

**Educating for Conservation: A Self-Study on Developing Anchoring
Phenomenon-Based Curricular Resources for the Western Tiger Salamander
Integrating Biodiversity Research**

By Salma Valeria Macias Torres

M.S. University of Wyoming, 2024

Submitted in partial fulfillment of the requirements for the degree of Masters in Science
in Natural Science in the Science and Mathematics Teaching Center at the University of
Wyoming, 2024

Laramie, Wyoming

May, 2024

Masters' Committee:

Committee Chair: Dr. Ana Houseal
Committee Co-chair: Dr. Emil Eidin
Outside Member: Dr. Melanie Murphy
Committee Member: Dr. Brett Addis

To the University of Wyoming:

The members of the Committee approve the Educating for Conservation: A Self-Study on Developing Anchoring Phenomenon Curriculum Resources Integrating Biodiversity Research Plan B Project of Salma Valeria Macias Torres presented on April 26, 2024

Ana Houseal, Chairperson

Emil Eiden, Co-chair

Melanie Murphy, Outside Member

Brett Addis, Third Committee Member

Abstract

Researchers and educators at the Biodiversity Institute, University of Wyoming recognized a need for devising more resources to foster awareness and educate the public about certain species of importance to the state of Wyoming. Those efforts include an increase of pedagogical resources about species needing more resources and attention from the general public. The institute aims to increase the number of pedagogical resources for teachers and students in Wyoming to connect them to science and math concepts using local wildlife issues. This self-study explored my approach to developing anchoring phenomenon-based curricular resources using the education theories of social constructivism, place-based education, and problem-based learning. In addition, these curriculum resources are based on the three-dimensional learning of the Next Generation Science Standards. The scenario of the local phenomenon is the migration of western tiger salamanders in LaBonte Park, Laramie, and human intervention. Data collection included 93 journal entries, analysis elicited five prominent themes: content development, final products, personal reflection, process and methodology, and support. This framework and process resulted in the development of three artifacts: the anchoring phenomenon-based curricular resources, my master's paper, and a resource development guide. My results show how these artifacts can be used to replicate my process in the future to create anchoring phenomenon curricular resources for teachers and outreach activities with species of interest.

© 2024, Salma Valeria Macias Torres

“If children don’t grow up knowing about nature and appreciating it, they will not understand it. And if they don’t understand it, they won’t protect it. And if they don’t protect it who will?”

Sir David Attenborough

To my family, my mom and siblings, Salome, Karla, Pablo, and Gordito

ACKNOWLEDGMENTS

First and foremost, I would like to thank my committee members, Dr. Ana Houseal, Dr. Emil Eiden, Dr. Brett Addis, and Dr. Melanie Murphy, for their continuous support, guidance, and feedback throughout this process. Their encouragement was a key factor in the development of this Plan B.

Thanks to the Biodiversity Institute and Ann and Richard Boelter, who were the ones who benefited me with my Graduate Assistantship and funding. A big shout out to Tad for being the little creature who inspired this journey and gave me motivation to keep going during all my brain breaks.

I would also like to thank my Ecology Project International and Teton Science Schools family who engaged me in the world of environmental education and place-based education through hands-on experiences in non-formal education and fostering wildlife conservation.

Last but not least, I want to acknowledge the UW Writing Center, especially Barbara Allen Bogart, who helped me improve the writing of this product.

TABLE OF CONTENTS

Introduction	1
Purpose of this research project	5
Research Questions	6
Theoretical Framework and Literature Review	7
Social Constructivism	9
Place-based education	12
Problem-based learning.....	13
Three-Dimension Learning and Anchoring Phenomena Curricular Resources	15
Western Tiger Salamander.....	17
Social Constructivism and Western Tiger Salamander.....	20
Place-based education and Western Tiger Salamander.....	21
Problem-based learning and Western Tiger Salamander	21
Anchoring Phenomenon and Western Tiger Salamander.....	22
Conclusion.....	23
Methods	24
Background and Context for the Study.....	24
Biodiversity Institute Mission.....	24
Self-study as a Research Tool.....	25
Data Collection	26
Data Analysis.....	27

Positionality Statement	28
Results	29
Content Development	37
Process and Methodology	38
Personal Reflection.....	39
Final products	40
Analysis of Co-occurrence	41
Discussion and Conclusion	44
Interpreting and Contextualizing the Results	44
Broader Implications and Applications.....	44
Iterative and Improved Process Through Self-Study	48
Limitations and Future Directions	50
Conclusion.....	51
Appendix 1	59
Appendix 2 Guide Overview.....	60
How to create anchoring phenomenon - based curriculum resources within the biodiversity context?	60
Step #1 – Learning about instructional phenomenon and how the three-dimension work together.....	¡Error! Marcador no definido.
Background.....	¡Error! Marcador no definido.
Resources.....	¡Error! Marcador no definido.
My example.....	¡Error! Marcador no definido.
Summary.....	¡Error! Marcador no definido.
Step 2 – Identifying local phenomena by reaching out to researchers and defining the scenario for this set of curricular materials	¡Error! Marcador no definido.
Background.....	¡Error! Marcador no definido.

Resources	¡Error! Marcador no definido.
My Example	¡Error! Marcador no definido.
Summary.....	¡Error! Marcador no definido.
Step 3 – Developing the activities.....	¡Error! Marcador no definido.
Background	¡Error! Marcador no definido.
Resources	¡Error! Marcador no definido.
My example.....	¡Error! Marcador no definido.
Summary.....	¡Error! Marcador no definido.
Step 3a. Unpacking the concepts	¡Error! Marcador no definido.
Background	¡Error! Marcador no definido.
Resources	¡Error! Marcador no definido.
My example.....	¡Error! Marcador no definido.
Summary:.....	¡Error! Marcador no definido.
Step 3b. Developing driving and sub-driving questions	¡Error! Marcador no definido.
Background	¡Error! Marcador no definido.
Resources	¡Error! Marcador no definido.
My Example	¡Error! Marcador no definido.
Summary.....	¡Error! Marcador no definido.
Step 3c. Look for resources that could be used in the storyline....	¡Error! Marcador no definido.
Background	¡Error! Marcador no definido.
Resources	¡Error! Marcador no definido.
My Example	¡Error! Marcador no definido.
Summary:.....	¡Error! Marcador no definido.

