Summer 2022

A Menu About Me: A Next Generation Science Standards Aligned 9-12 Life Science Curriculum Adapted for Students With Limited or Interrupted Formal Education

Madeline Carras

A MENU ABOUT ME: A NEXT GENERATION SCIENCE STANDARDS ALIGNED 9-12 LIFE SCIENCE CURRICULUM ADAPTED FOR STUDENTS WITH LIMITED OR INTERRUPTED FORMAL EDUCATION

by

Madeline Carras

A capstone submitted in partial fulfillment of the requirements for the degree of Master of Arts in Teaching.

Hamline University

St. Paul, Minnesota

August 2022

Primary Advisor: Abigail Rombalski, Ph.D.

Content Reviewers: Leeka Gwanganalie, Betsy Parrish, and Laura Halldin

Peer Reviewers: Krista Espelien, Valerie Ozaksut, Erin Hustad, and Hannah Crook

To my parents. Thank you for your kindness, generosity, and unwavering support. The world is a better place because you are in it.

TABLE OF CONTENTS

CHAPTER ONE

Introduction

Life science is a rapidly evolving field of study that will need to be embraced and understood by a diverse group of thinkers if we are to successfully surmount the global health and environmental challenges of our present and future world. In Chapter One, I describe my personal journey that led me to developing the capstone research question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* The research will aid in the creation of my capstone project, namely a 4-week long unit plan, *A Menu About Me*, that explores the biological science behind students' personal and cultural connections to food. This chapter provides rationale for this question, and contextualizes the question in terms of my current role and school of employment. Furthermore, Chapter One outlines how stakeholders--including fellow educators, students, families, and the community at large--benefit from this research and curriculum development. Finally, I will close this chapter with a preview of the remaining sections of this project.

My Journey

"Miss, if you went out into the forest, would you rather meet the silent lion, or the lion who roars?" This was a question I received from a student of mine while I was working as an educational assistant for English learners at an upper-Midwest high school. This particular student was a highly motivated young woman in her late teens, who was a recent refugee from her home country. Prior to arriving in the United States during her high school years, she had never experienced formal “Western” education and her exposure to English was limited. When she asked me about the two lions, I told her that I was unsure of what she meant.

She smiled gently, welcoming the opportunity to clarify. “For me, Miss,” she said, “I’d always choose the roaring lion, because he tells you that he’s coming. He gives you a chance for what comes next.”

As we talked more, she revealed that the story of the lions was her way of describing the two types of teachers she had met in America. She claimed the silent teachers were those who pitied her: they held low expectations, and they did not tell her when or how she needed to improve in her studies. Though they were kind, they also tacitly assumed that she was forever trapped by the traumas of her past, and therefore could not hope to strive for a brighter future. The roaring teachers, on the other hand, were honest. They were not afraid to correct her when she was wrong, or to make her go back and try again. They told her truthfully where she was at, and laid out the skills she would need to master if she were to achieve her dream of becoming a pediatric nurse. “The teachers who respect me the most push me the most,” she said. “They are the ones who will help me when I go into the forest.”

I am currently in my second year of teaching high school science full-time, following my two years as an educational assistant. My current school of employment is an urban charter high school in the upper Midwest that especially caters to students with limited or interrupted formal education (SLIFE). In this time, I have come to appreciate the wonderfully diverse perspectives and insights that SLIFE bring to science, technology, engineering, and mathematics (STEM), as well as the unique challenges they face. For example, during a unit covering macromolecules this past year, I assigned students the bioengineering task of designing a model of a strong and sturdy structural protein using only ten pieces of printer paper, and one meter of masking tape. The objective of this project was to build a structure that would support the weight of as many textbooks as possible without collapsing, thereby illustrating the biological maxim, "form follows function."

Traditionally, students will find that rolling their papers into a concentric set of freestanding cylinders forms the strongest structure, which ultimately reflects the molecular structure of the protein, collagen. However, many of my students found creative, alternative solutions to the problem. One young lady from Tanzania, for instance, cut her papers into thin strips, and then wove them into a shape that approximately resembled an overturned bird's nest. Fascinated by her ingenuity, I asked her what inspired her design. In response, she showed me a Google Image on her iPad of a hadzabe hut, which is commonly made from weaving bent tree branches in her home country. Similarly, another student chose to shred his paper and then twist the bits tightly together until they were like a stiff rope that could be molded into a bridge-like shape supported by the tape. In form, his structure was very much like the old Incan grass bridges that still connect mountainsides to mountainsides in his country of origin today.

Upon reflection following the end of my first year of teaching, I realized that I needed to afford my students far more opportunities like this that allowed them to draw on experiences and understandings from their cultural backgrounds (commonly referred to in the literature as "funds of knowledge") as a strength in order to solve authentic, real-world problems (Hogg, 2011, p.666). The positive difference in engagement and retention of content was marked when students were given inquiry-based challenges, versus more traditional learning experience ("inquiry" means learning is student-led through natural lines of questioning, investigating, and problem-solving in response to relevant phenomena) (Minner et al., 2010, p.474). This strengthened my resolve that not only did I have to adapt my whole curriculum to better meet the cultural and linguistic needs of my students, but I needed to do it in such a way to empower them as the capable, and essential citizen scientists that they have every right to be. SLIFE students have a unique ability to change the world using science, but need help accessing certain tools - such as English language and formalized academic process skills - to make their mark.

The Rationale for the Capstone Question

As of 2019, the state of Minnesota reviewed its existing science standards and elected for full implementation of Next Generation Science Standards by the 2023-2024 school year (DOE, 2019). While 9-12 Life Science standards remain mostly unchanged or similar in terms of content, NGSS is unique in its specifications of how these standards should be taught, and how they will be assessed. The guiding framework of NGSS is the three-dimensional learning model, which mandates that (1) Scientific and Engineering Practices, (2) Crosscutting Concepts, and (3) Disciplinary Core Ideas are built into every course objective. In general, NGSS requires student-directed science education through "phenomena" (defined by NGSS as, "observable events that occur in the universe and that we use our science knowledge to predict and explain") and inquiry-based learning, as presented through authentic unit storylining (NRC, 2012).

Overall, I am highly supportive of this framework, and I believe that it will ultimately help all my students, including SLIFE students, achieve deeper understanding and engagement with material and practices in the life sciences. However, at this time, there are very few NGSS-approved curricular examples freely available that are adapted for EL students, let alone SLIFE students. Adaptation of the 9-12 Life Science curriculum for SLIFE students is of particular importance because NGSS differs from previous state science standards in that it is extremely iterative, meaning that every year, from Kindergarten to 12th grade, students dig a little bit deeper into the same content, as opposed to exploring completely new content in each grade level. This distinction is important because most SLIFE students enter formal schooling in the United States in their late middle school or early high school years, and therefore do not have that foundational knowledge in the content that is presupposed here. Thus, earlier iterations of life science standards have to be taught concurrently with 10th grade standards in order to meet the needs of all students. Through my research and capstone project, I hope to fill that gap in the curricular resources by answering the question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* Specifically, I will develop a 14-week unit, “A Menu About Me” that is guided by both the deep funds of knowledge and personal story-telling that SLIFE students bring to the various facets of the biology of food, and the inquiry-driven practices set forth by NGSS. This unit will also be scaffolded to provide English language support and formal education support for SLIFE students, according to best practices.

Context

According to the Minnesota Department of Education's Report Card (2022), the school of my employment had a student body composed of 64.0% Black or African American students, and 36.0% Hispanic or Latino students in the 2021-2022 school year. The DOE 2022 report also disclosed that 85.6% of the school's students were classified as English Learners, and over 90% of students received free or reduced-price lunch. In addition, DOE records indicated that only 3.6% of students were proficient in science in 2021, as determined by performance on the 10th grade science Minnesota Comprehension Assessment. Assessments from 2021 also showed that 3.3% of students were proficient in math, while 7.7% were proficient in reading.

In order to address student academic proficiency, the school enacted an improvement plan in 2018 with support and guidance from the DOE. Specific action steps for improvement in science instruction and achievement included enacting "special half class period study sessions", and increasing "benchmarking opportunities" (2018). Moreover, the school established a "Numeracy and Inquiry" working group of educators beginning in the 2020-2021 school year in order to promote and assess STEM teaching practices and engagement across the disciplines. Currently, I am going into my third school year as part of the Numeracy and Inquiry working group, and thus far our primary focus has been improving foundational math skills for all students. Moving forward, the aim of this group will expand to include design and implementation of NGSS standards.

Stakeholders

Determining the answer to this research question can benefit a wide range of stakeholders, including fellow educators, students, families, and the community at large.

This capstone project benefits fellow educators by freely providing previously unavailable full curriculum resources for 9-12 Life Science, which all Minnesota educators will need to completely adopt by 2023. Moreover, while this curriculum is adapted to meet the needs of SLIFE students, its materials are also transferable and relevant to ELs and mainstream students, as well. In addition, the literature review in Chapter Two provides a synthesis of current scholarship on SLIFE students, and inquiry and phenomena-based learning, which was highly useful to STEM educators at large.

This research and unit plan also has a profound impact on students and their families. Through the implementation of the curriculum, students are able to see their cultures reflected in the study of life science, and they are also able to use their deep cultural and linguistic funds of knowledge to reach a critical and authentic understanding of the world as practicing citizen scientists. Furthermore, they are able to explore careers in the sciences and make everyday scientific connections to their lives as consumers, so as to establish a relationship with the curriculum bound to last beyond the classroom. Families also benefit from the capstone project by frequent integration of familial perspectives, insights, and partnerships throughout the curriculum, as well as several outreach projects and events.

Finally, the larger community benefits from this research and unit plan because of increased engagement and understanding of diverse students and their families in the life science processes that are currently central to the global marketplace, including public health concerns, and environmental changes. Moreover, and perhaps most importantly, clearing pathways for diverse students to share their already profound knowledge and abilities in science and science practices is critical; as they say, the best way to look at a problem is from all perspectives. If we hope to surmount the challenges of tomorrow, we must hear from the scientific minds of all perspectives, today.

Summary

Chapter One Summary

In Chapter One I introduced my research question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* Following this introduction, I provided context detailing my personal journey as an educator which led me to this question, while also sharing how my past interactions with the unique stories, insights and perspectives of SLIFE students shaped my current educational philosophy as it relates to the life sciences.

In addition, I discussed the rationale behind my research question and capstone project in terms of an ever-changing and increasingly diverse American populace, and the immense need for scientifically literate and engaged citizens as we move forward into the future. I further elaborated upon this rationale by addressing how the promotion of life science achievement and interest amongst SLIFE students benefits a range of stakeholders including fellow educators, students, families, and the community at large. Current challenges in biological spheres like public health and the environment impact families directly and require the empowerment of all minds to meet them successfully.

Chapter Two Preview

Chapter Two reviewed at length the relevant body of literature associated with NGSS, the life sciences, and SLIFE students. The chapter opens with an evidence-based discussion of NGSS rationale, and the associated scholarship on phenomena and inquiry-based learning. Next, I devote particular attention to the 9-12 life science standards, while reviewing current best practices specific to the life sciences. Additionally, I report on recent biological developments and trends that will impact the lives and education of my students and other stakeholders. Finally, the chapter concludes with an overview of SLIFE students, and the opportunities and challenges they face in the classroom. Special attention is given to best practices for engaging SLIFE students in the sciences.

Chapter Three Preview

Chapter Three synthesizes the information and strategies detailed in Chapter Two in order to provide the foundation for the design of an NGSS-aligned 9-12 life science unit, focused specifically on the biology of food, adapted to meet the needs of SLIFE students. Special attention is paid to the following curricular frameworks that are utilized in the curriculum: understanding by design (UBD), 5E, the mutually adaptive learning paradigm (MALP®), and 5R. Using the extant literature, Chapter Three systematically justifies the objectives of the curriculum and described the timeline and themes of the included academic units in detail.

