English speaking peers. They argue that while these methods help make the content accessible, they often “water-down” the content and simplify complex language tasks with sentence frames. A sheltered approach often results in reduced literacy and language demands.

Zwiers and O’Hara call for a shift that provides students with the power to possess and use language that is meaningful by experts within the discipline. To this end, he proposes a transition from “piece” skills to “whole-message” skills. Unfortunately, our educational systems’ overuse of multiple choice tests has created an environment where teachers have students memorize vocabulary meanings and discrete facts. They suggest that a focus on academic language tasks that are required of experts in the discipline provide the proper context and objectives for English learners to accelerate their language growth and content area knowledge. The ownership of the language needs to shift from the teacher to the student in authentic and meaningful contexts. In science, this means that students need to be guided to develop their own unique questions, identify their methods for inquiry, and communicate their unique findings and conclusions. The common core state standards also require and promote students’ abilities to communicate and collaborate in an academic setting.

**Authentic Assessment**

Glynn and Muth (1994) argue that students develop metacognitive ability through learning science by utilizing prior knowledge, using science process skills, and applying the four modalities of listening, speaking, reading, and writing to learn the scientific content. One way to assess students’ content knowledge of science and their ability to access and use the language associated with the content is through science journals. Used well, science notebooks provide a space for students to deepen their conceptual understanding of a topic and practice various
language structures that are important in developing academic English. Teachers can use specific instructional strategies such as sentence starters, prompts, and other language scaffolds to facilitate the writing process for the students (Klentschy, 2008). The science journals also provide an authentic measure of students’ understanding of the content area as well as their language development. Additionally, students can create science poster projects to communicate their questions, hypothesis, procedures, data, and conclusions to their peers.

Partnerships with Higher Education in STEM

A challenge of the elementary teacher is that they are expected to be an expert in all content areas including math, reading, writing, science, and social studies. Another problem is that the current focus of legislation is based on outcomes, not processes. Real science is inquiry; and thus it is founded on investigating questions. Standards and benchmarks are predetermined knowledge and outcomes that are to be imparted onto a student. Most primary educators lack the background, education, experience, and materials to conduct authentic science investigation in their classroom without the support of higher education. Moreover, they lack the creative planning time and instructional time that truly fosters an environment that supports student inquiry.

Many of the higher education personnel participating in collaborative work with elementary students are graduate students, postdoctoral fellows, and other scientific trainees, science education partnerships provide an excellent forum for integrating teaching and learning into the methodology of training of scientists. There is emerging evidence that both the teacher and scientist benefit from their involvement in partnerships with respect to their communication and pedagogy skills (Tanner, 2000).
An example of an effective partnership between higher education and K-12 schools is the program of Integrated Science Education Outreach (InSciEd Out). InSciEd Out is a trendsetting approach to collaboration between K-12 schools, higher education, and the local community. InSciEd Out was originally formed as a partnership between the Mayo Clinic, Winona State University, and Rochester Public Schools. The program is a collaboration between university scientists, teachers, and the local community. Teachers from all disciplines within a school are offered the access to contemporary science using zebrafish as a model organism. Within the internship, the teachers write authentic curriculum, with the support of an advanced degree scientist, that directly addresses opportunities for science education improvement at their own school.

Following two years of implementation in the classroom, teachers report increased access to local scientific technology and expertise. Additionally, educators point to improved integration of other disciplines into the scientific curriculum and a flow of concepts vertically from K through 8. Students in this system more than double selection of an “honors” science track in high school to nearly 90%. Additionally, 98% of students show medium or high growth in science proficiency as determined by the state science proficiency test. Cooperation and collaboration between educators and scientists can result in positive change in student science proficiency and demonstrate that a higher expectation in science education can be achieved in US public schools (Pierret et al., 2012).

Summary

The best practices for effective STEM instruction for ELs include an integrated approach, project-based learning, a backward design approach to planning a lesson or unit, authentic assessments, and partnerships with higher education to bolster student engagement and
learning. The chapters that follow attempt to synthesize these methods into an upper elementary lesson in order to model the ways that STEM curriculum can serve as a vehicle to teach both content and language. Chapter Three describes the educational context where the curriculum was developed, a summary of the methods utilized to create the curriculum, as well as a rationale for the lesson design and format.
CHAPTER THREE: METHODOLOGY

Introduction

As mentioned previously, this research paper seeks to answer three central questions: 1) How are the various STEM disciplines integrated in an effective and meaningful manner to improve both academic language and content area knowledge of ELs? 2) What lesson design format best prepares teachers to implement a project-based or integrated curriculum? 3) How can partnerships between higher education and K-12 public schools enrich students’ learning and promote authentic scientific inquiry?

The methodology chapter lays the framework for creating an integrated STEM unit that utilizes a backwards design approach to more clearly draw connections between content and language. The chapter begins with an overview of Birchbark STEM School with regard to the demographic makeup of the students. Next, context is provided on teacher preparation, lesson planning, and delivery model for student instruction at the school. This context lays the framework for the development of an integrated STEM unit of study that utilizes a UbD backward-design approach (. Finally, methods for modifying a UbD planning template are proposed and justified.

Educational Context

Birchbark STEM School (fictitious name) is a culturally and linguistically diverse elementary school. The demographics have shifted within the last 20 years from being homogeneously white to an extremely diverse population culturally, linguistically, and economically. Thirty-two percent of the school’s students are native Spanish speakers.
Additionally, 59% of students qualify for free or reduced cost lunch. Birchbark is considered an inclusive STEM school, as students within the area have a choice to attend the school and students outside the district are able to open enroll.