Step 3d. Identify concepts that are repetitive among the standards and the selected resources you will like to use**¡Error! Marcador no definido.**

Background**¡Error! Marcador no definido.**

Resources**¡Error! Marcador no definido.**

My example**¡Error! Marcador no definido.**

Summary:.....**¡Error! Marcador no definido.**

Step 3e. Incorporate these concepts into the storyline, brainstorm possible questions students might have about the phenomenon, and categorize these questions under the concepts in a concept map**¡Error! Marcador no definido.**

Background**¡Error! Marcador no definido.**

Resources**¡Error! Marcador no definido.**

My example**¡Error! Marcador no definido.**

Summary:.....**¡Error! Marcador no definido.**

Step 3f. Create a concept map with your main concepts, show the connections between them and with the performance expectations and task learning performances.....**¡Error! Marcador no definido.**

Background**¡Error! Marcador no definido.**

Resources**¡Error! Marcador no definido.**

My example**¡Error! Marcador no definido.**

Summary:.....**¡Error! Marcador no definido.**

Step 3g. Create the storyline skeleton with the driving question and sub-driving question**¡Error! Marcador no definido.**

Background**¡Error! Marcador no definido.**

Resources**¡Error! Marcador no definido.**

My Example**¡Error! Marcador no definido.**

Summary:.....**¡Error! Marcador no definido.**

Step 3h. Adding the resources to each station and the instructions of the activities
.....¡Error! Marcador no definido.

Background.....¡Error! Marcador no definido.

Resources.....¡Error! Marcador no definido.

Step 3i. Adapting the Activities for Different Age Groups.....¡Error! Marcador no
definido.

Background.....¡Error! Marcador no definido.

Resources.....¡Error! Marcador no definido.

My Example¡Error! Marcador no definido.

Summary:.....¡Error! Marcador no definido.

Step 4. Refining the assessment¡Error! Marcador no definido.

Background.....¡Error! Marcador no definido.

Resources.....¡Error! Marcador no definido.

My Example¡Error! Marcador no definido.

Summary:.....¡Error! Marcador no definido.

Step 5. Piloting the educational rally and assessment.¡Error! Marcador no definido.

Background.....¡Error! Marcador no definido.

Resources.....¡Error! Marcador no definido.

My Example¡Error! Marcador no definido.

Summary:.....¡Error! Marcador no definido.

References¡Error! Marcador no definido.

Chapter 1

Introduction

Around the world, there are many encounters between people and wildlife that are affecting and damaging the wildlife and people involved (Redpath et al., 2015). Human-wildlife encounters is a key topic in conservation. It is necessary to design sustainable management plans and policy instruments to make better decisions considering the realities and perceptions of human-wildlife interactions (König et al., 2020). At the same time, environmental ethics education has emerged as a critical tool for wildlife conservation research (Bhurekeni, 2022).

Education and outreach programs contribute to sustainable behavior, promote public support for conservation, reduce vandalism and poaching practices in protected areas, and raise compliance with environmental regulations (Meadows, 2011). By educating individuals about the importance of sustainable practices with educational initiatives, communities can adopt sustainable behaviors that benefit the environment. Educating the public about conservation efforts helps garner support for preserving natural habitats and endangered species. When people understand the significance of maintaining biodiversity and the consequences of habitat loss, they are more likely to participate in conservation initiatives actively (Fischer and Young, 2007). Raising awareness about the detrimental impacts of vandalism and poaching on ecosystems and wildlife promotes a more vigilant community and actively prevents such harmful practices. Education empowers individuals and communities to understand the necessity of environmental regulations. When people comprehend the rationale behind

these rules, they are more likely to comply willingly, leading to better adherence to environmental laws and guidelines.

According to Burns et al., (2003) by encouraging the Awareness, Enjoyment, Interest, Opinion-forming, and Understanding of Science (AEIOU) responses in its participants, science communication seeks to improve public scientific knowledge, comprehension, literacy, and culture. The AEIOU are the significant individual reactions to science communication. "...an interest in science, a confidence to talk about it, and a willingness to engage with science wherever and whenever it crosses their paths" (pg. 189) are among the things it enables the public to achieve. To improve interactions between the general public, mediators, and science practitioners, science communication also offers tools, media, activities, and dialogue. Science communication is an important area of study and activity that should be continued.

Wildlife conservation education can improve teenagers' willingness to protect wildlife and the local culture is highly correlated with wildlife conservation (Zheng et al., 2022). Teachers practicing pedagogies designed to promote sharing perspectives related to connections between culture and ecological degradation can make a change in the conservation of local wildlife and natural resources (Glasson et al., 2006).

As scientists, we have the knowledge to identify threatened species, their status, and the importance of protecting wildlife for both human and ecological communities. However, we lack professional training as teachers and we use many concepts and data that are hard for the general public to understand, especially children and teenagers. In other cases, we develop activities and materials for the general public, but

they may not be effective as we do not have pedagogical training or are familiar with education concepts and theories.

On the other hand, many teachers may be interested in integrating issues related to wildlife conservation in their science and math lessons. However, they may not have the scientific training or knowledge to understand many of the wildlife conservation issues or concepts. One more challenge for teachers is the lack of time to develop education resources and to integrate the resources into their lessons and meet the education standards required by the state.

There is a need for scientists and teachers to communicate in order to improve wildlife conservation and the way they can be used to help students learn science and math concepts. Scientists and educators can benefit from getting students involved in projects related to wildlife research (Soanes et al., 2020). Involving students can improve science interest, literacy, and conservation efforts (Henter et al., 2016). In addition, some of these projects can give scientists a way to collect data and engage with the general public, but it can also improve science instruction and raise awareness in the next generation (Soanes et al., 2020). When students and the general public engage in a research project related to their community, they gain an understanding of a local conservation issue situated in a social context and learning theory

Even in the best circumstances, wildlife research can be difficult, and there are not many guidelines to help scientists design effective programs for K-12 students (Soanes et al., 2020).

Clearly, more opportunities need to be made available for students and the general public to learn from scientific research (Henter et al., 2016). According to the NGSS, all students in elementary and secondary grades (ages 5-18) should understand science as it is conducted outside of “school science” (Henter et al., 2016). However, for many teachers, teaching science concepts in a social and ecological context could be challenging as they do not know of have the connections ore resources to take their students to the field. That is why another teaching strategy that could be helpful is the use of instructional anchoring phenomena.

Phenomena provide contexts in which students can actively engage in science and science discourse. At its core, a phenomenon is a means to help students learn and do science by using available data to construct claims about what is happening, and by critiquing claims in the light of the behavior of nature, as a community (p. 2, Inouye et al., 2020).

A scientific instructional phenomenon is an observable event that occurs in the universe one that we can use our scientific knowledge to explain or predict (Amplify Science, 2019). Phenomenon-based learning, then, is a holistic, interdisciplinary approach in which the starting point for inquiry is that specific, observable, real-world event (Amplify Science, 2019). The Next Generation Science Standards (NGSS) focus on helping students use science to make sense in the natural and designed world by using science and engineering practices to solve problems (NGSS Lead States, 2013). Creating a curriculum that successfully engages students in three-dimensional learning can be accomplished through making sense of a phenomenon. The three dimensions of learning are defined as the Disciplinary Core Ideas, Crosscutting Concepts, and

Science and Engineering Practices. Students explain phenomena by developing and applying the Disciplinary Core Ideas and Crosscutting Concepts through the use of the Science and Engineering Practices (National Research Council, 2013).