Chapter Four Preview

Chapter Four serves as a reflection on my research question and the delivery of the capstone project. I revisit points from the literature that proved especially poignant to my curriculum, in addition to drawing new connections between NGSS, life science, and SLIFE that were not previously anticipated in Chapter 2. Finally, I discuss how my work may impact policy decisions going forward, and I advocate for the benefits of my curriculum design to the profession as a whole.

CHAPTER TWO

Literature Review

The following literature review addresses the relevant research pertaining to my research question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?*

The chapter opens with a discussion on students with limited or interrupted formal education (SLIFE). SLIFE students represent a rapidly growing subgroup of English language learners in the United States (DeCapua, 2016). This section reviews the history and legal designation of SLIFE students, and the rationale for ensuring that this group of students receives the highest quality life science education. I explore research regarding strategies for SLIFE student learning adaptations, including their strengths and challenges in the Western-style formal education system.

In the next section, I explore NGSS, including its rationale and framework. In particular, the section examines the three dimensions of science learning proposed within the standards, namely: crosscutting concepts, disciplinary core ideas, and science and engineering practices (National Research Council, 2012). I also review benefits and obstacles to NGSS implementation in the classroom.

Building on the general NGSS framework, the following section dives deeper into the specific standards and best practices of a 9-12 Life Science program. I present studies concerning ideal pedagogy directed towards the major disciplinary core ideas of life science, as well as literature focused on the particular learning processes involved with the successful attainment of biological knowledge and processes. This chapter will conclude with how the NGSS framework in the life sciences also aligns with best practices for the education of SLIFE students.

Students with Limited or Interrupted Formal Education

Students with limited or interrupted formal education (SLIFE) are a growing subset of English language learners (ELLs) who did not receive--or received minimal or inconsistent--schooling prior to entering the United States education system due to factors of poverty or trauma in their home countries (DeCapua, 2016). This section investigates the designation and definition of SLIFE, as well as their unique assets and challenges in the American school system.

Definition. The face of the United States is changing. The U.S. Census Bureau projects that the American population could increase by as much as 127 million people by 2060, assuming that levels of immigration remain high (Johnson, 2020). In terms of racial diversity, the White (non-Hispanic) populace is expected to shrink to 44 percent in 2060 from 61 percent in 2016, with significant increases in the number of immigrants from Latin America, Asia, and Africa.

With these changes in population, the United States will also see changes in the student body of its public schools. Many of these students are classified as English Learners (ELs), meaning that their primary language (or languages) is something other than English (DeCapua, 2010). While there exists a growing support system and infrastructure for serving ELs in U.S. schools, it is important to acknowledge that the EL population is far from monolithic; students may vary widely in terms of their socioeconomic class, prior education, and traumatic experiences (Freeman et al., 2002).

One particular group of ELs emerged in recent years as needing a specific designation are those who have experienced limited or interrupted access to education. While these students only represent between 10 percent and 20 percent of ELs (Ruiz-de-Felasco & Fix, 2000), this subgroup tends to have fewer opportunities to attain literacy or adequate subject knowledge in their home languages prior to entering American schooling, and thus face unique challenges in academic achievement (Shanahan & August, 2007).

Several terms for classifying this group of learners have come into and out of the lexicon over the last few decades. These include: “unschooled migrant youth” (Purcell-Gates, 2013, p.69), “newcomers” (Ramirez & Jaffee, 2016, p.45), “students with truncated education” (Berumen & Silva., 2014, p. 52), and “students with interrupted formal education” (Custodio & O’Loughlin, 2017, p.23). Here, I will use the term “students with limited or interrupted formal education” (acronymized “SLIFE”), as proposed by DeCapua et al. (2009, p.159). This is the preferred term for the context of this capstone, as it includes those students whose schooling was never “interrupted,” but is considered inadequate in comparison to that of their U.S. peers.

Before I proceed, I will further break down the components of the SLIFE acronym. “Limited” education refers to schooling that did not meet the same standards of rigor or duration as U.S. schooling (Naidoo, 2013, p. 450-451). These limitations may be the result of decreased access to academic resources (e.g. books, writing materials, science equipment, technology), decreased access to educational professionals (either through lack of certified educators available, or extremely overcrowded classrooms), or decreased number of hours spent in school. Education may also be limited due to pedagogical methods (e.g. rote memorization, copying the board, religious instruction only, etc.).

A student's education may be "interrupted" for many reasons. Some of these interruptions may originate externally from the student's environment, and others may originate internally from the student's family, or the student themselves (Shapiro et al., 2018, p. 67). External factors might include war, natural disasters, migration, or elimination of access to school. Internal factors may include students needing to be at home (e.g. to take care of younger siblings, or to take care of sick family members), or students needing to go to work (either seasonally, or based on family income levels). The length of time for schooling interruptions can also vary significantly, and the formal and/or legal ramifications of these durations will be discussed in the next section.

We must also, of course, clarify what is meant by the term "formal education". Admittedly, the way formal education is defined in the United States is heavily dependent on Western values and beliefs (Zagar et al., 2014). Western-style formal education centers on scientific reasoning, and logical processes, and usually consists of a trained teacher teaching in a specified school building (Ozmon & Craver, 1999). The goal of education is largely "future-focused," with students learning information and skills that are not typically of immediate relevance or use (Folkestad, 2006, p.137).

While many countries worldwide have adopted the Western model of education, "informal" learning is still prevalent elsewhere (Grigorenko, 2007, p.165-167). This style of learning happens as a result of the practices needed for everyday life, and for survival (Nygren et al., 2019). Characteristically, family and community members are responsible for children's tutelage, and learning occurs "on-the-job" as opposed to within the classroom (Paradise & Rogoff, 2009, p.104). In contrast to decontextualized Western-style formal education, informal learning is pragmatic, and immediately practicable (Offit, 2008).

Legal considerations. The U.S. Department of Education does not formally recognize the SLIFE student designation, and therefore definitions and policies regarding SLIFE are fluid from state to state. In New York, for instance, a student must have received two fewer years of schooling to be considered SLIFE (Shapiro et al., 2018), whereas in Maryland a loss of just six months of formal education is sufficient for the SLIFE classification (COMAR 13A.05.07, 2016).

In Minnesota, a student must meet three of the following five criteria in order to be designated SLIFE: (1) Be an ELL, (2) Start school in the U.S. after grade 6, (3) Have, at minimum, two years fewer formal education than their U.S. peers (4) Be, at minimum, two years below grade level in both reading and math, or (5) May be preliterate in their primary language (Minnesota Learning English for Academic Proficiency and Success, Minn. Stat. § 124D.59, Subd. 2a.(2014)). This statute was embedded in the Minnesota Learning English for Academic Proficiency and Success (LEAPS) Act of 2014, marking the first time the SLIFE student designation was formally recognized by the Minnesota Department of Education. Under this provision, districts must report annual SLIFE student enrollment, and the state provides SLIFE student identification checklists and protocols to aid teachers in this process. Benefits to the official SLIFE student classification include elucidating the proper curricular, mentorship, as well as the potential to earn an official multilingual badge through the state; at this time the state does not provide additional funding for SLIFE enrollees (MN DOE, 2018).

The process of SLIFE student identification is sometimes complicated by the fact that students may come from an area where school records such as transcripts are very different from those in the U.S., or where records are simply not kept at all (Váldes, 2018). Thus, reliable interpreters or translation services in the family's home language are also essential for the correct determination of their educational background (Marshall & DeCapua, 2014). This is especially important when attempting to determine a student's level of formal education, wherein family input is often crucial in order to assess the student's connection to literacy sources at home, as well as prior exposure to academic content knowledge. Similarly, any standardized assessments used to determine reading, mathematics, or science abilities should be given in the student's home language; otherwise, the test will only truly be rating the student's English proficiency (WIDA 2015). There have been cases where on-grade-level English language learners have been misidentified as SLIFE students due to lack of care with home language adapted assessment tools (Klein & Martohardjono, 1999). This is a problem because non-SLIFE student English language learners often require much different supports and services than SLIFE students in order to be successful. In the next sections, I will examine the strengths and challenges of SLIFE students in the American school system.

Strengths. The literature tends to take a deficit view of SLIFE students, focusing on their academic obstacles to the exclusion of their strengths (DeCapua et al., 2020). However, recently there has been a push back on this tendency, with researchers centering how SLIFE students' experiences can enhance both their own learning, and the learning of their school community at large (King et al., 2017). Although SLIFE students, by legal definition, have little to no background in the formal Western learning environment, they have considerable "funds of knowledge" (Moll et al., 1992, p.132) in topics as wide-ranging as agriculture, zoology, construction, cooking, fishing, hunting, home economics, immigration, and the destruction caused by corruption, conflict, and war. Students have a rich body of life events and skills on which they can draw to make authentic connections to their formal educational work (González et al., 2005). In one afterschool STEM program dedicated to Burmese refugee adolescents, researchers noted how students often drew on their funds of knowledge in order to make connections to scientific topics of discussion (Ryu et al., 2019). For example, when discussing weather patterns, students recalled a ground bark paste they used known as *thanakha* that was used to protect the body from different weather conditions. This connection excited the students, and deepened their understanding of the content.

Many SLIFE students come from collectivist cultures that commonly value the success of the group, over individual accomplishments (Triandis, 1995). This is in sharp contrast to traditional Western attitudes that typically reward personal preferences and actions, as well as competition between individuals (Hofstede & McCrae, 2004). Due to this orientation, SLIFE students tend to excel in cooperative assignments and projects, as they see themselves as necessary contributors to the collective achievement (Hofstede et al., 2010). Importantly, this value does not mean that SLIFE students are not concerned with individual effort, rather that they are more motivated by shared success, as opposed to personal success (Rothstein-Fisch & Trumbull, 2008).

As discussed previously, most SLIFE students learned in primarily informal venues prior to entering U.S. schools. Much of the time, informal learning is characterized by orality, or spoken knowledge, in contrast to Western-style formal education which is heavily influenced by print literacy, or written knowledge (Eisenstein, 1979). In relation to the oral tradition, students have learned to compose, recite, and memorize epic stories, poems, and songs that are used to convey knowledge between many generations (Bigelow, 2010). As a result, SLIFE students often exhibit tremendous skills in oral literacy, and motivation in storytelling activities, as well as outstanding capacity for memorization and recall (Hos, 2016). Both of these assets can be leveraged in the classroom to increase SLIFE student engagement through increased oral communication and activities. For example, Burton and Van Viegen found that spoken word activities and poetry slams achieved high engagement amongst SLIFE students and other multilingual students in Canada, while also helping these students retain new information and providing a space for translanguaging practice (2021). Similarly, one researcher working with Somali SLIFE students in Minnesota recalled a poetry recitation event where students were so enthusiastic about their classmates' performances that the winners were "spontaneously lifted to the shoulders of their friends and carried around the gymnasium like star athletes" (Bigelow, 2010, p.36).

Visual literacy, or the ability to think in pictures, symbols, and diagrams, is also a strength for many SLIFE students (Brown & Castellanos, 2019). This skill is a particular asset in the sciences, where symbolic representation is similarly significant such as in models of the cell, the periodic table, and anatomical drawings. One recent study showed that SLIFE students achieved success in explaining an abstract concept when using claymation videos, thus drawing on their strengths in oral, visual, and gestural literacies (Hepple et al., 2014). Similarly, Burmese refugee students found success relating their personal experiences to school content through the use of digital storybooks that allowed for audiovisual communication in addition to practice with the written word (Cun, 2021).

Many SLIFE students have faced multiple changes and obstacles in their lives, and as a result, SLIFE students are often noted for their particular “resourcefulness, bravery, and resolve” (Newcomer et al., 2021, p. 418). Students have likely already overcome much in their lives, and therefore teachers should approach SLIFE students with the mindset that they can similarly face the challenges of formal education, given the right support.