A positive characteristic of the school is the relationships between mainstream classroom teachers and their collaborating ESL teachers. Birchbark’s ESL service model is primarily inclusion with the ESL teachers teaching in the classroom with the mainstream teachers. The majority of teachers are well trained in best practices of teaching ESL and familiar with both content and language objectives. Moreover, teachers have had significant practice implementing different collaborative instructional delivery models that help meet the needs of all the students in the class. Approximately half of the classroom and ESL teachers at the school completed a graduate-level STEM teaching certificate from a local college. Additionally, the school district uses the UbD lesson design (Wiggins & McTighe, 2011) for all content units of study, and most teachers are familiar with how to both read and write this type of curriculum.

The ELs in the 4th grade at Birchbark STEM Elementary generally have a cumulative English proficiency score that identifies them as “developing” or “expanding” their level of English according to WIDA “Can Do Descriptors” for the elementary grades. This means the students are beginning to use some specific and technical language, employ a variety of sentence lengths with varying complexity, and speak and write in a manner that is generally comprehensible. The grade level has no students who are classified as new-to-country. The integrated lesson discussed further in Chapter Four is designed to be taught within the general education classroom using a collaborative teaching model. Adaptations, including language scaffolds, are included in the lesson to differentiate instruction so that all students can access the material within their 4th grade classroom.
Birchbark transitioned to become a K-5 STEM school five years ago. The school has primarily a value-added approach to teaching STEM subjects. That is, STEM specific lessons have been written specifically to address STEM programming and goals. However, these lessons are usually taught during a 50-minute block that was historically reserved for students’ science and social studies learning. Therefore, these students are not receiving extra instruction in STEM as this time is simply replacing the content time that already existed.

Teachers at the school feel that there is inadequate collaborative planning time to teach integrated STEM units of study. Additionally, teachers are pressured to follow both a literacy and mathematics curriculum with fidelity and often complain about the lack of instructional time to teach all standards and benchmarks. As mentioned previously, The STEM subjects are taught primarily in “silos” with very little integration within the STEM subjects themselves, as well as literacy and English language learning.

Rationale

The goal of the unit discussed in the following chapter is to create the curriculum design for an integrated fourth grade STEM unit on water quality. This curriculum design seeks to serve as a model for other elementary schools on how to integrate subjects, utilize project-based learning, and assess using science notebooks and other authentic measures.

More specifically, the unit focuses on the local water quality of the city in which the Birchbark STEM Elementary School resides to engage students by using their environment and its real-world problems as the central theme for student learning. The design for the unit utilizes a backward design approach developed using essential questions, common core content objectives, and corresponding language objects.
The unit is designed using a modified version of the Understanding by Design template (Wiggins & McTighe, 2011). The rationale for selecting this particular tool is that it provides sufficient opportunity and space for integrating multiple content areas with English language objectives. Additionally, Birchbark STEM Elementary and its district already use UbD lesson-planning templates. While the template would be slightly modified to meet the needs of a fully integrated STEM lesson, the format would be familiar and useful to educators.

The modification to the UbD lesson planning template creates a logical and visually apparent link between each content objective and its corresponding language objective on the template. The sheltered instruction model recommends a clear link between content and language objectives for both teachers and students (Echevarria & Vogt, 2008). Thus, the unit of study will integrate multiple content areas including science, technology engineering, math, and English and draw a clear link between each content objective and language objective. This modification to the UbD lesson format is necessary to create a unit that is complex in its content and rigor, yet user-friendly for the teacher who is planning and carrying out the lesson.

The school is still in a process of transition to becoming a STEM school and seeks to fully implement an integrated curriculum with the STEM subjects being a central, unifying focus. Integrated STEM units of study are being written using a UbD, backwards design approach. However, teachers developing and utilizing the curriculum are often confused by the plethora of initiatives set forth by the district. Additionally, the current UbD template used by the school does not clearly correlate content and language objectives. The integrated STEM unit developed in the following chapter seeks to meet the needs for fulfilling these needs. Moreover, the unit demonstrates how to develop a lesson content lesson plan to more clearly draw the connections between content and language.
Chapter Three described the educational context where the curriculum was developed, a summary of the methods utilized to create the curriculum, as well as a rationale for the lesson design and format. Chapter Four will provide a planning template that more clearly aligns content objectives with corresponding language objectives. A sample unit of study is included that utilizes the modified backwards design planning template. Additionally, language tasks are broken down into word, sentence, and extended discourse levels for each lesson.
CHAPTER FOUR: CURRICULUM INTEGRATION

Unit Overview: Water Quality of Minnesota Wetlands

The following unit was developed for an upper elementary classroom with intermediate to advanced ELs. The lessons are developed with the intention of the mainstream or science educator teaching in collaboration with an ESL teacher using an inclusion service model. During the unit, students investigate the water quality within their watershed/community using a curriculum that integrates science, math, engineering, social sciences, and English language in a project-based context.

The geographical area surrounding Birchwood Elementary is interesting in that it is split between two major watersheds. To compare the water quality within the city, students will do a comparative analysis of two stormwater lakes within the city that flow into the watersheds mentioned above. Birch Lake is a stormwater lake and wetland area that eventually flows into the Wimawak River. The students within the local school district partner with the Birch Lake Nature Center for extended learning and field trips. Parker Pond is a stormwater pond that flows into Wimahahaha Creek and eventually the Wimawak River. Both locations are within the students’ walkable community, and teachers will point out the short distance between these bodies of water and the school.

Lessons 1-5 are repeated for each of the two bodies of freshwater to be investigated. In the first lesson, students visit the stormwater lake, use their scientific notebooks to draw scientific sketches and record observations, measure air and water temperature, and conduct a turbidity test. Additionally, students take two separate water samples. One sample will be used to
conduct tests for pH, phosphorus, nitrates, and dissolved oxygen. Another sample of aquatic macroinvertebrates is collected by students using kick nets and collection containers. These samples are brought back to the school for later investigations. The second lesson is an analysis of the macroinvertebrate water sample. Students spend one day in the lab identifying as many species of macroinvertebrates as they can, sketching a particular species, and explaining the characteristics of the animal. The second day of the lesson is used to debrief the lab and quantify the water quality according to the pollution tolerance index. The third lesson is another lab day dedicated to testing the water quality using various tests and measurements including pH, phosphorus, nitrates, and dissolved oxygen. The fourth lesson is used to summarize and synthesize the previous lessons. Students discuss their observations, investigations and tests to develop conclusions about the water quality of the stormwater lake.