Since I was a child, I have had a passion and love for wildlife. Because of this, I have attended conferences, workshops, and other general public events. In many of these events, I noticed that there is a gap in the communication between scientists and the general public. As I moved forward in my life and worked on an undergraduate degree in Marine Biology and worked as a field instructor for nonprofits in both the Baja Peninsula, Mexico and in Wyoming, I noticed I was making some of the same mistakes.

Purpose of this research project

The purpose of this research project is to describe the process of creating anchoring phenomena-based curriculum resources related to biodiversity conservation projects. One of the results of this will be the development of a guide that outlines the process and is intended to be used by the Biodiversity Institute of the University of Wyoming, their scientists, and teachers across Wyoming. The curricular resources developed were NGSS, NGSS-aligned, and phenomenon-based. Social constructivism, place-based education, and problem-solving learning served as theoretical frames that guided the resources development.

The issue of human assistance necessary for the migration of the Western Tiger Salamander (*Ambystoma mavortium*) related to its lifecycle in LaBonte Park, Laramie, Wyoming will be used as the instructional phenomenon.

Research Questions

This self-study is being guided by the following research questions:

1. How does one approach the development of a phenomenon-based curricular resources collaborating with scientists on the instructional phenomenon?
2. What are the steps/processes that I went through to create a phenomenon-based curriculum resource about local species in collaboration with scientists and science educators?

Chapter 2

Theoretical Framework and Literature Review

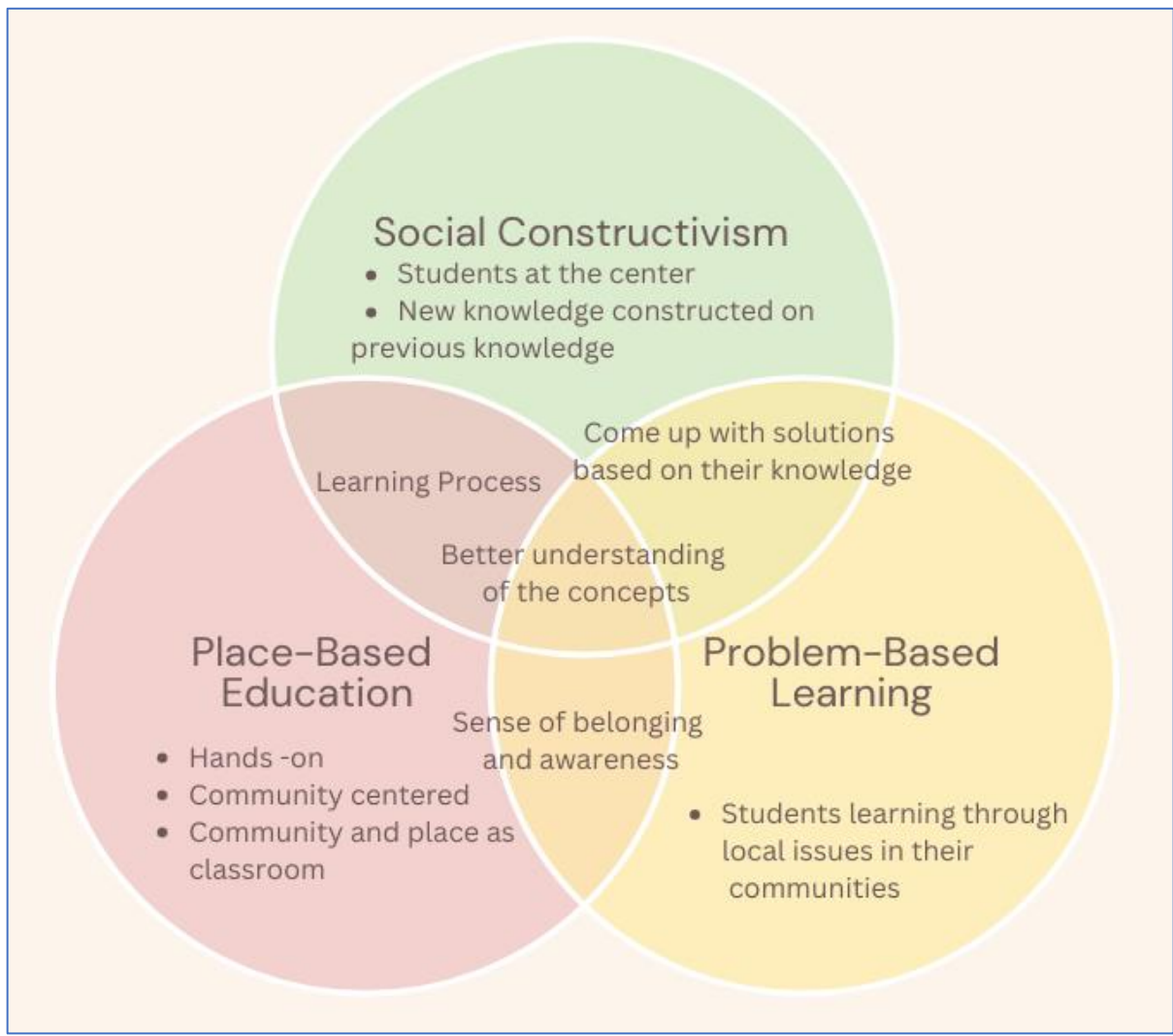
Schools and educational centers are increasingly interested in how to instruct their K-12 students to be aware of environmental problems and possible solutions. Specifically, environmental education can provide the knowledge and skills that young people need to take action on social and environmental issues within their hometowns and surrounding areas (Ardoin et al., 2022). Different approaches and pedagogies have been designed and proposed to tackle environmental issues with an environmental education perspective.

Using different pedagogical approaches to promote engagement and learning experiences is important in contemporary education. Social constructivism, Place-based education, and Problem-based learning are three theories that foster engagement and learning experiences (Hmelo-Silver et al., 2007, Jonassen & Rohrer-Murphy, 1999; Sobel 2004). I use these theories in my theoretical framework (Figure 1).

The idea that knowledge is actively constructed by individuals through social interactions by emphasizing collaborative learning, shared experiences, and the role of culture in shaping understanding is the basis for social constructivism (Vygotsky, 1933). Place-based education focuses on connecting learning to local environments, communities, and cultural settings to make education more applicable and meaningful (Sobel, 2004). It highlights the importance of hands-on experiences and promotes a sense of stewardship and belonging to one's surroundings (Sobel, 2004). Problem-based learning is an instructional approach where students acquire knowledge by

actively engaging with real-world problems (Barrows, 1968; Barrows, 1966). Wilder (2015) also notes that this approach calls for collaborative problem-solving, critical thinking, and application of knowledge to address complex issues, promoting a deeper understanding of the community problems.