Challenges. An asset-based lens is essential for educators to assume in order to regard SLIFE students as capable learners deserving of high expectations. At the same time, it would be neglectful not to address some of the challenges that SLIFE students face in the American educational system. In other words, it is not that the students are lacking in skill or ability, but rather that the rigidity and biased nature of Western education creates disproportional obstacles for many students, including SLIFE students. While the creation of this capstone unit seeks to dismantle some of these obstacles by centering student funds of knowledge and lived experiences, other obstacles–such as the prioritization of the written word in Western culture and communication–are likely to remain deeply rooted for the foreseeable future. This section highlights some of those rigidities of Western education, and discusses why they can often be challenges for SLIFE students to overcome.

Informal learning contexts are driven by tangible objects, practices, and needs which have an immediate impact on the learner’s life and environment (Shapiro et al., 2018). As such, SLIFE students can experience confusion and difficulty during their introduction to abstract elements of Western-style formal education that may have no clear purpose in the present (Marshall & DeCapua, 2014). One example of a common abstraction practice in Western classrooms--that can be foreign for SLIFE students--is categorization (e.g. by color, by size, by shape, by species, etc.). Luria (1976), designed the following two categorization tests shown below for non-literate farmers in remote areas of the U.S.S.R., and they have since been used for SLIFE students (DeCapua, 2016).

Figure 1. Which item does not belong? (Adapted from Luria, 1976).

Figure 2. What do these animals have in common? (Adapted from Luria, 1976)

Those schooled in Western-style formal education will usually remove the log, because it does not belong in the same category of "tools" within which the other three items fit. In contrast, many SLIFE students will say that the hammer does not belong (Naidoo, 2013). Why? Because the axe and saw can be used to chop the log, but the hammer cannot. Similarly, for the second test, many students used to the abstract concept of commonalities might say that both animals have fur, or both animals are mammals. SLIFE students, on the other hand, will often say that both animals can be eaten. In both cases, SLIFE students are focusing on their pragmatic, or utilitarian relationship to the objects or animals, as opposed to more scientific categorizations that have been ingrained from an early age in Western classrooms.

As noted earlier, many SLIFE students also come from orality-based cultures with little reliance on written materials, and, as such, are often not fully print "literate" in writing and reading. "Literacy" can be a contentious term, with many researchers and theorists proposing a range of definitions and conceptions. DeCapua, Marshall, and Tang (2020) outline four pertinent levels of literacy that SLIFE students in particular may fall under, including "pre-literate" (meaning the student has no previous experience of print literacy skills; and their home language may not have a written form, or only been recently written with few text-based resources), "non-literate" (meaning the student's home language has an established written form, but the student has not been exposed to it), "semi-literate" (meaning the student has some basic literacy skills in their home language, but these skills are not adequate to meet grade-level standards), or, finally, "literate" (meaning the student is fully literate in their home language, and needs to transfer those skills to English). It should be noted however that these definitions function more as checkpoints across a continuum of literacy, as opposed to concrete categorizations, and students may fluctuate between levels on different literacy skills (August & Shanahan, 2006).

For many SLIFE students, the challenge with entering a literacy-based education program is two-fold: (1) They must learn to read at grade level, and (2) They must learn to rely on the written word as a source of written language, instead of relying solely on oral communications (DeCapua et al., 2020). Often the second challenge poses one of the largest obstacles for SLIFE students since teachers in the U.S. expect secondary students to use print resources to deepen their understanding of concepts without necessarily providing context orally. In order to help SLIFE make the transition from the two-dimensional world to the three-dimensional world, it is important to heavily scaffold literacy-based instruction with oral directions, as well as visual aids (preferably realia) (Altherr Flores, 2017).

Finally, many SLIFE students have experienced, or continue to experience, significant trauma (Custodio & O'Loughlin, 2017). Some students may have post-traumatic stress disorder (PTSD), or PTSD-like symptoms, stemming from events in their home country, such as war, natural disasters, or famine. It is common for SLIFE students to have lost family members, or to be separated from family upon arrival in the U.S. Moreover, immigration and culture shock (which is often doubly extreme in the case of SLIFE students), carry their own stressors of adjustment to a new environment, with its own rules, norms, and customs (Ho & Levesque, 2005). Being conscious of this condition, as well as helping SLIFE students develop resilience, is paramount to their success in the United States. A teacher of newly arrived high school aged SLIFE and refugee students in the U.S. leveraged students' skills in storytelling in order for her to learn about students' experiences and potential trauma, and also to help guide their practice and the curriculum moving forward (Stewart, 2015). The teacher first scaffolded the storytelling experience by sharing non-fictional accounts written by other adolescent refugees. The students discussed the story, and shared similarities and differences between the author's experiences and their own. Then they worked on developing their own stories using multiple literacies, including visual, oral, and print. Both the students and their teacher noted how fundamental this project was in building connections between students, the school, and their own narratives.

For this capstone project's 14-week life science unit plan, *A Menu About Me*, I will ensure consistency in supporting SLIFE students' print literacy and academic language development by utilizing the 5R Instructional Model for emerging multilingual students in science (Weinburgh et al., 2019). Further information about this framework is discussed in Chapter Three.

The next section will examine new national science standards, and the third section will address how best to adapt the teaching of these standards in the life sciences for SLIFE in order to answer the question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?*

Next Generation Science Standards

The Next Generation Science Standards (NGSS) are a new set of K-12 national standards developed by the National Research Council (2012) with the goal of ensuring that, “by the end of 12th grade, all students have some appreciation of the beauty and wonder of science…and…possess sufficient knowledge of science and engineering to engage in public discussion on related issues” (p.1). Research reviewed in this section will provide a rationale behind the initial design and adoption of NGSS, as well as literature detailing best practices and efficacy of the standards as they have already been enacted. Special attention will be given to the three dimensions of science learning, namely “crosscutting concepts”, “science and engineering practices”, and “disciplinary core ideas” (NRC, 2012, p. 2).

Rationale. We are living in a world where the importance of science--and people who understand science--is becoming ever more central. According to a 2021 report from the President’s Council of Advisors on Science and Technology, advances in developing areas of research such as artificial intelligence, quantum computing, and biotechnology are amongst those most likely to shape the future of our next century (PCAST, 2021). The U.S. Bureau of Labor Statistics predicts that the number of job openings in science, technology, engineering, and mathematics (STEM) fields will grow far faster than occupations in other sectors, with some of the largest increases seen in the healthcare and technology sectors (Vilorio, 2014). Wages in STEM professions are also well above average, with the median annual 2020 salary of STEM careers listed at $69,760, and the median annual salary of all occupations falling at $41,950 (BLS, 2021). As noted in the previous section, one of the largest growing demographics of the U.S. population will be immigrant groups, including those representing SLIFE. Ensuring that SLIFE receive a high quality of education will provide them with the skills necessary to fill these critical roles in the job market.

Beyond the job market, the importance of a scientifically literate population is also apparent. Gaps in understanding in life, physical, and earth sciences have only exacerbated the effects and inequities perpetuated by such global crises as climate change, health care, pandemic response, and depletion of natural resources (IBM, 2021). Engagement in the scientific process and community trust in scientific thinking will best prepare the United States, and the world at large, to meet these coming challenges with confidence and intelligence (Thomke, 2020).

However, recent reports have indicated flagging achievement of American K-12 students in STEM. The most recent Trends in International Mathematics and Science Study (TIMSS) report showed that U.S. 8th graders ranked 11th out of 46 globally participating educational systems in a standardized science test, significantly behind international economic competitors in China, Japan, Russia, and Korea (Mullis et al., 2020). Moreover, the U.S. had one of the largest score gaps between its highest achieving students, and its lowest-achieving students--suggesting a high level of inequality across the nation's science education program.

Reasons for the current rate of success (or lack thereof) in American science education include a lack of coherence in curricula across the grade levels, an emphasis on adding content over adding deeper understanding, and the dearth of opportunities for students to engage authentically and meaningfully in scientific inquiry (Schmidt et al., 1997). The Next Generation Science Standards (NGSS) were designed in order to provide a framework to address these deficiencies head on.

In contrast to previous national science standards, NGSS limited the number of concepts that should be taught in favor of a greater focus on mastery, building connections between disciplines, and practices (NRC, 2012). This framework also allowed for increased clarity in the natural progression and incremental building of learning between the grade levels, so as to construct a more solid scientific foundation. The basis for this foundation, as set forth by NGSS, are the three dimensions of science learning, namely: science and engineering practices, crosscutting concepts, and disciplinary core ideas.

Science and Engineering Practices. Science is not simply a body of isolated facts and figures, but rather a way of understanding and interacting with the world. Prior standards and science pedagogies have emphasized the content of scientific knowledge to the detriment of developing students as engaged, practicing scientists (Driver, 1996). In placing science and engineering practices as one of its driving dimensions, NGSS stresses the criticality of practice, and its fluid interaction with existing content knowledge.

It is easy for students to feel distanced from major scientific discoveries (and their discoverers) when they are presented as self-evident, and static truths of nature. However, in reality, the nature of science is exploratory, often messy, and always evolving (Giere, et al., 2006). While certain terms and definitions relevant to experimental procedure are sometimes taught as their own unit (e.g. " the six steps of the scientific method", "hypothesis building", "independent vs. dependent variables", etc.), this approach does not allow students to engage with these ideas as a way to understand later units, and it often excludes other important tenets to the nature of science including modeling, cooperation, critique, and redesign (Ford, 2008, p. 147). Moreover, when students are given the chance to actually do science, it has been shown to increase their motivation to engage, and deepen their conceptual understanding of the topic (Florman, 1976; Petroski, 1996).

In the development of NGSS, the National Research Council identified eight practices that were intentionally woven into the fabric of the standards: (1) Asking questions (for science) and defining problems (for engineering); (2) Developing and using models; (3) Planning and carrying out investigations; (4) Analyzing and interpreting data; (5) Using mathematics and computational thinking; (6) Constructing explanations (for science) and designing solutions (for engineering); (7) Engaging in argument from evidence; and, (8) Obtaining, evaluating, and communicating information (NRC, 2012).

The intention of these practices is not to present them as a concrete, linear progression to be quickly memorized, and then set aside, but rather to enact them organically as part of a student's fluid cycle of personal scientific investigation (Bauer, 1992). Furthermore, it should be made clear that science is always changing; what was once widely accepted as true (e.g. the Earth being at the center of the solar system), may be rejected in the wake of new evidence. In the same vein, students can come to see themselves as active contributors to the scientific community, perhaps changing our collective understandings of tomorrow.

Crosscutting concepts. While it is often our tendency to group certain ideas with particular scientific subjects--such as biology, chemistry, and physics--the truth is that all of science (and knowledge in general) shares many of the same basic concepts (American Association for the Advancement of Science, 1989). Although this understanding may develop naturally for some students, intentional instruction and integration of these "crosscutting concepts" into the standards will serve to deepen all students' interaction and conceptual understanding between grade levels and topics (NRC, 1996). The crosscutting concepts have been described as "the learning goals" for science literacy (Duschl & Grandy, 2012, p.2113), in that they describe the foundational language of science that should be returned to and built upon with each progression between topics and years in science education.

The formative committee behind NGSS identified seven essential crosscutting concepts, which can be further categorized into three sections (NRC 2012). (1) "Patterns", and (2) "Cause and effect: Mechanism and explanation", fall under basic understanding of the nature of science. The third (3) crosscutting concept, "Scale, proportion, and quantity" deals with mathematical descriptions and frameworks for the purpose of comparison. Meanwhile, the final four crosscutting concepts--(4) "Systems and system models", (5) "Energy and matter: Flows, cycles, and conservation", (6) "Structure and Function", and (7) "Stability and change"-- can be understood as interconnected facets of visualization and modeling (College Board, 2009).

Repeated representation and use of the crosscutting concepts as prescribed by NGSS has been shown to assist students in contextualizing their own understanding of new and difficult concepts (Yoon et al., 2018). Other work has indicated that teachers who specifically scaffolded assessments using crosscutting concepts as a frame saw more and deeper connections illustrated in their student's *or* students' output (Zangori et al., 2015).