The procedures for lessons 1-4 are repeated with the second stormwater lake on week two. Week three is used to compare the two bodies of water and develop overall conclusions of the stormwater water quality in the community. Finally, students complete an independent investigation centered on authentic and novel question. The students develop the question and hypothesis, plan and conduct the investigation, and write and communicate a scientific report.
Unit:
Lesson:
Content Area(s):

Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Standard:</th>
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<table>
<thead>
<tr>
<th>Benchmark Content Objective:</th>
<th>Corresponding Language Objective:</th>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Step 2: Assessment or Performance Indicator

Step 3: Learning Plan
I.
II.
III.
IV.
V.

*This document is a modified template based on Grant Wiggins and Jay McTighe (2011). Some of the terms have been changed to more clearly align with the language of the common core standards. Additionally, a column has been added next to content objectives for corresponding language objectives. This allows the curriculum writer(s), as well as the teacher reading the document, to make a clearer connection between the content objectives and the academic language necessary to communicate in both oral and written form.

Figure 1: Modified Backwards Design Template
Unit: Water Quality
Content Area(s): Science, Math, and Language Arts

Overview:
The geographical area surrounding Birchwood Elementary is interesting in that it is split between the Mississippi River and Minnesota River Watersheds. To compare the water quality within the city, students will do a comparative analysis of two stormwater lakes within the city that flow into the watersheds mentioned above. Wood Lake is a stormwater lake and wetland area that eventually flows into the Minnesota River. The students within the local school district partner with the Wood Lake Nature Center for extended learning and field trips. Christian Park Pond is a stormwater lake that flows into Minnehaha Creek and eventually the Mississippi River. This pond is within walking distance of the school.

Science Standards:
Living things are diverse with many different characteristics that enable them to grow, reproduce and survive.

Natural systems have many components that interact to maintain the living system.

In order to maintain and improve their existence, humans interact with and influence Earth systems.

Scientific inquiry is a set of interrelated processes incorporating multiple approaches that are used to pose questions about the natural world and investigate phenomena.

Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms

Math Standards:
Tools and mathematics help scientists and engineers see more, measure more accurately, and do things that they could not otherwise accomplish.

Represent and compare fractions and decimals in real-world and mathematical situations; use place value to understand how decimals represent quantities.

Objectives: This page is an overview of the entire unit. Each individual lesson contains content objectives, corresponding language objectives, assessments/performance indicators, and the learning plan for the individual lesson. Students will make observations, conduct water experiments on site and in the lab, identify macroinvertebrates, and do a comparative analysis of the two bodies of water. The unit culminates with students formulating their own questions,
designing an experiment, analyzing their own data, and communicating their findings through a scientific poster project.

Assessments and Performance Indicators:
I. Science journal entries
II. Comparison Essay
III. Scientific Poster Project

Unit Level Learning Plan:
I. Student observations of lake/pond. Test temperature and dissolved oxygen. Collect samples of water and macroinvertebrates.
II. Water lab testing: pH, phosphorus, and nitrates.
III. Data Analysis from water lab
IV. Macroinvertebrate lab
V. Data Analysis from macroinvertebrate lab
VI. Repeat I-V for second lake/pond
VII. Analyze data, make comparisons, generalizations for the community.
VIII. Students develop their own question for investigation, make hypothesis, and plan investigation in small groups.
IX. Students complete investigation.
X. Students create a scientific poster that communicates their findings
Unit: Water Quality
Lesson 1: Scientific Freshwater Observations and Sample Collection
Day 1
Content Area(s): Science

Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th>Standards:</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the water quality of our local community?</td>
<td>Scientific inquiry is a set of interrelated processes incorporating multiple approaches that are used to pose questions about the natural world and investigate phenomena.</td>
</tr>
<tr>
<td>What ways can we measure water quality?</td>
<td>Tools and mathematics help scientists and engineers see more, measure more accurately, and do things that they could not otherwise accomplish.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Objective</th>
<th>Corresponding Language Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.1.2.3 Maintain a record of observations, procedures and explanations, being careful to distinguish between actual observations and ideas about what was observed.</td>
<td>Students describe a freshwater habitat including the air and water temperature, aquatic and terrestrial plant and animal life, presence of pollution, water clarity, etc.</td>
</tr>
<tr>
<td>4.2.1.1.1 Measure temperature, volume, weight and length using appropriate tools and units.</td>
<td>Students describe measurements for air temperature, water temperature, and water clarity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature, degrees, Fahrenheit, Celsius, clarity, turbidity, centimeters</td>
<td>Students are able to use data to formulate complete sentences: For example, “The water temperature is 14 degrees Celsius.”</td>
<td>Students are able to discuss their observations and data collection with their peers as scientists.</td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator
Science journal observations, sketches, and tables. See attached rubric.

Step 3: Learning Plan
I. Initial observations of water quality (trash, clear/mucky, vegetation along bank, wildlife.
II. Students measure the air temperature and record weather observations.
III. Students measure and record water temperature at various depths
IV. Turbidity is measured using a Secchi dish or a turbidity tube
V. Students use data to discuss the observations and data in pairs.
VI. Students collect a 2-gallon water sample to be used in the following lab.