Figure 1. Educational theories



Approach of each theory used to build up the theoretical framework and curriculum resources

Combining these into a framework is powerful when applied to wildlife conservation education, as it offers a solid base for the development of curricular

resources focusing on anchoring phenomena and aimed at connecting learners with wildlife conservation and local problems. By integrating these theories, I aim to achieve three-dimensional learning, engaging students not just in disciplinary core ideas but also in scientific practices and crosscutting concepts.

Based on these theories and components, I describe my process on developing anchoring phenomenon curricular resources where the students in my project had been studying the Western Tiger Salamanders' (*A. movartium*) migration and lifecycle in Wyoming as the phenomenon. This aligns with problem-solving learning by presenting real-world challenges related to the life cycle, migration, and road ecology that students can investigate and work together to solve; place-based education as it is a species native to Wyoming; and social constructivism by the way the content will be presented to students to make connections between their environment and current knowledge.

This theoretical framework is supported by my findings in the literature as described in the next section and will be used to frame the data analysis and subsequent resource development guide.

Literature Review

Social Constructivism

Social constructivism is based on the idea that knowledge is actively constructed through experiences and environmental interactions. This theory is based on the ideas of Vygotsky (1930s) and Dewey (1938).

Vygotsky started the conversation by noting that knowledge gain is the result of activities related to specific cultural settings (Roelofs & Terwel, 1999). He stated that the ways of thinking and interpretation of the world come from social experiences, where the development of cognition progress is derived from the social situation (Jaramillo, 1996).

Dewey (1938) talked about how the social environment influences the development of knowledge and learning experiences. Learning was a process related to experience, “the principle that development of experience comes about through interaction means that education is essentially a social process” (p.58). Dewey talked about how students are expected to have an authentic learning experience (Handrianto & Rahman, 2018). The authentic learning experience is defined as knowledge development and acquisition that comes from students’ experiences (Roberts, 2003). Bringing real-life situations to students allows them to learn from their experiences and earn knowledge that they can apply later in their lives (Roberts, 2003). In addition, for Dewey, science-related content should be applied in terms of everyday occurrence (Roberts, 2003). In this way, students acquire new and meaningful knowledge and skills, through active learning and real and practical experiences (Handrianto & Rahman, 2018), because it allows students to have a better comprehension of the world (Roberts, 2003). Another key component of experiential learning theory is the teacher’s role, “the teacher loses the position of external boss or dictator but takes on that of a leader of group activities” (Dewey’s, 1938 p.59).

“The use of a constructivist framework which views the learner within a position of power and embraces all dimensions of learning-teaching would allow educators to

articulate meaningfully the ways in which they might provide for children's educational rights" (quoted in Watson, 2001, p. 140). In this way, constructivism recognizes the potential of students and fosters the different and best ways students learn to improve their knowledge.

According to Adams (2006), Brooks and Brooks (1993), as well as (Watson, 2001), teachers who adhere to social constructivist educational principles prioritize several key approaches:

- Empowering students' autonomy and active involvement in constructing knowledge.
- Shifting focus from performance to deeper comprehension of concepts.
- Using assessments that uncover shared understanding and real-world applicability.
- Guiding rather than instructing
- Fostering dialogical discourse
- Encouraging inquiry, challenging initial ideas, and promoting discussion.
- Allowing time for deeper student engagement and metacognition in learning cycles.

Implementing these principles allows students to become more aware of their environment and gain useful knowledge from it, which improves the way they are learning the concepts that are taught in the classroom. As a result, students become more naturally conscious of their surroundings.

Place-based education

Place-based education highlights the significance of connecting learning to the local context. It is a promising approach that emphasizes the vital link between learning and the physical environment where teachers and students are situated (Yemini et al., 2023). The themes of Place-based education include aspects of economic development, community's life, civic involvement, and environmental issues (Smith & Sobel, 2010). Its core aim is to reconnect individuals with their surroundings, which could include urban or rural settings (Ardoin, 2006). By integrating the local culture and history into students' school experience they can realize what is valuable and worthy in their home communities, as their learning is tied to their own identities (Smith & Sobel, 2010).

However, there's ambiguity surrounding the definition of "place" within this context, and addressing distinctions between various categories like place/non-place or urban/rural settings remains a concern (Nespor, 2008). For this framework, I will define place as the geographic site and surroundings where students are located.

Importantly, this educational strategy goes beyond conventional academics, fostering the development of essential social skills such as leadership and public speaking. Students become catalysts for change within their communities, inspired by their newfound knowledge and connection to the world around them. Place-based education increases the scientific literacy skills of students, while they become active community members and earn a better understanding of social and biophysical ecosystems (Wright et al., 2021).

In practice, Place-based education helps students explore their local community, gaining a deeper understanding of concepts in subjects like science and mathematics by witnessing their real-world applications. Simultaneously, this approach cultivates problem-solving skills as students tackle community issues and propose solutions. Moreover, it nurtures an authentic learning experience, providing them with firsthand experiences that fuel their curiosity and learning. Place-based education curriculum is applied by teachers who see a curricular alignment and show curricular agency (Wright et al., 2021). For example, In Wright's study, using the assistance of local wildlife specialists, teachers were able to address academic requirements using real-world examples, adopt an interdisciplinary approach, and look into possible opportunities for civic engagement (Dale et al., 2020).

Problem-based learning

The foundation of Problem-based learning was proposed by Barrows (1968), who emphasized learning as a unified process encompassing cognitive, metacognitive, and personal development (Newman, 2005). This theory was introduced initially in the field of medical education in the late 1960s (Merritt et al., 2017; Wijnia et al., 2019). The goal was to bring patients and their problems to students, so they could experience a more meaningful experience and keep motivated and stimulated by experiencing different case studies (Merritt et al., 2017; Wijnia et al., 2019). Currently, Problem-based learning has been implemented in the fields of K-12 education, engineering, business education, psychology, law, advertising, architecture, nursing, and physical therapy (Merritt et al., 2017; Wijnia et al., 2019).

Problem-based learning is inspired by constructivism and defined as learning through projects that are based on issues experienced in real-life, or life outside of the classroom setting (Merritt et al., 2017). The features shared by social constructivism and problem-based learning are: acquiring knowledge through trial and error, learning by doing, and applying new knowledge to new circumstances (Merritt et al., 2017). The characteristics problem-based learning brings to this framework are fostering critical thinking, and problem-solving skills in real-world learning settings (Yeh & Gow, 2016). Using this educational theory empowers students to engage effectively with significant problems, encouraging collaborative problem-solving, the creation of mental models for learning, and the development of self-directed learning habits (Yeh & Gow, 2016).