At the same time, it is important to note that there are detractors to the crosscutting concepts dimension. Some researchers argue that the crosscutting concepts do not make sense as a group, and therefore come across as a handful of vaguely scientific ideas that were thrown together in the guise of a cohesive third dimension (Cooper, 2020). Similarly, it has been suggested that, while there are some commonalities across the disciplines, there is also a danger of excluding the uniqueness of different practices in the effort to synthesize (Osborne et al., 2018). In addressing these concerns the NGSS framework suggests that shared phenomena be reinforced so as to best support disciplinary core ideas, rather than to obscure them (NRC, 2020).

Disciplinary Core Ideas. The third and final dimension of NGSS is disciplinary core ideas. The disciplinary core ideas, at the superficial level, may be thought of as classical academic disciplines in the sciences, namely physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science (NRC, 2012). However, in incorporating science and engineering practices and crosscutting concepts into the disciplinary core ideas, the rich connections between the core ideas are emphasized, therefore creating a more complex and holistic network of science understanding across disciplines and grade levels. Building on the notion of depth over breadth, the disciplinary core ideas are limited to only the most essential concepts in each discipline, which then can be iteratively enriched over subsequent grade levels (NAE & NRC, 2009).

Disciplinary core ideas specific to the life sciences domain--and particularly those in the 9th-12th grade band--will be explored at a greater depth in the following subtopic section, in concert with the mutual best practices for NGSS life science and SLIFE student education in order to answer the question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards*

(NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?

9-12 Life Science

As put forth by the Next Generation Science Standards (2013), the "performance expectations for high school life science blend core ideas with scientific practices and crosscutting concepts to support students in developing usable knowledge that can be used across the disciplines"(p.1).

This section examines the rationale, context, and relevant research for NGSS standards specific to the high school life sciences, including representations from each disciplinary core idea: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, and 4) Biological Evolution: Unity and Diversity. Literature concerning best teaching practices for SLIFE in NGSS-aligned life science is discussed.

Life Science Disciplinary Core Ideas. Life science, traditionally thought of as the youngest of the major natural sciences, is constantly growing in its scope, and its implications are evolving rapidly. Despite the far reach of the life sciences, the National Research Council--in the development of the life science disciplinary core ideas (DCIs)--chose to focus on the concepts that unify the essential ideas in the field, following the example of the National Academy of Sciences and the Institute of Medicine (2008).

Life science (also known as biology), is increasingly central to understanding the complexities of today's global landscape (Reiss, 2020). How do students make sense of the current anthropocene era, and its connections to mass extinction, overpopulation, global food supply chains, and the spread of zoonotic diseases (Kolbert, 2014)? How do American teachers educate forthcoming generations on the intricacies of their personal health care, from understanding choices in diet and hygiene, to antimicrobial resistance, to advances in limb regeneration and gene editing (Topol, 2015)? These questions only represent a small fraction of the vast score of highly interconnected biological topics that humans will have to tackle (or continue to tackle) in coming years. The NGSS framework particularly prioritizes the contextualization of these vital core ideas in the life sciences at the 9-12 grade band (NRC, 2012).

The first DCI in the life science dimension is “From Molecules to Organisms: Structures and Processes” (NRC, 2012). At the high school level, this DCI covers the building blocks of life, from macromolecular and cellular structure, to the shape and function of DNA, to the complex processes that enable organismal growth, metabolism, and reproduction. Froshauer (2016) argues that the ideal progression for student learning in this DCI is to begin with direct observations (i.e. “What does the structure of a leaf look like using my eyes? What does it look like under the microscope?”), then progress to models (i.e. “What are the components of the plant cell that I can’t see, and what are its functions?”), and finally delve into exploring the processes that govern these structures (i.e. “How does the process of mitosis affect the plant on the cellular level, and also on the organismal level?”).

The second DCI is “Ecosystems: Interactions, Energy, and Dynamics” (Bybee 2012). For students in grades 9-12, this core idea entails the exploration of limiting factors and carrying capacities faced by interdependent populations, the influence of metabolic processes such as photosynthesis and cellular respiration on the conservation of energy within ecosystems, the impact of ecological disturbance (anthropogenic or otherwise) on the sustainability of the system, and lastly the behaviors that govern interactions of individuals within and between groups. Cizmas (2021) urges that direct connections between students and the ecosystems they (or the school building) occupy are vital for authentic engagement with ecosystem core ideas.

The third and fourth DCIs for the life sciences, namely: ‘Heredity: Inheritance and Variation of Traits’ and ‘Biological Evolution: Unity and Diversity’ are intimately entwined (NGSS, 2012). Heredity of genes and the processes that underlie the replication and passing on of DNA are, of course, integral to the determination of traits that organisms carry evolutionarily for reproduction, and ultimately, speciation. These are also the two core ideas that, historically, have inspired the greatest developments, and, in some cases, the most controversial within the scope of the life sciences. In the examination of relevant hot-button topics ranging from stem cell research, to gene therapy, to the age-old evolution versus creation debate, teachers are encouraged to acknowledge the preconceived notions and beliefs that students bring to the classroom, while maintaining fidelity to the standards (Bybee, 2003). Often, direct instruction on what constitutes the nature of science helps students to navigate the distinctions between personal beliefs, and the process of evidence and inference in the life sciences.

SLIFE and NGSS Life Science Best Practices

At first blush, the NGSS framework and preferred pedagogy for SLIFE students might seem at odds. NGSS is student-centered and inquiry-based, meaning that students need to be the primary producers of their own academic knowledge, as well as the language surrounding and supporting that knowledge. This is clearly a challenge for SLIFE students for whom not only is English proficiency an obstacle, but also lack of familiarity with the basic forms of Western academic language and the formalized scientific process (Nutta et al., 2011). However, there is growing evidence that the best methods for teaching life sciences through NGSS, overlap strongly with best practices for reaching SLIFE students.

One area where this overlap in best practices is demonstrated is in the NGSS commitment to coherence between topics (Grapin, 2021). Prior curricula in high school life science were heavily unit-based, with lessons in evolution, for example, categorized and kept separate from lessons in genetics. In contrast, the NGSS framework requires the integration of crosscutting concepts, therefore stimulating students to build a bigger and more comprehensive mental network of biological sciences as a whole. For SLIFE, this organization of the curriculum plays into their strengths in storytelling, and their focus on interrelationships between newly formed content knowledge (Colburn, 2000). Moreover, returning to past concepts helps SLIFE to strengthen and retain vocabulary and academic language forms (Echevarria et al., 2008). A project with a group of Karen SLIFE students at the elementary level showed that the implementation of a cross cultural storytelling feature utilizing the multimedia application, Photovoice, allowed students to film real-life science connections in their homes, and then share those experiences with classmates in school (Harper, 2017). This had the dual outcome of not only increasing student engagement with, and retention of science content, but also increasing family engagement with the school community.

NGSS-aligned life science lessons are particularly benefited by group work (McConnell et al., 2016). Students are required to work together to ask questions, discuss possible solutions, and conduct investigations. This practice not only reflects the real-life processes of working scientists, but it is also beneficial to SLIFE who come from collectivist cultures. SLIFE are able to have the familiar experience of working towards a goal as a group, while being gradually scaffolded to present their individual learning and achievements (Marshall & DeCapua, 2014). In one school in Australia, secondary science teachers and ESL teachers worked together to help SLIFE students develop a collaborative multilingual science dictionary (Miller, 2009). Not only did this student-driven dictionary help students develop print literacy skills in a culturally relevant cooperative manner, but students also used stories and images/drawings from their own lives to make authentic connections to their new vocabulary.

As noted previously, SLIFE tend to value contextualized learning that has immediate relevance to their lives. Fortunately, contextualization and problem-based learning are at the heart of NGSS life sciences (Bybee, 2013). Students are presented with scenarios that are directly applicable to their lives (e.g. "How do different foods give me energy?" or "What causes me to feel sick?"), and then in working through the scenarios they tackle concepts and vocabulary organically as they occur during the investigation. This approach allows SLIFE to see the real-life applications of their learning, and it reinforces the importance of their prior knowledge with different scenarios. In a life cycles unit designed for elementary school SLIFE students in Australia, students embraced hands-on learning experiences in a school garden (Brown et al., 2017). Students worked daily in the garden, raising various plants from seeds, all the while making detailed observations and measurements on their plants' growth, learning to ask questions about the biological phenomena they witnessed, and eventually carrying out their own investigations based on their questions. The project culminated with an art project where students made connections between the life cycles of the plants they had nurtured in the garden, and those vegetables that they enjoyed with their families in their home countries. And, of course, when the time came, the students harvested, and feasted on the literal fruits of their labor. This multidisciplinary project is a prime example of how the immediate, and cross-cultural relevance of growing food can be incorporated into an effective unit that both promotes student inquiry and investigation, and supports the strengths of SLIFE students.

In the design of my 4-week unit plan, *A Menu About Me*, I will use the 5E framework to ground the unit in NGSS-aligned inquiry-driven instruction, and I will use the mutually adaptive learning paradigm (MALP®) to guide the equity of my lesson designs for SLIFE students; more details on both of these guiding frameworks will be illustrated further in Chapter Three (Bybee, 2015; DeCapua et al., 2020).

Summary

In this chapter, I dissected the academic literature relevant to the three major subtopics of this capstone project, namely: SLIFE, NGSS, and 9-12 Life Science Standards. I discussed the definition and designation of SLIFE, and their strengths and challenges in the American formal education system. Following that, I overviewed the rationale for NGSS and the foundational aspects of the NGSS framework. Finally, I more fully broke down 9-12 Life Science standards under NGSS, and closed with a survey of methodologies that are mutually beneficial for both SLIFE and science learning under the new science learning paradigm. In the next chapter, I will apply the information given in this literature review to the synopsis of my unit project to answer the question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* First, I illustrate the general outline for the 4-week long unit plan, *A Meal About Me*. Then, I discuss the four theoretical frameworks that underpin my unit design: Understanding by Design (UBD) for general unit design (Wiggins & McTighe, 2011), the 5E instructional model for science inquiry (Bybee 2015), the mutually adaptive learning paradigm (MALP®) for SLIFE students (DeCapua et al., 2020), and the 5R instructional model for multilingual science learners (5R) (Weinburgh et al., 2019). Following that, I define the project's intended audience. Finally, I set forth the setting of the project, followed by a timeline for the project's implementation.

CHAPTER THREE

Project Description

Introduction

Educators frequently speak of preparing today's students for tomorrow's challenges. But increasingly we find that those so-called "future" problems have already arrived, and the time for students to grapple with them is now. Students with limited or interrupted formal education represent a vital and growing, yet often overlooked subset of the population, whose varied life experiences can grant them unique perspectives and skills for the solving of these critical problems. The Next Generation Science Standards establish a framework for developing curricula that help all learners utilize their knowledge for an immediate and authentic purpose, including via addressing those global issues particularly concerning the life sciences. I believe that a strong unit design for a 9-12 life science course that incorporates best practices for SLIFE student education in conjunction with NGSS principles, is essential for shaping generations of diverse investigators, engineers, and thinkers who have the power to change both today and tomorrow. Therefore, for this capstone project I will answer the question: *How can science educators design and implement a 9-12 Life Science unit that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?*

This chapter will present an in-depth description of my project. First, I will outline the flow and content of my 4-week 9-12 life science unit, *A Menu About Me*, including sources for the relevant NGSS, and WIDA standards. The first four weeks of this plan will be fully fleshed out for the capstone project, and the remaining ten weeks will be outlined. Then, I will address the theories underlying my unit design process, including those set forth in *Understanding by Design* (UbD) (Wiggins & McTighe, 2011), Biological Sciences Curriculum Study (BSCS) 5E Instructional Model (5E) (Bybee 2015), the mutually adaptive learning paradigm (MALP®) (DeCapua et al., 2020), and the 5R instructional model for emergent multilingual learners in secondary science (5R) (Weinburgh et al., 2019). After that, I will discuss the intended audience for the project. Next, I will disclose the setting for my project, as well as the project's participants. Finally, timelines for the design and implementation of the curriculum will be provided.