VII. Students use “kick nets” to sample macroinvertebrates for following lab.

*Figure 2: Student Observations*

*Figure 3: Turbidity Tube Measurement*

*Figure 4: Collecting macroinvertebrate sample.*
Unit: Water Quality  
Lesson 2: Macroinvertebrate Observations  
Days 2-3  
Content Area(s): Science

Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What can an analysis of aquatic macroinvertebrates (water insects) tell us about the quality of water?</td>
<td></td>
</tr>
<tr>
<td>How can I identify between different species of macroinvertebrates?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Living things are diverse with many different characteristics that enable them to grow, reproduce and survive.</td>
<td></td>
</tr>
<tr>
<td>Natural systems have many components that interact to maintain the living system.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Objectives:</th>
<th>Corresponding Language Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.1.1.2 Identify common groups of plants and animals using observable physical characteristics, structures and behaviors. For example: Sort animals into groups such as mammals and amphibians based on physical characteristics.</td>
<td>Students explain and justify how they identified an organism or macroinvertebrate.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Vocab: macroinvertebrate, wings, nymph, beetle, worm</td>
<td>I can infer that ________is a _______ because _________. Example, “This is a dragonfly larva because it has six legs, three body parts, and its body shape is long and skinny.”</td>
<td>Students are able to discuss their observations and data collection with their peers as scientists.</td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator

Students complete macroinvertebrate identification chart. Students sketch at least 2 macroinvertebrates that they identified in their science journals and write sentences explaining their characteristics.

Step 3: Learning Plan

I. Students work in groups of 4. Each table is given a small aquarium filled with a sample of macroinvertebrates in their freshwater habitat.

II. Students use magnifying glasses, microscopes, and their identification chart to identify as many species of macroinvertebrates in their habitat as possible.
III. Write/pair/share. Students sketch 2 interesting species of macroinvertebrates and explain the characteristics that helped them identify it. Share work with a partner.

IV. (end of Day 2)

V. Review Day 2 lab and compile a class list of macroinvertebrate using all groups info

VI. Students multiply x4, x3, x2, or x1 for each pollution tolerance category.

VII. Students add each category to get a total for the pollution tolerance index.

VIII. Students write a concluding paragraph on the macroinvertebrate lab that explains the water quality of the sample using macroinvertebrates as an indicator.

---

**Figure 5:** Macroinvertebrate identification sheet (Erdmann, 2010)
**Figure 6:** Pollution Tolerance Index (PTI) (Erdmann, 2010)

<table>
<thead>
<tr>
<th>PT GROUP 1</th>
<th>PT GROUP 2</th>
<th>PT GROUP 3</th>
<th>PT GROUP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerant</td>
<td>Moderately Intolerant</td>
<td>Fairly Tolerant</td>
<td>Very Tolerant</td>
</tr>
<tr>
<td>Stonefly Nymph</td>
<td>Dragonfly Nymph</td>
<td>Midge</td>
<td>Left-Handed Snail</td>
</tr>
<tr>
<td>Mayfly Nymph</td>
<td>Dragonfly Nymph</td>
<td>Black Fly Larva</td>
<td>Aquatic Worms</td>
</tr>
<tr>
<td>Goldfish Larva</td>
<td>Somag</td>
<td>Plecois</td>
<td>Loach</td>
</tr>
<tr>
<td>Dobsonfly Larva</td>
<td>Soul</td>
<td>Leech</td>
<td>Rat-Tailed Wiggly</td>
</tr>
<tr>
<td>Riffle Beetle</td>
<td>Crane Fly Larva</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Penny</td>
<td>Clams/Mussels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-Handed Snail</td>
<td>Crayfish</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># of TAXA Weighting Factors (x4)</th>
<th># of TAXA (x3)</th>
<th># of TAXA (x2)</th>
<th># of TAXA (x1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 or more: Excellent</td>
<td>17-22: Good</td>
<td>11-16: Fair</td>
<td>10 or Less: Poor</td>
</tr>
</tbody>
</table>

**Pollution Tolerance Index Rating**

(Add the final index values for each group.)

**Other Organisms Observed:**
- Mosquito larvae
- Water Striders
- Diving Beetles
- Water Boatman
- Minnows
- Daphnia (water fleas)
- Water Scorpions
- Cyclops
- Other

---

**Figure 7:** Macroinvertebrate Lab Setup
Unit: Water Quality  
Lesson 3: Measuring pH, DO, nitrates, and phosphorus  
Content Area(s): Science and Math

Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the water quality of our local watershed?</td>
<td></td>
</tr>
<tr>
<td>How do humans impact the local aquatic environment?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Represent and compare fractions and decimals in real-world and mathematical situations; use place value to understand how decimals represent quantities.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Objectives:</th>
<th>Corresponding Language Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.2.4 Read and write decimals with words and symbols; use place value to describe decimals in terms of thousands, hundreds, tens, ones, tenths, hundredths and thousandths.</td>
<td>Students are able to identify, describe, and compare numbers that include decimals.</td>
</tr>
<tr>
<td>4.1.2.5 Compare and order decimals and whole numbers using place value, a number line, and models such as grids and base 10 blocks.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved oxygen, nitrogen, phosphates/phosphorus, pH, acid, base, sample, indicator</td>
<td>Students are able to express the value of numbers that include a decimal and make comparisons.</td>
<td>Students are able to compare to values and draw conclusions with justification.</td>
</tr>
<tr>
<td></td>
<td>_________ is greater than _________</td>
<td></td>
</tr>
<tr>
<td></td>
<td>_________ is less than _________</td>
<td></td>
</tr>
<tr>
<td></td>
<td>_________ is equal to _______</td>
<td></td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator  
Science journal observations, tables, and comparison sentences.
Step 3: Learning Plan
I. Students use various indicators to test levels of nitrogen, phosphorus, and pH.
II. Data is transcribed in a table in students’ science journals (see Appendix A)
III. Students analyze data and discuss observations
IV. Students write sentences that compare the tested levels to recommended water quality standards

Figure 8: Water Testing Lab Setup
### Unit: Water Quality
Lesson 4: Data Analysis, Conclusions, Future Questions
Days 5
Content Area(s): Science

#### Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
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</thead>
<tbody>
<tr>
<td>What is the water quality of our local watershed?</td>
</tr>
<tr>
<td>How do humans impact the local aquatic environment?</td>
</tr>
<tr>
<td>How can citizens help to improve the water quality in their local community?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Represent and compare fractions and decimals in real-world and mathematical</td>
</tr>
<tr>
<td>situations; use place value to understand how decimals represent quantities.</td>
</tr>
</tbody>
</table>

Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms.