The application of problem-based learning in K-12 Mathematics and Science Education has been effective in improving the knowledge retention, attitudes, and conceptual development of students' academic achievement (Merritt et al., 2017). However, there are few studies comparing Place-based education and Problem-based learning (Williams & Houseal, 2018).

It is necessary to investigate the long-term outcomes of problem-based learning to analyze the integration of skills and transfer of knowledge from primary to secondary education (Wilder, 2015). Studies show that the long-term memory can retain the knowledge acquisition from problem-solving and increases the latter's accessibility over time (Schmidt et al., 2011).

Three-Dimension Learning and Anchoring Phenomena Curricular Resources

NGSS (NGSS Lead States, 2013), promote the simultaneous use of a three-dimensional framework within science instruction. According to the Framework (NRC, 2013), the three dimensions of science education center on the knowledge and skills that students need to succeed as scientists or as knowledgeable consumers of scientific information. Disciplinary Core Ideas underline the big ideas of science that are the basis for comprehending how the world works by concentrating on the how's and whys of science procedures; using this method in classroom activities implicates a change in the focal points of classroom activities toward research how and why the phenomena evolve (Fick, 2018). Crosscutting Concepts connect the big ideas around which science can be linked with other disciplines (Houseal, 2016). These concepts are the subjects that researchers use across different fields to promote comprehension of how the phenomena function (Fick, 2018). Scientific and Engineering Practices encompass what is the process or procedure of building science knowledge (Houseal, 2016). These practices help students to engage in the habits of mind necessary to construct scientific knowledge (Fick, 2018).

The use of phenomena-based units aids students and teachers in comprehending the flow of new learning through investigation, sense-making, scientific modeling, drawing on real-world connections, and exploring new questions (Redpath et al., 2015). When the new questions come up, the cycle restarts with a new inquiry. Students become adept at recognizing this pattern, and it fosters a culture of questioning, analysis, and the creation of new questions (Sinoradzki & McKenna, 2021). The idea is that this phenomenon should be something observable but complex enough

to provoke students' curiosity and motivation to begin exploring how to explain that phenomenon-through the application of scientific inquiry skills.

Using phenomena that give students time to consider what they are seeing is an excellent way to assess their level of understanding and prior knowledge (Richards et al., 2023). Storylines are shaped by the phenomena that students are attempting to understand, and they serve to link and inspire learning activities that take place over a few weeks or longer (Nordine et al., 2019). Students' questions are used to guide their learning, and making them the "right" questions can help to extend their previous knowledge and keep their interest in the project (Chin & Chia, 2004). Furthermore, in *Taking Science to School* (NRC, 2007), they state that, "Students learn science by actively engaging in the practices of science, including conducting investigations; sharing ideas with peers; specialized ways of talking and writing; mechanical, mathematical, and computer-based modeling; and development of representations of phenomena" (pg. 251). This approach is typically implemented in formal settings over a several-week period, my study is looking for the application in non-formal settings over a short period of time, like a single visit to the Biodiversity Institute in a two-hour period. However, the review of the literature reveals limited research addressing this specific adaptation (bringing formal education to non-formal education over a short-period time) highlighting the contribution of my research.

To encourage knowledge generation, eight strategies have been proposed: mapping, drawing, imagining, summarizing, self-explaining, teaching, self-testing, and enacting (Fiorella & Mayer, 2016). These strategies incorporate various cognitive and language practices (Richards et al., 2023). For my study, I implemented mapping,

drawing, and summarizing. With the use of concept mapping, students are able to pinpoint important ideas and graphically represent how they relate others, building models that either summarize what they have learned or refute claims (Martinez-Maldonado et al., 2012). Drawing is an activity that generates knowledge by combining action, cognition, and perception (McGuirk, 2014). Summarizing is a method where students integrate new knowledge into long-term memory by converting their knowledge into written or visual representations (Hand et al., 2021).

While incorporating phenomena can help students learn science more concretely, it might not be sufficient for conceptual understanding and meaning-making (Richards et al., 2023). Giving students the chance to create their knowledge is crucial, but they must also be able to connect the dots in their minds between the concepts associated with the phenomena and the scientific terms they can use to explain them (Richards et al., 2023).

Western Tiger Salamander

I decided to focus on this species because of its relevance to Laramie and the Biodiversity Institute. In addition, I have never worked with amphibians before and there were so many facts that I learned about them and sparked my curiosity to learn more about them and use the western tiger salamander migration as the scenario of my anchoring phenomena-based curriculum resources. In the next paragraphs I am going to introduce you to some of the facts I learned and lead me to choose this specie.

Since the first World Congress of Herpetology in 1989, herpetologists have been documenting amphibian declines worldwide (Campbell Grant et al., 2020; Fisher &

Garner, 2020; Green et al., 2020; Stuart et al., 2004). Habitat loss and/or modification, invasive species, contaminants and pollution, climate change, exploitation, and diseases seem to be the threats causing the amphibian decline (Campbell Grant et al., 2020; Green et al., 2020).

Road disturbance influences the spatial and local diversity of amphibians (Cosentino et al., 2014). Road mortality is a widely recognized and major area of amphibian research. In addition to the amphibian road kills, roads also affect population dynamics, create genetic isolation, and serve as barriers to migration (Beebee, 2013). Successful amphibian conservation requires minimizing the impacts of future road projects and mitigating the impacts of current roads (Cosentino et al., 2014).

The International Union for Conservation of Nature Red List and U.S. Endangered Species Act categorize Western Tiger Salamanders as stable. However, they recognize that some populations and subspecies are declining. On the other hand, the Wyoming Game and Fish Department includes Western Tiger Salamander as a Species of Greatest Conservation Need with a NSS4 (Bc) status (Wyoming Game & Fish Department, 2017). This means there is not a clear statement about the current conservation status of Western Tiger Salamander and information or knowledge about the species is insufficient. The species is widely distributed and populations appear stable, but there is a need to conduct baseline surveys for a better understanding of the distribution, abundance, habitat, associations, and disease status within Wyoming (Wyoming Game & Fish Department, 2017). The Biodiversity Institute also created a database where you can report the sight of a Salamander across Wyoming (University of Wyoming Biodiversity Institute, 2023).