Curriculum Description

This curriculum is designed to fulfill the requirements of one high school life science (a.k.a. "biology"). In Minnesota, the 2019 NGSS-aligned science standards must be fully implemented by the 2023-2024 academic year, at which time those new standards will be assessed on the Minnesota Comprehensive Assessment (MCA) (MDE 2020).

As this curriculum is being adapted for SLIFE students who are ELLs, it is also essential that I follow the new 2020 WIDA English Language Development Standards Framework for 9-12 students (WIDA 2020). This framework will guide my daily academic language objectives, as well as overarching goals for students' English language progress.

The general theme organization for my 4-week long unit plant (and additional 10-week unit outline) curriculum is given by Table 1, below. The overarching question is, "Can you tell a story about a meal that is important to you and its connections to biology?" As the unit progresses, students will follow related lines of inquiry to more deeply contextualize their meal, what it means to them, and the biological links of the ingredients involved. Food science was chosen as the unit focus for several reasons: (1) Cross cultural relevance- Most people have meaningful connections to food, and important stories from their lives that surround food, (2) Opportunities for inquiry and immediate relevance- Food items such as fruit and vegetables are readily available, easy to observe and study, and provide immediate relevance to students' lives, (3) Crosscutting concepts and disciplinary core ideas- Food science is relatively easy to tie to the various crosscutting concepts in science, and to many of the core ideas of 9-12 life science standards as put forth in NGSS.

Table 1. Unit organization overview.

Unit Story Section	Driving Question(s)	Standard(s)	Estimated Duration
Story 1: You Are What You Eat (Macromolecules Focus)	Can you design the "best" possible school lunch program? What makes food "healthy"?	**NGSS**: HS-LS1-6 **WIDA**: ELD-SC 9-12 Explain. Interpretive	2 weeks
Story 2: Solar-Powered (Photosynthesis/ Cellular Respiration and Energy Cycle Focus)	Why do we need to eat? Where does energy come from?	**NGSS**: HS-LS1-5, HS-LS1-7, HS-LS2-3, HS-LS2-4, HS-LS2-5 **WIDA**: ELD-SC 9-12 Explain. Expressive	4 weeks
Story 3: Food's Past, Present, and Future (Genetics and Evolution Focus)	Has food ever changed in the past? Can we change what food is like in the future?	**NGSS**: HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-LS4-1, HS-LS4-2, HS-LS4-4 **WIDA**: ELD-SC 9-12 Argue. Interpretive	4 weeks

Story 4: Hunger (Human-Ecosystem Interactions Focus)	Is it possible for all humans to have enough food to survive and be healthy?	**NGSS**: HS-LS2-1, HS-LS2-2, HS-LS2-6, HS-LS2-7, HS-LS2-8, HS-LS4-6 **WIDA**: ELD-SC 9-12 Argue. Expressive	3 weeks
Culminating Project: A Menu About Me	Can you tell a story about a meal that is important to you and its connections to biology?	Review of all previous concepts	1 week

Curricular Theoretical Frameworks

In addition to the NGSS three-dimensional science learning framework, and the other theories and practices outlined in Chapter Two, I have utilized three curriculum-design theories to assist with this project: *Understanding by Design* (Wiggins & McTighe, 2011), and the BSCS 5E Instructional Model (Bybee, 2015).

The philosophy of *Understanding by Design* (UbD) is centered on a few main tenets of teaching and learning (Wiggins & McTighe, 2011). First, UbD warns against 'activity-driven' instruction that puts the focus on what students are *doing*, as opposed to what they are meant to be *learning*. This is particularly true for the sciences, where there is a tendency to instruct students to "do a lab", without necessarily requiring students to make authentic connections between that lab and the associated content objectives, thereby doing nothing to deepen their understanding. Similarly, UbD encourages "backwards design", meaning that educators intentionally plan units by beginning with objectives and assessments, and then work backwards to create appropriate lessons. This approach helps prevent a "coverage orientation" wherein instruction often feels disconnected from assessment, and the lack of direction leads to inefficiency and confusion in the curriculum.

The BSCS 5E Instructional Model fits naturally into UbD (Bybee, 2015). Originally developed specifically for instruction in the life sciences, the 5E model helps ensure that science lesson progression is intentional and meaningful for students by establishing a five-step learning sequence: (1) **E**ngage--draw students' interest by posing a relatable question or phenomenon, (2) **E**xplore--provide opportunities for students to further grapple with the problem and come to their own questions and hypotheses, (3) **E**xplain--directly address student misconceptions on the problem, and provide vocabulary and conceptual frameworks for students to build into their understanding, (4) **E**laborate--provide new opportunities for students to apply and practice their knowledge, and (5) **E**valuate-- teachers assess students' progress towards objectives, and provide feedback as necessary. This framework will help ensure that students are personally engaged in the learning process, and that they have the ability to use their knowledge to solve authentic problems. In general, I plan to incorporate the 5E model over the course of a weeklong learning cycle, with one to two NGSS standards addressed each week. The structure of this implementation is shown in Table 2.

Table 2. 5E implementation over weeklong cycle

Day 1: Engage (Guiding phenomena introduced/ students generate questions)	**Day 2**: Explore (Students dig deeper, explore supporting data, generate more questions and hypotheses)	**Day 3**: Explain (Teacher introduces formal terms and vocabulary, corrects misconceptions)	**Day 4:** Elaborate (Students apply new terms to connecting phenomena and stories, as well as to their lives outside of school)	**Day 5:** Evaluate/ Extend (Students have a summative assessment, and are given an opportunity to learn more)

The mutually adaptive learning paradigm (MALP®) is a framework designed specifically for adapting content-area lessons for SLIFE students based on best practices for SLIFE education, such as immediate relevancy, the centering of student narratives and the use of multiple literacies, as delineated in Chapter Two (DeCapua et al., 2020, p.135). I will use the publicly available MALP® checklist, given below in Table 3, to ensure consistency and adherence to best practice.

Table 3. MALP® checklist, adapted from DeCapua et al., 2020, p.135.

A. Accept Conditions for Learning	**B. Combine Processes for Learning**	**C. Focus on New Activities for Learning**
☐ I am making this lesson/project immediately relevant to my students' lives. ☐ I am helping students to develop and maintain interconnectedness with each other.	☐ I am incorporating both shared responsibility and individual accountability. ☐ I am scaffolding the written word through oral interaction.	☐ I am developing academic ways of thinking. ☐ I am teaching students how to engage in decontextualized tasks to demonstrate mastery. ☐ I am using familiar language and content as scaffolds.

In the secondary science classroom (and particularly in life science), content vocabulary acquisition is a necessary component of accessing new scientific concepts to the fullest extent (Weinburgh et al., 2019). Scientific vocabulary instruction has traditionally been front-loaded–that is words and definitions are explicitly taught before students have had the opportunity to experience phenomena or make personal connections to the material. Clearly, this pedagogical approach to vocabulary is at odds with best practices for both NGSS and SLIFE students. As such, the 5R model was developed specifically for language development in the secondary sciences for emerging multilingual learners,which aligns with the previously discussed 5E model. The 5R instructional model consists of the following phases: **(1) Replace**: After students describe a phenomenon using familiar language (e.g. first language, non-academic English, orally, in drawings, etc.) the teacher acknowledges their description, and then gives them academic language to replace it if necessary (this phase would align with the "Explain" phase of the 5E model. **(2) Reveal:** The teacher reveals any new words/language that students did not have a "translation" for in their original description. **(3) Repeat:** Both teachers and students practice new vocabulary by repeating its use in various related contexts. **(4) Reposition:** If necessary, the teacher repositions the new vocabulary that students are using if they are using it in non-conventional grammatical ways (e.g. using a noun in a sentence as though it were an adjective). **(5) Reload:** This component of the 5R model addresses the supports that will be used to reinforce the new vocabulary in the classroom environment (e.g on word walls, in practice flashcard sets, etc.). For this unit plan, I will informally refer back to the principles of 5R to help guide my curriculum development in terms of vocabulary introduction and practice.

Figure 3. 5R key for theme vocabulary

5R Stage	**Key Abbreviation**
Replace Reveal Repeat Reposition Reload	RP RV RPT RPS RL

Intended Audience

This unit design is intended for use in 9-12 life science classrooms in American classrooms that are implementing, or planning to implement the NGSS framework. While this unit pays particular attention to the needs of SLIFE students, the practices used are optimal for all students on their science-learning journey.

Settings

This curriculum will be designed for at an urban public charter high school in the Upper Midwest, serving a small population of about 180 students, over 80% of whom are ELLs (with a large percentage of those being SLIFE students, refugees, and/or newcomers), and over 90% who receive free or reduced price lunch. About 60% of the student body is African (primarily Eastern and Central African), and the other 40% is Latino (primarily indigenous South American).

The participants for this study will be students at the above location who are participating in the year-long biology course. Although the majority of students taking biology will be in the 10th grade, it is also common for 11th and 12th graders to take the course depending on their graduation requirements, and their English and academic proficiency levels prior to coming to the U.S.

In the school of implementation, every Friday is a half-day for students, which means shortened periods (30 minutes, as opposed to the 55 minute class period on Monday-Thursday). This half-day is incorporated into the schedule so as to accommodate the large population of Muslim students who go to prayer on Friday afternoons. This shortened Friday is incorporated into the unit plan.

Also of note is the fact that class sizes at the school of implementation are typically small (averaging between fifteen to twenty students).

Timeline

Curriculum development will be completed by the end of summer 2022. Curriculum will be ready for implementation in fall 2022. This unit is meant to be implemented approximately four weeks after the beginning of the school year (following an introductory unit), and will run for the remainder of the standard fall semester.

Summary

In the preceding chapter I discussed my plan for curriculum development design and implementation in order to answer the question: *How can science educators design and implement a 9-12 Life Science curriculum that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* I presented an overview of UbD and addressed how it will be employed as the theoretical design framework for this unit plan. I also discussed three other theoretical frameworks that will ground my unit design: 5E, MALP®, and 5R. Finally, I shared when and where the curriculum will be implemented, including a description of the intended audience for the project. In the next chapter I provide a reflection on the curriculum design and implementation, as well as the conclusion to this capstone project.

CHAPTER FOUR

Conclusion

Introduction

The main objective of this capstone project was to design a curriculum unit to answer the question: *How can science educators design and implement a 9-12 Life Science curriculum that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* As stated in Chapter One, the need for this capstone project was clear given that there are few full NGSS-aligned 9-12 life science units that are freely available, and even fewer units designed for high school-aged SLIFE students. Units that both align with NGSS (NRC 2012), and are made with SLIFE students in mind are virtually nonexistent. In Chapter Two I addressed the literature and frameworks that guide best practices for NGSS implementation, and for supporting the strengths and needs of SLIFE students, and in Chapter Three I set forth my plan for unit development. Chapter Four discusses the process of building the curriculum, limitations of the project, and possible directions for future work. Throughout this chapter I refer back to the relevant literature. The chapter ends with a personal reflection on the summation of the project.

Writing the Curriculum

I created the curriculum using three primary frameworks, as described in the literature review. For curriculum development, I followed Understanding by Design (UbD; Wiggins & McTighe, 2011); for NGSS and inquiry-driven alignment I used the 5E Model (Bybee, 2015); and for appropriate SLIFE student adaptation I incorporated the

Mutually Adaptive Learning Paradigm (MALP®), as designed by DeCapua and Marshall (2021). In this section, I will break down how each of these frameworks were implemented.

In my first full year of teaching I had three science preps, none of which had any existing curriculum. Between my naivete as a new teacher, and independently developing these three courses on the fly, a lot of slapdash forward planning occurred. I felt directionless and disorganized, and I am certain that my students suffered for it. This was not the way I wanted to teach.