<table>
<thead>
<tr>
<th>Content Objectives</th>
<th>Corresponding Language Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare and order decimals and whole numbers using place value, a number line,</td>
<td>Students will be able to compare the measurements of their sample to federal standards.</td>
</tr>
<tr>
<td>and models such as grids and base 10 blocks.</td>
<td></td>
</tr>
<tr>
<td>Explain what would happen to a system such as a wetland, prairie or garden if</td>
<td>Students are able to explain the possible impacts of pollution on the water quality of their local</td>
</tr>
<tr>
<td>one of its parts were changed. For example: Investigate how road salt runoff</td>
<td>community using proper paragraph format.</td>
</tr>
<tr>
<td>affects plants, insects and other parts of an ecosystem. Another example:</td>
<td></td>
</tr>
<tr>
<td>Investigate how an invasive species changes an ecosystem.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal standard, pollution, ecosystem, indicate, conclude, conclusion</td>
<td>_________ is greater than __________ which indicates __________.</td>
<td>Students are able to write a paragraph on the effects of a human impact on their local environment and justify their conclusions with relevant data.</td>
</tr>
<tr>
<td></td>
<td>_________ is less than __________.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Therefore, __________.</td>
<td></td>
</tr>
</tbody>
</table>

#### Step 2: Assessment or Performance Indicator
- Science notebooks: completed chart comparing lab data with federal standards.
- A paragraph that draws conclusions from the data and discusses possible human impacts on local aquatic environments.
Step 3: Learning Plan

Day 2

I. Class data from the previous lab is compiled on the front Smartboard/white board.

II. A column on the chart should include the federal standards for each area of measurement.

III. Teacher models and guides students to orally compare their sample data with the federal standards.

IV. Students color-code the chart to indicate healthy/unhealthy/inconclusive.

V. Think/pair/share. Students reflect on the data: what does it tell us? Share ideas with a partner. Share out as a class.

VI. (end of Day 2)

VII. Students write a paragraph reflecting on the results of both the macroinvertebrate lab and the chemical testing noting any significant data. The paragraph should include possible impacts of healthy or unhealthy water quality. Graded according to rubric

Table 2:

<table>
<thead>
<tr>
<th></th>
<th>Wood Lake</th>
<th>Christian Park</th>
<th>Federal Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>14 degrees C</td>
<td>14 degrees C</td>
<td></td>
</tr>
<tr>
<td>turbidity</td>
<td>65 cm = 8 NTU</td>
<td>55 cm = 10 NTU</td>
<td>&lt;25 NTU</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>7</td>
<td>6.5-9.0</td>
</tr>
<tr>
<td>nitrates</td>
<td>1 ppm</td>
<td>0.5 ppm</td>
<td>&lt; 4ppm</td>
</tr>
<tr>
<td>dissolved oxygen</td>
<td>3.5 ppm</td>
<td>4 ppm</td>
<td>4 - 11 ppm</td>
</tr>
<tr>
<td>phosphates</td>
<td>0 ppm</td>
<td>1 ppm</td>
<td>&lt; 0.03 ppm</td>
</tr>
</tbody>
</table>
Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th>Standards:</th>
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<tr>
<td>What is the water quality of our local watershed?</td>
<td>Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms</td>
</tr>
<tr>
<td>How do humans impact the local aquatic environment?</td>
<td></td>
</tr>
<tr>
<td>How can citizens help to improve the water quality in their local community?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Objectives:</th>
<th>Corresponding Language Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate a scientific question and plan an appropriate scientific investigation, such as systematic observations, field studies, open ended exploration or controlled experiments to answer the question.</td>
<td>Students can generate a testable scientific question related to water quality in their local community.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testable, vague, hypothesis, hypotheses, investigate, investigation</td>
<td>Student are to generate and write testable scientific questions and corresponding hypotheses.</td>
<td>Students are able to explain and justify their interest in investigating a particular question.</td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator
Science journal entry (rough draft) and science poster project (final copy). Students are able to generate and write a testable scientific question and corresponding hypotheses.

Step 3: Learning Plan
I. Teacher explains that scientists ask questions that can be tested through a scientific investigation.
II. Give students examples of several questions. Have students identify which questions are better suited for a scientific investigation.
III. Students brainstorm scientific questions related to the water quality in their community they would like to research.
IV. Students share questions whole group and teacher writes ideas on the board. Teacher helps narrow topics to novel and testable questions.
V. Students self-select groups according to interest. Groups should be approximately 3-4 students each.
VI. Groups work to develop questions and hypotheses related to their questions and write them in their science notebooks.

Sample Small Group Question and Hypothesis

The following independent investigation is a sample of the type of student work possible for an independent investigation related to water quality. In this case, the investigation was conducted with the support of members of the InSciEd Out Program at the University of Minnesota and the Mayo Clinic. The partnership between InSciEd Out and the schools allowed teachers and students to conduct their investigations with zebrafish embryos. Zebrafish embryos are used by students to test their authentic questions and conduct investigations. The table below shows the questions and hypothesis developed by one group. Each lesson that follows will provide a similar example for that portion of the independent investigation to serve as a model.