Community scientists can address social-ecological problems through participation in projects they create and benefit from bottom-up initiatives (Lin Hunter et al., 2023). A proposed general framework by Pandya (2012) to have better engagement in a community project is to align the research and education with community priorities, plan for co-management of the project, engage the community in every step, incorporate multiple kinds of knowledge, and disseminate results widely. Community Science, also called *citizen science* has the capacity to “develop connections between students’ everyday lives and science so that they will have tangible reasons for continuing with the lifelong learning of science” (Jenkins, 2011, p. 501).

In the past 20 years, the number of community science programs and volunteers has increased (Sterrett et al., 2019). Events like the synchronous spring migratory breeding events of amphibians are great scenarios where citizen scientists involve the community in local and regional conservation efforts (Sterrett et al., 2019).

In Laramie, Wyoming, the migration of Western tiger salamanders occurs every spring on rainy nights above freezing (University of Wyoming Biodiversity Institute, 2023). These organisms will move from the neighborhood yards to LaBonte Pond (University of Wyoming Biodiversity Institute, 2023). On the way, many salamander adults are killed when they cross the roads (University of Wyoming Biodiversity Institute, 2023; Sterret *et al.*, 2018). The Laramie community has been helping the salamanders to cross the road, although there is no record of when this informal initiative started (B. Addis, personal communication, October 13, 2023). In 2012, a graduate student from the PIEE program at University Wyoming started to coordinate people in the neighborhood around Labonte, Park (M. Murphy, personal communication, April 26,

2024). Since 2022, the Biodiversity Institute has been organizing the *Laramie Salamander Migration Initiative* (B. Addis, personal communication, October 13, 2023), an event where researchers from the University of Wyoming, volunteers, and other stakeholders will help the salamanders cross the road (University of Wyoming Biodiversity Institute, 2023). During these migration nights, researchers also collect data about the salamanders. These data include sex, length, and weight. However, to avoid the handling and additional stress to the salamanders, volunteers are not involved in the taking of these data (M. Lee, personal communication, October 5, 2023). In addition to the Laramie Salamander Migration Initiative, the Biodiversity Institute has been hosting an event called *Salamander Saturday* to promote awareness of Salamanders among the general public (University of Wyoming Biodiversity Institute, 2023).

Given the Western Tiger Salamander Migration Nights Initiative in Laramie, the purpose of this project is to increase the awareness of amphibians within the communities throughout Wyoming by designing curriculum resources that teachers can use with their 5-8 grade students. The resources will use the Western Tiger Salamanders' (*Ambystoma mavortium*) lifecycle and the issue of human assistance surrounding their spring migration as the instructional phenomena.

Social Constructivism and Western Tiger Salamander

The social constructivism educational principles create an interactive, engaging, and collaborative learning environment. Through the use of Social Constructivism theory, students actively investigate the Western Tiger Salamanders' life cycle and how is related to their community. Students develop individual and group research to identify

problems related to road ecology and migration and construct their understanding of the phenomenon. *The driving question, “Why do salamanders move?”* and the sub-driving question, *Why do they need help moving into LaBonte Park in the spring?* attempt to scaffold the needs and challenges of Western Tiger Salamanders while involving students in hands-on explorations. The anchoring phenomenon curricular resources provide equal opportunities to participate and contribute.

Place-based education and Western Tiger Salamander

For this study, Place-based education and the case of the migration and the life cycle of western tiger salamander are ideas that are incorporated in the local community and the environment is used as a context for learning. Students learn about the ecosystem, abiotic factors, and problems where the Salamanders are found in the area. In addition, understanding the migration patterns, breeding habitat, and impact of human activities on their habitats are concepts embedded in the curriculum resources. Providing maps, local news notes, and tables with information about the salamanders in Wyoming; students engage in hands-on activities and fieldwork experiences that allow them to explore the salamanders’ habitat and places where they can be found. The goal is that students can relate this anchoring phenomenon to local and biodiversity issues in their local environment.

Problem-based learning and Western Tiger Salamander

The Problem-based term emphasizes the use of real-world problems as the starting point for learning and investigation. In my framework, problem-based learning refers to how the curriculum resources are made around the central phenomenon of

western tiger salamanders' life cycle and its associated issues. Students investigate the needs and challenges of salamanders from various angles and it strongly connects with both theories as we are focusing on a local issue (Place-based education) and bringing the previous knowledge students could have about amphibians or other groups of animals (Social Constructivism).

Adopting a problem-based learning approach engages students in authentic learning about the western tiger salamanders' life cycle, migration, and road ecology. By doing so, we promote the development of basic problem-solving skills as students analyze data, propose solutions, and collaborate to conserve amphibians.

Anchoring Phenomenon and Western Tiger Salamander

The anchoring phenomenon of the curricular resources I developed is the salamander migration. Students investigate the why and how of this migration, discovering the challenges amphibians face during this critical life stage. By exploring these challenges, students tackle the real-world problems of salamander population decline and the controversy of human impacts/assistance. Through exploring this, students share their arguments in oral and written presentations, including the scientific information and models they find, and finally, propose a solution to reduce or mitigate the salamander population decline based on their representation of the phenomenon. These practices align with social constructivism by promoting social learning as students learn in their social background, place-based education by connecting learning to the local environment, and problem-based learning by tackling real-world challenges related to the salamander's migration and life cycle. Furthermore, they contribute to

three-dimensional learning by integrating disciplinary core ideas like *from molecules to organisms: structures and process*, science practices like *ask questions and engage in argument from evidence*, and crosscutting concepts like *cause and effect and patterns*.

Conclusion

The use of social constructivism, place-based education, and problem-based learning theories to develop anchoring phenomena curricular resources and align them with the three learning dimensions is a way to improve biodiversity conservation and education. These theories are relevant for this project because they connect students with their community while they are learning; they build knowledge based on students' ideas and relevance to their daily lives; and they help students to identify, analyze, and propose solutions. At the same time, scientists and teachers can use these theories to develop curricular resources in their community science approaches and science and math lessons.

Connecting biodiversity conservation to science lessons can help students to have a better understanding of related concepts, as students are learning through seeing them being applied in their community and making connections with their previous state of knowledge.

Chapter 3

Methods

Background and Context for the Study

Biodiversity Institute Mission

This non-thesis master's project was part of my graduate assistantship with the Biodiversity Institute (BI) at the University of Wyoming, where I was a Graduate Assistant researcher. The BI is a space focused on exploring nature and building a solid network of humans dedicated to protecting and valuing Wyoming, the U.S., and the rest of the world's biodiversity through funding research and developing community science and outreach programs (BI Annual Report, 2023). My graduate assistantship assignment was to develop curriculum resources that could be used in the outreach program related to the Wyoming Science Standards and the mission of the BI.

The mission of the Biodiversity Institute is to foster the understanding, appreciation and conservation of biological diversity through innovative research, education, and outreach, and by engaging a broad audience in the scientific process.