When using UbD (Wiggins & McTighe, 2011) to guide my unit planning, I felt like a huge weight had been lifted from my teaching shoulders. Starting with the standards, and then designing the summative assessments around the confines of those standards (and *only* those standards) gave me a much better understanding of how to orient my daily lessons. It's a bit of a cliche, but it's true: it's difficult to plan a journey if you don't have a destination. Using UbD also helped me to be mindful about the vocabulary students needed to learn each week, and purposeful about the introduction of each new word over the course of the unit. I believe this will make it *much* easier for me to create additional support materials such as word walls, and review resources ahead of time. Overall, the experience of using UbD to construct my curriculum was exceptionally liberating as an educator because it gave me a sense of control over my content, and not the other way around.

In addition, the UbD framework fit in very organically with the 5E model (Bybee, 2015) which I employed to ensure that my science units were inquiry-based, and student driven. Although often-times the 5E model is applied two a single one to two day lesson cycle, I thought it made the most sense to spread out the steps across the five day week: Mondays for “Engage”, Tuesdays for “Explore”, Wednesdays for “Explain”, Thursdays for “Elaborate”, and Fridays for “Evaluate”. My main reason for using the 5E model across an entire week was to give my students (and, frankly, myself) a sense of weekly structure: for instance, the students will know that if they missed a Tuesday, they will need to make-up the “Explore” stations, or if they were gone Friday, they will need to set up a time to take the “Evaluate” assessment/test. This was important to me because it will mean less time resetting expectations for the activities of the day, and it will also ease my ability to plan in advance for labs and lab materials. Moreover, my students have a lot going on in their lives, and, unfortunately, absences are common. A more or less concrete weekly schedule should help them gain some independence and agency over their missed coursework.

Beyond sticking to the five day schedule, I also applied the core tenets of 5E (Bybee, 2015) and inquiry based learning within my daily lessons as much as possible. Whenever I encountered a new concept or vocabulary word that students would need to learn to meet the day’s objectives I would pause and ask myself, “Is there a way for students to discover this for themselves, instead of me just telling them?” I believe this thought process leads to much deeper learning on the students' side throughout the unit.

Finally, and perhaps most crucially, I used MALP® (DeCapua et al., 2020, p.135) to guide my lesson planning specifically for my SLIFE students. The first category of the MALP® checklist (as described in Chapter Three), is “Accepting Conditions for Learning”, which includes the objectives of “making the lesson/project immediately relevant to my students’ lives” and “helping students to develop and maintain interconnectedness with each other". One of the primary reasons that I made food the focus of this unit is that every single student brings their own personal connections to food, and it's an urgent connection that repeats everyday (whether that be from breakfast and lunch provided in the cafeteria, or from additional meals in the home). Throughout my unit, I have students continuously apply new concepts and vocabulary they learned to the food they ate the previous day for lunch, or perhaps food that is important to them or their culture. For example, they describe the macromolecules present in their lunch tray, and consider if said tray is well-balanced nutritionally, a question that is vital to their health and survival. Similarly, I incorporate numerous opportunities for students to share their knowledge, experiences, and learnings not only with each other through meaning-making tasks like "think-pair-shares" and interactive FlipGrid®s, but also with family and/or community members through "mini interviews". The goal with the mini interviews is for students to draw connections between what they are learning in school and other people in their lives, while also engaging with the deep funds of knowledge available beyond the classroom.

The second section of the MALP® (DeCapua et al., 2020, p.135) framework is "Combine Processes for Learning" with the accompanying objectives of "incorporating both shared responsibility and individual accountability", and "scaffolding the written word through oral interaction". In many of my class activities I designed opportunities for students to work together, while still ultimately being responsible for their own learning. For example, in the lunch tray project, students must work together to build the "best" lunch, but each individual must bring their own contributions, and turn in their completed work separately. I also heavily utilize this approach with review games, like Trashketball, wherein students are playing with a team, but the participation of each member of that team is crucial for team victory.

For scaffolding written words with oral interaction, I built in numerous experiences where students must both read and speak. For instance, in many of my whiteboard reviews that I use to start class, students will draw a model of a concept with a partner, and label that model with the corresponding vocabulary in print. Then, they will orally narrate the process to their partner using that same vocabulary. FlipGrid® videos are also used extensively to support students' orality.

The final section of the MALP® (DeCapua et al., 2020, p.135) checklist is a "Focus on New Activities for Learning" with the specific objectives of "developing academic ways of thinking", "teaching students to engage in decontextualized tasks to demonstrate mastery" and "using familiar language and content as scaffolds". Throughout my unit, I have several opportunities for students to build formal "Western" academic skills, such as practices of sorting (e.g. nutrition labels, and macromolecular structures), asking questions and developing a hypothesis (e.g. the plant growth and owl pellet labs), using mathematical models (e.g. photosynthesis and cellular respiration equations and trophic pyramid calculations), and making inferences about a passage (e.g. macromolecular deficiency stories and food web collapses). Students also engage in decontextualized tasks such as quizzes on core concepts and vocabulary, and the processing of abstract concepts (e.g. thinking about molecules that are so small, we can't see them with our classroom microscopes, let alone the naked eye). Finally, I repeatedly scaffold new concepts and vocabulary with familiar language through either providing students with translations, giving students time and space to make their own translations, encouraging home language use in some circumstances, embracing cognates where applicable, and leaning into familiarity with shared prefixes and suffixes students may know (for example “auto” or “photo”).

In conclusion, I feel that all three of these frameworks enhanced the construction of my unit plan, and pushed me to create experiences for more profound academic connections for my students, that will hopefully engage their minds inside and outside of the classroom. In this section I have discussed the writing of the curriculum. In the next section, I review the limitations of my work.

Limitations

While I believe that this capstone project has the potential to greatly benefit both my own teaching and others in the profession, there are limitations to this work. One limitation is that currently only four weeks are fully planned, with an additional ten weeks outlined. As noted previously, resources for teaching NGSS 9-12 life science specifically with SLIFE students (or even just EL students, for that matter) in mind, are essentially unavailable to the public. So, while four weeks is an improvement over nothing, there is a desperate need for more.

Another limitation is that this unit presumes 1:1 device access (with video-recording capabilities) for all students, as well as the use of Google Suite programs, and FlipGrid®. Even in my school, where we *do* have 1:1 devices, I fear this may be a limitation because students will inevitably forget their iPad/Chromebook, or it will be uncharged. In general, I approve of a strong digital focus because it cuts down on wasted paper, and makes it easier for students (and me) to keep track of their work, but as with any technology, challenges are to be expected.

An additional limitation of the project is that, in some cases, it centers around the primary home languages of the student population that I work with, with translations provided in Spanish, Somali, Arabic, and Swahili. Of course, these can be adapted by different teachers for their own students, but sometimes translations are not so easy to come by (e.g. Oromo is not available on Google Translate).

This leads into a corresponding limitation of the work: it is not perfectly suited for "brand new" newcomers. In my school I currently teach the first three science courses in sequence: one year of "General Science" for brand new newcomers, then a year of "Environmental Science", and *then* a year of "Life Science". Newcomer students follow this sequence regardless of their age and/or any previous high school credits. So, basically, I designed this unit for students who already have at least two full years of science, and English in the U.S. In larger schools where brand new newcomers and/or SLIFE students may be enrolled in 10th grade life science alongside higher level ELs and native English speakers, considerably more adaptation, differentiation, and scaffolding would almost certainly be necessary.

In this section I have reviewed the limitations of my work. In the next section, I examine possible future directions of this project.

Possible Future Work

The first future step for this work is to finish the full 14-week lesson cycle as I have already outlined. It takes considerable time to complete these plans and the accompanying student activities with fidelity, but I believe that ultimately doing so will be a boon to my life science teaching, and to the science education community as a whole (as well as my sanity).

As stated previously, I currently teach two other science courses, and have had to basically build my own curriculum for each of them. I am excited to apply the same frameworks and pedagogies that I used for this project to the curricula of General Science and Environmental Science. For General Science, in particular, I believe this process of unit building will be exceptionally helpful because this is the course for brand new newcomers where students have the lowest English proficiency, and the least exposure to American education.

Beyond my own practice, I would love to see the ideas from this project utilized for other science courses, like Computer Science, Chemistry, and Physics, as well as in Math, where even fewer inquiry-based and SLIFE student-adapted materials are widely available.

In this section, I discussed directions for possible future work building of this project. In the next section, I will summarize the project as a whole.

Summary

This capstone project was designed to address the question: *How can science educators design and implement a 9-12 Life Science curriculum that aligns with Next Generation Science Standards (NGSS), and is adapted to meet the needs and promote the achievement of students with limited or interrupted formal education (SLIFE)?* In this chapter I reviewed my process of developing my curriculum, as well as limitations, and connections to potential future work. In doing so, I referred back to the relevant literature and frameworks I utilized in the creation of the curriculum.

My goal is to share my work with fellow STEM educators, both within my school and across the country, and especially those who work with SLIFE students. I hope that this literature review and unit design provides a strong foundation for others who want to support the unique strengths and needs of SLIFE students through inquiry-driven practices. The interconnectedness and the smallness of our world has perhaps never been more strongly felt than it is right now. The contributions of all to the vast body of science are of the utmost importance if life will find a way.

REFERENCES

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945-1969. https://doi.org/10.1080/09500690701749305

Ardasheva, Y., Bowden, J., Morrison, J., & Tretter, T. (2015). COMIC RELIEF: Using comics and illustrated trade books to support science learning in first-year english language learners. *Science Scope (Washington, D.C.); Science Scope, 38*(6), 39-47. https://doi.org/10.2505/4/ss15_038_06_39

Ardasheva, Y., & Tretter, T. R. (2017). Developing science-specific, technical vocabulary of high school newcomer english learners. *International Journal of Bilingual Education and Bilingualism, 20*(3), 252-271. https://doi.org/10.1080/13670050.2015.1042356

Bal, A. (2014). Becoming in/competent learners in the united states: Refugee students' academic identities in the figured world of difference. *International Multilingual Research Journal, 8*(4), 271-290. https://doi.org/10.1080/19313152.2014.952056

Banko, W. (2013). *Science for the next generation : Preparing for the new standards*. NSTA Press.

Barba, R. H. (1998). *Science in the multicultural classroom : A guide to teaching and learning* (2nd ed.). Allyn and Bacon.

Bass, J. E., Contant, T. L., & Carin, A. A. (2009a). *Activities for teaching science as inquiry* (7th ed.). Allyn & Bacon/Pearson.

Bass, J. E., Contant, T. L., & Carin, A. A. (2009b). *Teaching science as inquiry* (11th ed.). Allyn & Bacon/Pearson.

Bauer, H. H. (1992). *Scientific literacy and the myth of the scientific method*. University of Illinois Press.

Berumen, & Silva, C. (2014). A Journey with a Refugee Family: Raising Culturally Relevant Teaching Awareness. *New Directions for Teaching and Learning*, *2014*(140), 51–67. https://doi.org/10.1002/tl.20114

Bigelow, M. (2010). *Mogadishu on the mississippi : Language, racialized identity, and education in a new land*. Wiley-Blackwell.

BLS. (2021). *Employment in STEM occupations*. https://www.bls.gov/emp/tables/stem-employment.htm

Boss, S., & Krauss, J. (2007). *Reinventing project-based learning : Your field guide to real-world projects in the digital age / suzie boss, jane krauss* (1st ed.). International Society for Technology in Education.

Bowman, Jr, Larry,L., & Govett, A. L. (2014). Becoming the change: A critical evaluation of the changing face of life science, as reflected in the NGSS.

Bowman, Larry L., Jr, & Govett, A. L. (2015). Becoming the change: A critical evaluation of the changing face of life science, as reflected in the NGSS. *Science Educator, 24*(1), 51.