Table 3: Sample Questions and Hypotheses Developed by Students

<table>
<thead>
<tr>
<th>Sample Questions</th>
<th>Sample Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do de-icing road salts impact aquatic ecosystems?</td>
<td>High concentrations of dissolved salt will result in the death of fish.</td>
</tr>
<tr>
<td>How do de-icing road salts effect heart rate of fish?</td>
<td>High concentrations of salt will increase the heart rate of fish.</td>
</tr>
<tr>
<td>How do de-icing road salts effect the rate of growth of fish?</td>
<td>High concentrations of salt will accelerate the growth rate of fish.</td>
</tr>
</tbody>
</table>
Unit: Water Quality
Lesson 6: Independent Investigation (Methods, Materials, and Experiments)
Days 13-16
Content Area(s): Science, Literacy
Step 1: Outcomes

<table>
<thead>
<tr>
<th>Essential Questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the water quality of our local watershed?</td>
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<td>How do humans impact the local aquatic environment?</td>
</tr>
<tr>
<td>How can citizens help to improve the water quality in their local community?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards:</th>
</tr>
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<tbody>
<tr>
<td>Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Objectives:</th>
<th>Corresponding Language Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use appropriate tools and techniques in gathering, analyzing and interpreting data.</td>
<td>Students explain the materials, methods, and procedures necessary to conduct an experiment. Students are able to write items in a list using commas in a series.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods, procedures, materials, variable, independent variable, dependent variable, control</td>
<td>Students can make a materials list using commas in a series.</td>
<td>Student are able to explain their methods using ordinal numbers and sequencing words.</td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator
Science journal entry (rough draft) and science poster project (final copy). Students are able to write their methods and procedures using commas in a series.

Step 3: Learning Plan
Day 1:
I. Review the scientific process whole group
II. Teacher provides a model of a sample experiment. Ex. How do pesticides in water impact fish? Generate a hypothesis as shared/guided task.
III. Guided: Ask the class what procedures/steps are necessary to carry out the task. Ex. Control (no pesticides), 1/100 dilution of pesticide, 1/1,000 dilution, 1/10,000 dilution. Record results.
Day 2:
IV. Whole group: review the procedures followed on the prior day in the sample experiment.
V. Small group: groups develop procedure and materials for their independent experiment.
VI. Teacher explicitly teaches ordinal numbers and commas in a series. Models how to turn material list and procedures into a paragraph.
VII. Students write the procedures and materials necessary for the experiment.

Day 3:
VIII. Groups conduct their experiments in the lab.
IX. Students write down results and observations in their science notebooks.

Sample Methods and Materials Section:

We plan to compare a control group of zebrafish embryos to three other experimental groups placed in the following solutions: sodium chloride, magnesium chloride, and calcium chloride. First, we will make two concentration levels (100mg/l, 500 mg/l) for each type of salt solution. Second, we will place 20 the zebrafish embryos in each solution. Third, we will put all containers in a room at 70 Fahrenheit. Finally, we will check on the zebrafish development at 24, 48, and 72 hours. The zebrafish will be monitored for mortality, heart rate, and developmental growth stage rate. To complete our investigation we need 160 zebrafish embryos, 7 petri dishes, a high-powered microscope, and a tablet with Motic microscope software.
Unit: Water Quality
Lesson 7: Independent Investigation (Data Analysis)
Days 17-19
Content Area(s): Science, Technology, Math, Literacy

Step 1: Outcomes

<table>
<thead>
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<td>What is the water quality of our local watershed?</td>
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<td>Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms</td>
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<tbody>
<tr>
<td>Use appropriate tools and techniques in gathering, analyzing and interpreting data.</td>
<td>Students explain the materials, methods, and procedures necessary to conduct an experiment. Students are able to write items in a list using commas in a series.</td>
</tr>
<tr>
<td>Create and analyze double-bar graphs and line graphs by applying understanding of whole numbers, fractions and decimals.</td>
<td>Students are able to explain data and graphs in sentence format.</td>
</tr>
</tbody>
</table>

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<tr>
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<th>Sentence Level:</th>
<th>Extended Discourse:</th>
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</thead>
<tbody>
<tr>
<td>Federal standard, pollution, ecosystem, mean, median, percent, indicate, conclude, conclusion</td>
<td>___________ is greater than___________ which indicates____________________________.</td>
<td>Students are able to write a paragraph on the effects of a human impact on their local environment and justify their conclusions with relevant data.</td>
</tr>
<tr>
<td></td>
<td>___________ is less than___________</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Therefore,____________________________.</td>
<td></td>
</tr>
</tbody>
</table>

Step 2: Assessment or Performance Indicator
Science journal entry (rough draft) and science poster project (final copy). Students are able to produce a graph (bar or line) that shows their results. Students are able to explain how the graph represents their data.

Step 3: Learning Plan
Day 1:
I. Introduce lesson on bar graphs and line graphs. Give examples of different graphs and ask students the benefit for each type of graph
II. Students work in groups to develop rough copy graphs in their notebook.
III. Teacher edits graphs and provides feedback. Teacher approves graph for final copy.