The Biodiversity Institute works with scientists, resource managers, educators, and the public to further the understanding and conservation of biodiversity. We seek to provide a unique service to Wyoming and beyond by facilitating collaborative research projects, disseminating research, distributing grants, and

providing educational, outreach, and citizen science programs for scientists, students, and the public (Biodiversity Institute, 2024).

This Plan B is a part of the larger project and was a self-study being used to determine my process of curriculum materials development using 3D (instructional) phenomenon-based storyline strategies while connecting to the place-based themes. The goal for this part of the work was to describe my process so others can replicate it in the future with species/wildlife conservation projects of their interest. In the next sections, I describe self-study methodology and my data collection and analysis processes.

Self-study as a Research Tool

A self-study is the seeking to “understand the relationship between the knower and the known” as well as seeking to “understand what is the form and nature of reality” (Kuzmik & Bloom, 2008, p.2007). Action research has taken on many different shapes over the years, but they all follow a methodically iterative approach: (1) problem identification; (2) planning; (3) action; and (4) reflection-based action evaluation (Aubbusson and Gregson, 2008).

Self-study research is about educators researching their practice with the aim of improving it, making a clear and authentic use of their professional expertise, and simultaneously adding to the knowledge foundations of teacher education (Vanassche & Kelchtermans, 2015). For the present study, a self-study of teaching and teacher education practices (S-STEP) is defined on the definition of Pinnegar and Hamilton (2009), who defined it as a research methodology in research allows educators to

document their findings on teaching and educational practices. It also facilitates the integration of their personal experiential knowledge and enrich our collective understanding of teaching. In addition, it allows educators to bring their biases and previous knowledge into their teaching by using this methodology for studying teaching practices.

Data Collection

According to Ovens & Garbett (2020), journaling is a useful research method for S-STEP researchers as it allows the researcher to gather or create data for post-analysis, but it is also a helpful tool for introspection, processing, and deep, ongoing reflection. By documenting events and offering insights into people's thoughts, objectives, and feelings related to our process, journaling has been essential in improving our understanding of teaching. To serve as a tool to encourage deeper thoughts and growth, journaling is considered a method and artifact that helps capture the nature of practitioners' lives through the process of incorporating description, commentary, introspection, and analysis.

The categories I set up in my journal to take my field notes were *today's progress, emotions, and tomorrow's progress* (see Appendix 1). For the first category I asked myself and recorded the answer to the questions; What am I doing today? How is it helping with this project? For the feelings and emotions category, I asked myself How do I feel? and break it down into frustration, satisfaction, confidence, and knowledge. Finally, in the last category, I recorded: What new questions do I have? Which resources do I need? What will I do tomorrow? By asking these questions to myself I

was able to record my daily progress, emotions, satisfaction, tasks to do for next day, resources I needed it, and questions.

Recording these data helped me to keep track of my daily progress, tasks, and emotions I had while I was working on developing the anchoring phenomenon curricular resources. The aim was to record my process of developing anchoring phenomenon resources that teachers across Wyoming so others can replicate this process later to develop resources for non-formal settings but align it with the three-dimension learning.

Data Analysis

I analyzed my data to identify my approaches, steps, and processes to create the curriculum resources for a local species. I used an exploratory coding method with a mix of provisional and hypothesis methods using Saldaña's manual (2021). I used a qualitative data sorting software tool (Atlas ti[®]) to explore my data. This software helped me to sort meaningful quotes collected in my journal entries that later emerged as the themes (Friese, 2019). For the data analysis, I did three cycles of coding and one cycle of co-occurrence analysis. In the first cycle, I carefully read and analyzed my daily journal entries, marking as codes the frequently used words and quotes. In the second cycle, I made a possible list of themes and codes and highlighted the quotes where my codes matched with the list. In the third cycle, I identified more codes by being more specific about the actions, steps, sections, questions, help and resources needed. Finally, I did the co-occurrence analysis. This analysis was made using Atlas ti[®] co-occurrence analysis tool. From this analysis, I identified several interesting junctions

between my codes. These helped me derive meaning or notice connections I did not before.

Positionality Statement

During the time of this study, I was an international student from Mexico with a BS in marine biology interested in wildlife conservation, environmental education, and outreach or non-formal education. Since 17 years of age, I have been volunteering for environmental non-profits in Mexico and the United States.

Based on my scientific and environmental education experiences, my goal was to connect researchers and teachers to develop curriculum resources they can use to improve their lessons and wildlife conservation efforts. My assumptions were that researchers might not have professional pedagogical training to develop curriculum resources aligned with the educational framework of K -12 grades and teachers might not understand or know the full picture of some of the issues and concepts related to wildlife conservation.

I chose to include a section on my positionality because my previous experiences and knowledge are reflected in my role as researcher in this self-study. The aim of this positionality statement is explaining where I am coming from and where I am hoping to go in this journey. This positionality influenced my research as I was studying myself while I developed anchoring phenomenon curriculum resources aligned with the three-dimensional learning framework of the NGSS for a non-formal setting and I used wildlife as the anchoring phenomenon. The notes of my journal and results of the analysis of this Plan-B research project were used to develop the resource development guide.

Chapter 4

Results

In this chapter, I outlined the themes that were elicited from my journal. The themes are: *process and methodology*, *content development*, *personal reflection*, *support*, and *final products*. *Process and methodology* highlighted the iterative cycles of research, reading, writing, and revision. *Content development* uncovered the underlying principles that guided the development of NGSS aligned curriculum resources. For *personal reflections*, I sorted it into questions, emotions, and goals. *Support* provides information about the feedback and comments of my committee members and the use of resources that helped me improve the resources. The anchoring phenomenon-based curricular resources, resource development guide, and this research are the *final products*. See Appendix B for the resource guide.

The curricular resource development was a progressive process that involved multiple cycles of researching, reading, summarizing, writing, revising, and refining. I started by researching educational theories, the NGSS, anchoring phenomena, and educational materials. This initial step of research and exploration helped me establish the main concepts of my research project and refine my definitions.