Brown, L., O'Keeffe, L., & Paige, K. (2017). The colour of velvet : A transdisciplinary approach to connecting students from a refugee background to the natural world. *Teaching Science (Deakin West, A.C.T.), 63*(4), 20-32.

Brown, T., & Mieses, C. A. (Eds.). (2019). *Chiselled horizons : A multi-cultural approach to visual literacy*. BRILL.

Burton, & Van Viegen, S. (2021). Spoken Word Poetry with Multilingual Youth from Refugee Backgrounds. *Journal of Adolescent & Adult Literacy*, *65*(1), 75–84. https://doi.org/10.1002/jaal.1178

Bybee, R. W. (2004). *Evolution in perspective the science teacher's compendium*. National Science Teachers Association.

Bybee, R. W. (2012). The next generation of science standards: Implications for biology education. *The American Biology Teacher; American Biology Teacher, 74*(8), 542-549. https://doi.org/10.1525/abt.2012.74.8.3

Bybee, R. W. (2015). *The BSCS 5E instructional model : Creating teachable moments*. NSTA Press.

Capraro, M. M., Whitfield, J., Etchells, M. J., & Capraro, R. M. (2016). *A companion to interdisciplinary STEM project-based learning : For educators by educators*. Sense Publishers.

Carr, J. (. W., Sexton, U., & Lagunoff, R. (2006). *Making science accessible to english learners : A guidebook for teachers*. WestEd.

Cizmas, E. (2021). Ecosystem in a jar. *The Science Teacher (National Science Teachers Association), 88*(3), 23-29.

Colburn, A. (2000). Constructivism: Science education's "grand unifying theory". *The Clearing House, 74*(1), 9-12. https://doi.org/10.1080/00098655.2000.11478630

COMAR 13A.05.07 (2016). http://mdrules.elaws.us/comar/13a.05.07.03

Cun. (2021). Analyzing Burmese refugee children's multimodal work: A case study. *Journal of Asian Pacific Communication*, *31*(1), 15–37. https://doi.org/10.1075/japc.00055.cun

Custodio, B. K., & O′Loughlin, J.,B. (2017). *Students with interrupted formal education: Bridging where they are and what they need*. SAGE Publications.

Custodio, B., & O'Loughlin, J.,B. (2020). Students with interrupted formal education: Understanding who they are. *American Educator, 44*(1), 9.

Dávila, L. T. (2012). 'For them it's sink or swim': Refugee students and the dynamics of migration, and (dis)placement in school. *Power and Education, 4*(2), 139-149. https://doi.org/10.2304/power.2012.4.2.139

Dearing, E., Walsh, M. E., Sibley, E., Lee-St.John, T., Foley, C., & Raczek, A. E. (2016). Can community and school-based supports improve the achievement of first-generation immigrant children attending high-poverty schools? *Child Development; Child Dev, 87*(3), 883-897. https://doi.org/10.1111/cdev.12507

Decapua, A.*Reaching students with limited or interrupted formal education through culturally responsive teaching*. Blackwell Publishing Ltd. https://doi.org/nfo:doi/

DeCapua, A. (2016a). Reaching students with limited or interrupted formal education through culturally responsive teaching. *Language and Linguistics Compass; Language and Linguistics Compass, 10*(5), 225-237. https://doi.org/10.1111/lnc3.12183

DeCapua, A. (2016b). Reaching students with limited or interrupted formal education through culturally responsive teaching. *Language and Linguistics Compass; Language and Linguistics Compass, 10*(5), 225-237. https://doi.org/10.1111/lnc3.12183

DeCapua, A., Smathers, W., & Tang, L. F. (2009). *Meeting the needs of students with limited or interrupted schooling : A guide for educators*. University of Michigan Press.

DeCapua, A., & Marshall, H. W. (2010). Students with limited or interrupted formal education in US classrooms. *The Urban Review, 42*(2), 159-173. https://doi.org/10.1007/s11256-009-0128-z

DeCapua, A., Marshall, H. W., & Tang, L. F. (2020). *Meeting the needs of SLIFE : A guide for educators*. University of Michigan Press.

DeCapua,, Andrea, Andrea. (a). *Students with limited or interrupted formal education in US classrooms*. Springer Science+Business Media BV. https://doi.org/nfo:doi/

DeCapua,, Andrea, Andrea. (b). *Students with limited or interrupted formal education in US classrooms*. Springer Science+Business Media BV. https://doi.org/nfo:doi/

Dimension 3: Disciplinary core ideas - life sciences (2012). . National Academies Press.

Driver, R., & Driver, R. (1996). *Young people's images of science*. Open University Press.

Duncan, R. G., Krajcik, J. S., & Rivet, A. E. (2016). *Disciplinary core ideas : Reshaping teaching and learning*. National Science Teachers Association.

Duschl, & Grandy, R. (2012). Two Views About Explicitly Teaching Nature of Science. *Science & Education*, *22*(9), 2109–2139. https://doi.org/10.1007/s11191-012-9539-4

Echevarría, J., Vogt, M., & Short, D. (2008). *Making content comprehensible for english learners : The SIOP® model*. Pearson/Allyn and Bacon.

Eisenstein, E. L. (1979). *The printing press as an agent of change : Communications and cultural transformations in early modern europe*. Cambridge University Press.

Farid, M., & McMahan, D. (2004a). *Accommodating and educating somali students in minnesota schools : A handbook for teachers and administrators*. Hamline University Press.

Farid, M., & McMahan, D. (2004b). *Accommodating and educating somali students in minnesota schools : A handbook for teachers and administrators*. Hamline University Press.

Fernando, C., & Ferrari, M. (2013). *Handbook of resilience in children of war* (1st ed.). Springer New York. https://doi.org/10.1007/978-1-4614-6375-7

Florman, S. C. (1976). *The existential pleasures of engineering*. St. Martin's Press.

Flueckiger, L. M. (2020). *An examination of the factors influencing high school graduation rates for students with limited or interrupted formal education*. ProQuest Dissertations Publishing.

Folkestad, G. (2006a). Formal and informal learning situations or practices vs formal and informal ways of learning. *British Journal of Music Education; Brit.J.Music.Ed, 23*(2), 135-145. https://doi.org/10.1017/S0265051706006887

Folkestad, G. (2006b). Formal and informal learning situations or practices vs formal and informal ways of learning. *British Journal of Music Education; Brit.J.Music.Ed, 23*(2), 135-145. https://doi.org/10.1017/S0265051706006887

Ford, M. (2008). 'Grasp of practice' as a reasoning resource for inquiry and nature of science understanding. *Science & Education, 17*(2), 147-177. https://doi.org/10.1007/s11191-006-9045-7

Freeman, Y. S., Freeman, D. E., & Mercuri, S. (2001). Keys to success for bilingual students with limited formal schooling. *Bilingual Research Journal, 25*(1-2), 203-213. https://doi.org/10.1080/15235882.2001.10162790

Freeman, Y. S., Freeman, D. E., & Mercuri, S. (2002a). *Closing the achievement gap : How to reach limited-formal-schooling and long-term english learners*. Heinemann.

Freeman, Y. S., Freeman, D. E., & Mercuri, S. (2002b). *Closing the achievement gap : How to reach limited-formal-schooling and long-term english learners*. Heinemann.

Froschauer, L. (2016). From molecules to organisms.(editor's note). *Science and Children; Science and Children, 53*(9), 5.

Fruja Amthor, R.*Multicultural education and newcomer youth: Re-imagining a more inclusive vision for immigrant and refugee students*. L Erlbaum Associates. https://doi.org/nfo:doi/

Gahungu, A., Gahungu, O., & Luseno, F. (2011). Educating culturally displaced students with truncated formal education (CDS-TFE): The case of refugee students and challenges for administrators, teachers, and counselors. *The International Journal of Educational Leadership Preparation, 6*(2)

Giere, R. N., & Giere, R. N. (2006). *Scientific prespectivism*. University of Chicago Press.

Grapin, S. E. (2021). Toward asset‐oriented and definitionally clear terminology: A comment on González‐Howard and suárez (2021). *Journal of Research in Science Teaching, 58*(5), 753-755. https://doi.org/10.1002/tea.21686

Grigorenko, E. L. (2007). Hitting, missing, and in between: A typology of the impact of western education on the non-western world. *Comparative Education, 43*(1), 165-186. https://doi.org/10.1080/03050060601162719

Harper. (2017). Engaging Karen refugee students in science learning through a cross-cultural learning community. *International Journal of Science Education*, *39*(3), 358–376. https://doi.org/10.1080/09500693.2017.1283547

Hepple, Sockhill, M., Tan, A., & Alford, J. (2014). Multiliteracies Pedagogy. *Journal of Adolescent & Adult Literacy*, *58*(3), 219–229. https://doi.org/10.1002/jaal.339

Hickey, P. J.*Behind the acronym: Multilingual learners with interrupted formal education*. University of Chicago Press. https://doi.org/nfo:doi/

Ho, V. T., & Levesque, L. L. (2005). With a little help from my friends (and substitutes): Social referents and influence in psychological contract fulfillment. *Organization Science (Providence, R.I.), 16*(3), 275-289. https://doi.org/10.1287/orsc.1050.0121

Hofstede, G., & McRae, R. (2004). Personality and culture revisited: Linking traits and dimensions of culture. *Cross-Cultural Research, 38*(1), 52-88. https://doi.org/10.1177/1069397103259443

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations : Software of the mind : Intercultural cooperation and its importance for survival* (3rd ed.). McGraw-Hill.

Hogg. (2011). Funds of Knowledge: An investigation of coherence within the literature. *Teaching and Teacher Education*, *27*(3), 666–677. https://doi.org/10.1016/j.tate.2010.11.005

Hos, R. (2016). Caring is not enough: Teachers' enactment of ethical care for adolescent students with limited or interrupted formal education (SLIFE) in a newcomer classroom. *Education and Urban Society, 48*(5), 479-503. https://doi.org/10.1177/0013124514536440

Hos, R. (2020). The lives, aspirations, and needs of refugee and immigrant students with interrupted formal education (SIFE) in a secondary newcomer program. *Urban Education (Beverly Hills, Calif.), 55*(7), 1021-1044. https://doi.org/10.1177/0042085916666932

IBM. (2021). *Science & technology outlook 2021*. https://www.research.ibm.com/downloads/ces_2021/IBMResearch_STO_2021_Whitepaper.pdf

Inquiry and the national science education standards : A guide for teaching and learning (2000). National Academy Press.

Johnson, L. R. (2016). Cultural and social uses of orality and functional literacy: A narrative approach. *Reading & Writing: Journal of the Reading Association of South Africa, 7*(1)

Johnson, S. (2020). *A changing nation : Population projections under alternative immigration scenarios*. U.S. Department of Commerce, U.S. Census Bureau.

Kapp, K. M. (2012). *The gamification of learning and instruction : Game-based methods and strategies for training and education*. Pfeiffer.

Kaukko, M., & Wilkinson, J. (2020). 'Learning how to go on': Refugee students and informal learning practices. *International Journal of Inclusive Education, 24*(11), 1175-1193. https://doi.org/10.1080/13603116.2018.1514080

Klein, E. C., & Martohardjono, G. (1999). *Development of second language grammars: A generative approach*. John Benjamins Publishing Company.

Kristiina Montero, M., Newmaster, S., & Ledger, S. (2014). Exploring early reading instructional strategies to advance the print literacy development of adolescent SLIFE. *Journal of Adolescent & Adult Literacy; J Adolesc Adult Liter, 58*(1), 59-69. https://doi.org/10.1002/jaal.318

Kugler, E., Eileen, G.*Go beyond the classroom to help immigrant and refugee students succeed*. Phi Delta Kappa. https://doi.org/nfo:doi/

Llewellyn, D. (2011). *Differentiated science inquiry*. Corwin Press.

Lowery, R. M., Pringle, R. M., & Oslick, M. E. (2019). *Land of opportunity : Immigrant experiences in the north american landscape*. Rowman & Littlefield.