Day 2:
IV. Students create graphs and tables in Excel
V. Print graphs for inclusion in scientific poster.
VI. Students partner share their graphs with a member of a different group.
Example Results from Zebrafish Study:

**Figure 9:** Example Bar Graph of Student Investigation on Road Salts

**Figure 10:** Example Line Graph of Mean Heart Rate Over Time in 500 mg/L Concentrations
**Figure 10:** Example Line Graph of Student Investigation on Road Salts

Unit: Water Quality  
Lesson 8: Independent Investigation (Scientific Poster Project)  
Days: 20+  
Content Area(s): Science, Technology, Math, Literacy

**Step 1: Outcomes**

<table>
<thead>
<tr>
<th>Essential Questions:</th>
<th>Standards:</th>
</tr>
</thead>
</table>
| What is the water quality of our local watershed?  
How do humans impact the local aquatic environment?  
How can citizens help to improve the water quality in their local community? | Humans change environments in ways that can be either beneficial or harmful to themselves and other organisms  
Science is a way of knowing about the natural world, is done by individuals and groups, and is characterized by empirical criteria, logical argument and skeptical review. |

<table>
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</thead>
<tbody>
<tr>
<td>Explain why evidence, clear communication, accurate record keeping, replication by others, and openness to scrutiny are essential parts of doing science.</td>
<td>Students are able to write a report in the form of a scientific poster. They are able to justify their methods, results, and conclusions when communicating with other scientists.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Vocab:</th>
<th>Sentence Level:</th>
<th>Extended Discourse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal standard, pollution, ecosystem, indicate, conclude, conclusion</td>
<td>Student are able to generate grammatically correct sentences that explain the scientific process.</td>
<td>Students are able to write paragraphs in the following areas: introduction (observations, questions, hypotheses), methods, discussion, and conclusion.</td>
</tr>
</tbody>
</table>

**Step 2: Assessment or Performance Indicator**

Science poster project and presentation.
Step 3: Learning Plan

Day 1:
I. Teacher distributes rubric for poster project.
II. Teacher provides sample project.
III. Teacher demonstrates proper formatting for each section: headings, indentation, conventions.

Day 2+:
IV. Student work time

Table 4: Science Poster Project Rubric

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Knowledge</td>
<td>Does not demonstrate knowledge of the scientific process.</td>
<td>Demonstrates a limited understanding of the scientific process.</td>
<td>Demonstrates an understanding of the scientific process with guidance.</td>
<td>Demonstrates an understanding of the scientific process independently.</td>
</tr>
<tr>
<td>Writing</td>
<td>Writing is difficult to comprehend, does not use grade-level vocabulary and is disorganized.</td>
<td>Writing is somewhat comprehensible, uses vocabulary approaching grade-level, and shows some organization.</td>
<td>Writing is usually clear, has vocabulary approaching grade-level, and is organized.</td>
<td>Writing is clear, uses grade-level vocabulary, and is well-organized.</td>
</tr>
<tr>
<td>Teamwork</td>
<td>Did not contribute to the team, did not work well with others.</td>
<td>Contributed minimally, some issues working with others</td>
<td>Contributed to the group, worked well with others</td>
<td>Contributed substantially, was a team leader</td>
</tr>
<tr>
<td>Presentation</td>
<td>Unable to communicate the scientific process related to investigation.</td>
<td>Communicates some of the scientific process related to investigation.</td>
<td>Communicates the basic principles of the scientific process related to the investigation.</td>
<td>Clearly communicates the scientific process related to the investigation as a scientist.</td>
</tr>
</tbody>
</table>
Summary of Local Water Quality Unit

The water quality unit provided in this chapter is meant to serve as a model unit for integrating the STEM content disciplines with language learning. The issue of local water quality is a relevant issue and problem for many communities in the 21st century. This lesson is intended to give students an opportunity to investigate their local realities using observations, conduct guided research utilizing the scientific method, and perform novel experiments on an issue of their choice. Each lesson integrates multiple disciplines and provides an authentic forum for oral and written communication of academic English. The unit was developed using a backwards design approach. Content objectives were drawn from overarching essential questions and
enduring understandings linked to state standards. Next, language objectives were provided that
give direction for both the teacher and students to meet the language demands of the assessments
or performance tasks associated with each content benchmark. These language objectives were
further articulated at the word, sentence, and extended discourse levels in order to explicitly meet
the full range of language demands inherent in the benchmarks and provide a framework for
students to progress their language skills in a more systematic manner.

Chapter Five will provide reflections on this capstone and the curriculum design
developed. More specifically, it will summarize the problems facing STEM education and
language learning, reflect on the curriculum design developed in chapter four, and outline the
future steps I will take as an a learner and educator.
CHAPTER FIVE: REFLECTIONS

Redefining the Problem

Students in the United States are falling behind their peers in other developed nations in the academic areas of math and science (Kuenzi et al. 2006). This issue is further exacerbated by a persistent achievement gap between white students and their non-white classmates (Wascalus, 2015). ELs specifically face the monumental task of achieving English language proficiency, while accelerating their growth in content areas to meet the demands of the new common core standards (Zwiers, O’Hara, & Pritchard, 2014). To combat these problems, elementary STEM schools are increasing in popularity in the U.S. The introduction of this paper provides data that suggests these program models are having a positive impact on ELs language proficiency and content area knowledge. Further studies need to analyze the effectiveness of STEM schools with regard to achievement in both science content area knowledge, as well as in the areas of language and literacy.

This research paper has attempted to answer three central questions. The first question was how are the various STEM disciplines being integrated in an effective and meaningful manner to improve both academic language and content area knowledge of ELs. Many scholars maintain that science and language complement each other perfectly. Science provides a meaningful context to practice communication and language with physical objects. Conversely, a focus on language in science improves students’ ability to articulate their ideas both orally and in written form. Thus, science and language instruction need to be taught in an integrated manner, not as isolated subjects. Inquiry-based science in particular is important for ELs because it
provides real-life context and direct experience, and offers multiple opportunities to engage in meaningful and authentic language use. (Lee & Buxton, 2013)

In addition to curriculum integration, project-based learning can function as a bridge between using English in class and using English in real-life situations outside of class. It does this by placing learners in situations that require authentic use of language in order to communicate. Teachers and classrooms that implement PBL provide students with relevant and meaningful contexts to explore real-world problems and issues. PBL increases student engagement and learning (Bas, 2011).