Luri͡ia, A. R. (Aleksandr Romanovich), Lopez-Morillas, M., Solotaroff, L., & Cole, M. (1976). *Cognitive development, its cultural and social foundations*. Harvard University Press.

Lyon, E. G. (2017). Exploring secondary science teachers' enactment of assessment practices to reflect responsive science teaching for english learners. *Journal of*

Science Teacher Education, 28(8), 674-698. https://doi.org/10.1080/1046560X.2017.1401415

Magnuson, P. (2002). *Serving refugee students : Case studies of somali, bosnian, and liberian students in minnesota schools*. Minnesota Dept. of Children, Families & Learning.

Marshall, H. W.*Reaching ELLs at risk: Instruction for students with limited or interrupted formal education*. Heldref Publications. https://doi.org/nfo:doi/

Marshall, H. W., & DeCapua, A. (2013). *Making the transition to classroom success : Culturally responsive teaching for struggling language learners*. University of Michigan Press.

Martusewicz, R. A., Edmundson, J., & Lupinacci, J. (2015). *EcoJustice education : Toward diverse, democratic, and sustainable communities*. Routledge.

McBrien, J. L. (2005). Educational needs and barriers for refugee students in the united states: A review of the literature. *Review of Educational Research, 75*(3), 329-364. https://doi.org/10.3102/00346543075003329

McCarthy, F. E., & Vickers, M. H. (2014). *Refugee and immigrant students achieving equity in education*. IAP - Information Age Publishing, Inc.

Menken, K.*Emergent bilingual students in secondary school: Along the academic language and literacy continuum*. Cambridge University Press. https://doi.org/nfo:doi/

Miller, E., Ziaian, T., Baak, M., & de Anstiss, H. (2021). Recognition of refugee students' cultural wealth and social capital in resettlement. *International Journal of Inclusive Education,* , 1-18. https://doi.org/10.1080/13603116.2021.1946723

Miller, J.*Teaching refugee learners with interrupted education in science: Vocabulary, literacy and pedagogy*. Taylor & Francis. https://doi.org/nfo:doi/

Minner, Levy, A. J., & Century, J. (2010). Inquiry-based science instruction-what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474–496. https://doi.org/10.1002/tea.20347

Minn. Stat. § 124D.59, Subd. 2a.(2014). https://www.revisor.mn.gov/statutes/cite/124D.59

Minnesota Department of Education. (2018). *Learning English for Academic Proficiency and Success (LEAPS) Act Key Provisions.* https://education.mn.gov/MDE/dse/el/leap/

Moll, Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice*, *31*(2), 132–141. https://doi.org/10.1080/00405849209543534

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). *TIMSS 2019 International Results in Mathematics and Science.* Retrieved from Boston

College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/international-results/

Naidoo, L. (2013). Refugee action support: An interventionist pedagogy for supporting refugee students' learning in greater western sydney secondary schools. *International Journal of Inclusive Education, 17*(5), 449-461. https://doi.org/10.1080/13603116.2012.683048

National Association of Secondary School Principals, (U. S.).*Reframing the conversation about students with limited or interrupted formal education: From achievement gap to cultural dissonance*. National Association of Secondary School Principals. https://doi.org/nfo:doi/

Newcomer, S. N., Ardasheva, Y., Morrison, J. A., Ernst-Slavit, G., Morrison, S. J., Carbonneau, K. J., & Lightner, L. K. (2021). "Whoa... welcome to america!": Supporting refugee background students' socioemotional well-being, english language development, and content area learning. *Journal of Research in Childhood Education, 35*(3), 417-437. https://doi.org/10.1080/02568543.2020.1734697

Ngo, B. (2010). *Unresolved identities : Discourse, ambivalence, and urban immigrant students*. SUNY Press.

Nutta, J. W., Bautista, N. U., & Butler, M. B. (2011). *Teaching science to english language learners*. Routledge.

Nygren, H., Nissinen, K., Hämäläinen, R., & Wever, B. (2019). Lifelong learning: Formal, non‐formal and informal learning in the context of the use of problem‐solving skills in technology‐rich environments. *British Journal of Educational Technology, 50*(4), 1759-1770. https://doi.org/10.1111/bjet.12807

Offit, T. A. (2008). *Conquistadores de la calle: Child street labor in guatemala city*. University of Texas Press.

Oikonomidoy, E., Eleni.*The multilayered character of newcomers' academic identities: Somali female high-school students in a US school*. Carfax Pub. https://doi.org/nfo:doi/

Osborne, J., Rafanelli, S., & Kind, P. (2018). Toward a more coherent model for science education than the crosscutting concepts of the next generation science standards: The affordances of styles of reasoning. *Journal of Research in Science Teaching, 55*(7), 962-981. https://doi.org/10.1002/tea.21460

Ozmon, H., & Craver, S. M. (1999). *Philosophical foundations of education* (6th ed.). Merrill.

Paradise, R., & Rogoff, B. (2009). Side by side: Learning by observing and pitching in. *Ethos (Berkeley, Calif.), 37*(1), 102-138. https://doi.org/10.1111/j.1548-1352.2009.01033.x

Petroski, H. (1996). *Invention by design : How engineers get from thought to thing*. Harvard University Press.

Porter, C. M. (2013). *Honoring counterstories: Utilizing digital storytelling in the culturally responsive classroom to investigate the community cultural wealth* *and resiliency of students with limited or interrupted formal education (SLIFE)*. ProQuest Dissertations Publishing.

Potochnick, S. (2018). The academic adaptation of immigrant students with interrupted schooling. *American Educational Research Journal, 55*(4), 859-892. https://doi.org/10.3102/0002831218761026

PCAST. (2021). *Industries of the future institutes: a new model for American science and technology leadership*. https://science.osti.gov/-/media/_/pdf/about/pcast/202012/PCAST---IOTFI-FINAL-Report.pdf?la=en&hash=0196EF02F8D3D49E1ACF221DA8E6B41F0D193F17

Ramirez, P., & Jaffee, A. T. (2016a). Culturally responsive active citizenship education for newcomer students: A cross-state case study of two teachers in arizona and new york. *International Journal of Multicultural Education; International Journal of Multicultural Education, 18*(1), 45. https://doi.org/10.18251/ijme.v18i1.1170

Ramirez, P., & Jaffee, A. T. (2016b). Culturally responsive active citizenship education for newcomer students: A cross-state case study of two teachers in arizona and new york. *International Journal of Multicultural Education; International Journal of Multicultural Education, 18*(1), 45. https://doi.org/10.18251/ijme.v18i1.1170

Rodriguez, G. M. (2013). Power and agency in education: Exploring the pedagogical dimensions of funds of knowledge. *Review of Research in Education, 37*(1), 87-120. https://doi.org/10.3102/0091732X12462686

Rogers, A. (2014). *The base of the iceberg : Informal learning and its impact on formal and non-formal learning*. Barbara Budrich Publishers.

Rothstein-Fisch, C., & Trumbull, E. (2008). *Managing diverse classrooms: How to build on students' cultural strengths*. Association for Supervision and Curriculum Development.

Roxas, K. (2011). Tales from the front line: Teachers' responses to somali bantu refugee students. *Urban Education (Beverly Hills, Calif.), 46*(3), 513-548. https://doi.org/10.1177/0042085910377856

Rozman Clark, T., & Vang, J. (2020). *Green card STEM voices : Stories from minnesota immigrants working in science, technology, engineering, and math*. Green Card Voices.

Ruiz-de-Velasco, J., & Fix, M. (2000). *Overlooked & underserved: Immigrant students in U.S. secondary schools*. Urban Institute.

Salva, C., & Matis, A. (2017). *Boosting achievement : Reaching students with interrupted or minimal education*. Seidlitz Education.

Schmidt, W. H., McKnight, C. C., & Raizen, S. A. (1997). *A splintered vision : An investigation of U.S. science and mathematics education*. Kluwer Academic Publishers.

Sellars, M. (2020). *Educating students with refugee and asylum seeker experiences a commitment to humanity*. Verlag Barbara Budrich.

Shanahan, T., & August, D. (2007). *Developing reading and writing in second-language learners: Lessons from the report of the national literacy panel on language-minority children and youth*. Routledge.

Shapiro, S., Farrelly, R., & Curry, M. J. (2018a). *Educating refugee-background students : Critical issues and dynamic contexts*. Multilingual Matters.

Shapiro, S., Farrelly, R., & Curry, M. J. (2018b). *Educating refugee-background students : Critical issues and dynamic contexts*. Multilingual Matters.

Sherwood, C. (2020). "The goals remain elusive": Using drawings to examine shifts in teachers' mental models before and after an NGSS professional learning experience. *Journal of Science Teacher Education, 31*(5), 578-600. https://doi.org/10.1080/1046560X.2020.1729479

Stewart. (2015). "My Journey of Hope and Peace": LEARNING FROM ADOLESCENT REFUGEES' LIVED EXPERIENCES. *Journal of Adolescent & Adult Literacy*, *59*(2), 149–159. https://doi.org/10.1002/jaal.445

Stewart, J., & Martin, L. (2018). *Bridging two worlds : Supporting newcomer and refugee youth : A guide to curriculum implementation and integration*. CERIC.

Strunk, C.*Cultivating belonging: Refugees, urban gardens, and placemaking in the midwest, U.S.A*. Routledge. https://doi.org/nfo:doi/

Suarez-Orozco, C.*The significance of relationships: Academic engagement and achievement among newcomer immigrant youth*. Teachers College. https://doi.org/nfo:doi/

Taylor, S., & Sidhu, R. K. (2012). Supporting refugee students in schools: What constitutes inclusive education? *International Journal of Inclusive Education, 16*(1), 39-56. https://doi.org/10.1080/13603110903560085

Thomke, S. H. (2020). *Experimentation works : The surprising power of business experiments*. Harvard Business Review Press.

Triandis, H. C. (1995). *Individualism & collectivism*. Westview Press.

Valdés, G. (2018). Analyzing the curricularization of language in two-way immersion education: Restating two cautionary notes. *Bilingual Research Journal, 41*(4), 388-412. https://doi.org/10.1080/15235882.2018.1539886

Van Orman, D. S.,J., Ardasheva, Y., Carbonneau, K. J., & Firestone, J. B. (2021). Examining the impacts of extended vocabulary instruction in mixed-english-proficiency science classrooms. *The Journal of Educational Research (Washington, D.C.), 114*(1), 74-88. https://doi.org/10.1080/00220671.2021.1881754

Victoria Purcell-Gates. (2013a). Literacy worlds of children of migrant farmworker communities participating in a migrant head start program. *Research in the Teaching of English, 48*(1), 68-97.

Victoria Purcell-Gates. (2013b). Literacy worlds of children of migrant farmworker communities participating in a migrant head start program. *Research in the Teaching of English, 48*(1), 68-97.

Vilorio, D. (2014). STEM 101: Intro to tomorrow's jobs. *Occupational Outlook Quarterly, 58*(1), 2.

Walqui, A. (2000). *Access and engagement : Program design and instructional approaches for immigrant students in secondary school*. Center for Applied Linguistics and Delta Systems Co.

WIDA. (2015). *WIDA focus on: SLIFE: Students with limited or interrupted formal education.* https://wida.wisc.edu/sites/default/files/resource/FocusOn-SLIFE.pdf

Wiggins, G. P., & McTighe, J. (2005). *Understanding by design* (2nd ed.). Association for Supervision and Curriculum Development.

Zacarian, D., & Haynes, J. (2012). *The essential guide for educating beginning english learners*. SAGE Publications.

Žagar, I. Z., Kelava, P., & Radovan, M. (2014). *From formal to non-formal : Education, learning and knowledge*. Cambridge Scholars Publishing.

Zangori, L., & Pinnow, R. J. (2020). Positioning participation in the NGSS era: What counts as success? *Journal of Research in Science Teaching, 57*(4), 623-648. https://doi.org/10.1002/tea.21607