The second primary question investigated in this paper focused on which lesson design format best prepares teachers to implement a project-based or integrated curriculum. The Understanding by Design Framework provides teachers with a tool for backwards lesson design. UbD clearly divides the lesson into three main areas: outcomes, assessment, and the lesson (Wiggins & McTinghe, 2011). This paper adapted the UbD lesson template to more clearly align with the language of the Common Core State Standards. Additionally, the lesson plan template provided draws a clearer link between content benchmarks and their corresponding language objectives.

The final question asked how partnerships between higher education and K-12 public schools enrich students’ learning and promote authentic scientific inquiry. There is emerging evidence that both the teacher and scientist benefit from their involvement in partnerships with respect to their communication and pedagogy skills (Tanner, 2000). Cooperation and collaboration between educators and scientists can result in positive change in student science proficiency and demonstrate that a higher expectation in science education can be achieved in US public schools (Pierret et al., 2012).
An example of an effective partnership between higher education and K-12 schools is the program of Integrated Science Education Outreach (InSciEd Out). InSciEd Out is a trendsetting approach to collaboration between K-12 schools, higher education, and the local community. InSciEd Out was originally formed as a partnership between the Mayo Clinic, Winona State University, and Rochester Public Schools. The program is a collaboration between university scientists, teachers, and the local community.

Implications for Teaching Language through Science

Many successful STEM schools are moving towards a more integrated model where various disciplines are woven together into a given unit of study. This program design promotes teaching language simultaneously through the various content areas. Teaching language through content is not a new approach, as sheltered instruction has provided a framework for making content curriculum “accessible” to ELs. However, there is a need to strengthen the sheltered model by drawing a clearer link between content and language objectives. Moreover, the language demands of the new common core standards require teachers to explicitly teach language at the word, sentence, and extended discourse levels.

This paper provided a unit of study related to water quality of a local ecosystem that drew on various disciplines including science, language arts, math, and technology. Investigating the local water quality of the students’ communities is a relatable subject area that provides a meaningful context for language use. To achieve both content and language demands, a planning design template was developed that more clearly draws a connection between content objectives and their corresponding language objectives. Each lesson in the unit utilized this modified backwards design template and required that students met both content and language objectives. Additionally, the language tasks were explicitly broken down to the word, sentence, and
extended discourse levels to help guide both the teacher and students to increasing complexity of language production.

The unit was designed to be used at Birchbark Elementary, but is intended to be a model for the school for future planning, as well as for other elementary schools that seek to improve their STEM programming. I plan to share this report with my superintendent, ELL coordinator, principal, literacy coaches, and fellow teachers. A method of dissemination will be to teach leadership academy classes. The simple adjustment of linking content and language objectives will improve teachers’ ability to link the language associated with comprehending and producing language on a given topic or task.

Designing integrated units of study that are culturally relevant, rigorous, and that embed meaningful language is a challenging and time-consuming task. Integrated units of study are most effectively developed and implemented when they are designed by a diverse group of mainstream, science, and ELL teachers. Bringing all stakeholders to the planning table ensures that these units of study are robust with regard to both their scientific content and language tasks. Additionally, cooperative planning and collaboration provides a forum for teachers to share their areas of expertise and to continue to learn from one another. As life-long learners, teachers must possess a growth mindset to continue to improve their own knowledge and instruction.

Partnerships with higher education can also be extremely beneficial for K-12 teachers and students, particularly in the area of science. The InSciEd Out Program is one example of such a partnership between a major state university and K-12 public schools. (Pierret et al., 2012) This program allows teachers to use scientists as resources for curriculum planning and classroom guidance. The partnership is particularly beneficial when students begin to conduct authentic scientific inquiry. Graduate and post-graduate scientists are able to help guide teachers and
students on how to develop novel scientific questions and develop experiments using the scientific method. Additionally, the partnership benefits K-12 students as they have access to cutting-edge equipment not found in a traditional public school setting.

While partnerships with higher education can be beneficial and fulfilling, they are not simple to develop or sustain. A clear framework, methods of communication, and demarcated roles and expectations of all participants is necessary to ensure the relationship is not one-sided. Another obstacle is time. Internships and professional development that takes place during the summer months is advised as it allows K-12 teachers and university professors to meet during a period where they aren’t preoccupied with the daily stressors of their respective jobs. While much of the professional development and curriculum writing can take place during the summer, a sustaining relationship and method of communication between the two groups needs to be developed in order to ensure the effective implementation of the curriculum at the K-12 building level.

Another challenge of partnerships between higher education and K-12 schools is financial sustainability. Higher education outreach programs often depend on time-bound grants. Programs may start strong initially but may fizzle out or run out of funding entirely. Assessing program efficacy are vital to sustaining funding for these projects. Baseline and summative data needs to be collected that can be utilized to demonstrate the effectiveness of higher education partnerships to help secure future grants and continued funding.

Future Steps

I plan to share both my lesson planning template with the school district’s curriculum advisory committee which includes the superintendent, assistant superintendent, and the directors of reading, math and ESL. I believe this committee provides the right forum and opportunity to
share the modified UbD planning template and explain the rationale for its implementation for future curriculum writing at the district level. The water quality unit will be provided as an example of a model unit to the committee. Additionally, I plan to share this unit of study with my upper elementary colleagues at the building level during our dedicated professional learning community (PLC) time. I feel that the PLC meeting is the ideal arena for sharing my work as it not only provides me the opportunity to share my work and ideas, it also allows my colleagues from diverse backgrounds and disciplines to make positive changes and contributions that will undoubtedly improve the unit and ultimately student learning.

Science provides the perfect methods and context for students to investigate their reality. Developing integrated lessons that draw on all disciplines helps prepare students for the real-world problems and issues that they will face as citizens. Learning language through science provides students with an authentic forum for producing language that is purposeful and meaningful. All teachers have the responsibility to strategically develop lessons and activities that cultivate both content area knowledge and language skills to meet the demands of the 21st century for our diverse learners.
References


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