With this fundamental knowledge, I embarked on unpacking the NGSS performance expectations and matching my anchoring phenomenon-based curricular resources with the three-dimensional learning framework. This required an in-depth investigation of the standards' disciplinary core ideas, crosscutting concepts, and

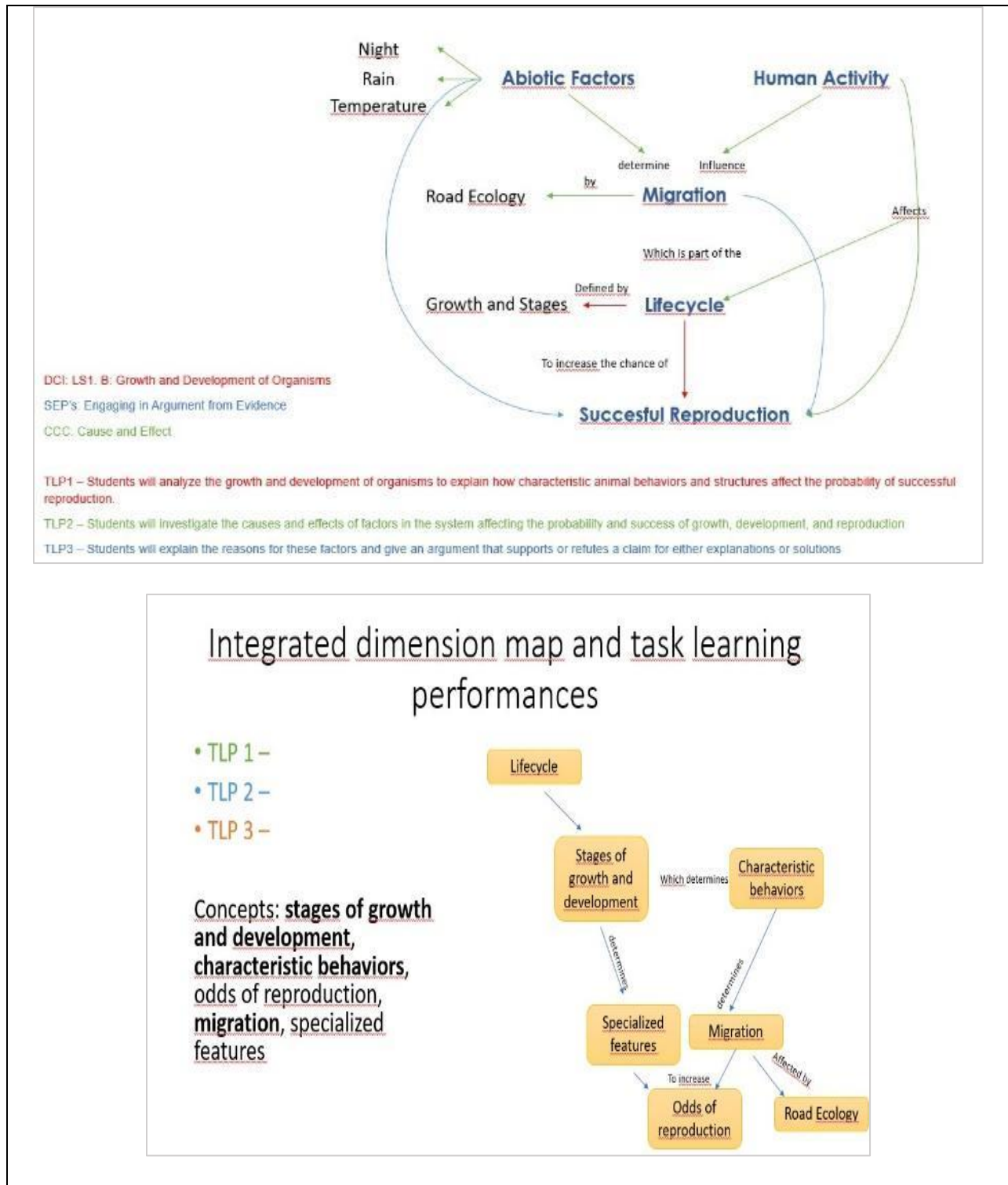
science and engineering practices. Throughout the unpacking of the performance expectations and aligning them with the selected phenomenon, I was able to make sure that my curriculum resources were closely aligned with the learning goals and objectives established by the NGSS.

As I worked on the different components of my curriculum resources, such as the sequence of activities for a non-formal event, which included, instructions, storyline, resources for each station, activities, and outcomes, I engaged in ongoing cycles of writing, feedback, and revision. This iterative process allowed me to refine the content, structure, and language of my resources, ensuring that they were hands-on, engaging, and dynamic for the students.

Throughout this journey, I regularly brainstormed the content development of the curriculum resources, adjusting and adapting my approach as needed. For example, after getting feedback from my committee members about the alignment of the content it was necessary to revisit my process and make improvements to the resources to get a better fit between my resources and the overarching goals and objectives. Figure 2 exemplified the iterative process of developing, getting feedback, and improvement. In this case, I initially created a draft of the concept map to use for the curriculum resources, then I presented it to my committee members to get feedback from them. Their suggestions helped me to refine the connections between the concepts and alignment with the performance expectations.

“After listening to Emil, Ana, and Brett I have a better understanding of how the concepts might work together” February 22, 2024

Figure 2. Drafts of the concept map



Note: Differences in the concept map and task learning performances of the anchoring phenomenon-based curricular resources before and after getting feedback from my committee members.

The difference between the one I made initially and the second concept map was that the first one was not showing a clear connection between the concepts while the second one shows the complexity of the phenomenon. The second version also broke down each of the concepts in a better way and reflected how they matched the performance expectations and the task learning performances. This flexibility and willingness to rewrite, rearrange, and refine my work was a crucial aspect of my process because it allowed me to consistently improve the quality and effectiveness of my final products.

Adopting this research methodology which was based on an in-depth understanding of educational theories and standards allowed me to create a curriculum resource. This resource met the learning needs of students aligned with the NGSS and represented the best practices in non-formal science education. The final products, including this research paper, the anchoring phenomenon-based curriculum resources, and the resource development represent the culmination of my journey. These products reflect the insights, revisions, refinements, and personal reflections at every stage of the research and development process (Table 1) and are described in the next section.

The thinking process that led me to select these themes for the analysis was guided by the examination of my journal and the quotes that emerged from it. Each theme was chosen to capture a distinct aspect of the process, reflecting the way I navigated the process along the way.

The theme *process and methodology* highlight the systematic steps that were relevant throughout the development of the products and artifacts, such as researching, summarizing, writing, refining, methodologies, data analysis, designing the framework, and making progress in each section of this Plan B. This theme served as the journey's roadmap. *Content development* emerged as describing the curriculum resources development process. Unlike the previous theme, this theme encapsulates the iterative process of developing anchoring phenomenon-based curricular resources.

My questions and feelings led to the emergence of *personal reflection*, which were motivated by the confidence in my knowledge, status on it, and progress. The questions and reflections were related to the way I was navigating the process and my status on it. For example, in my first journal entry on October 23, 2023, I wrote: "Which are the theories that I am going to apply?" On January 23, 2024 there's a personal reflection that reflects a high level of confidence, satisfaction, and knowledge: "I have a **better** understanding of which concepts might be helpful and what the anchoring phenomenon, disciplinary core ideas, crosscutting concepts, and science and engineering practices are". To get to this point and coming from the science field without listening about teaching concepts before, the readings about my educational theories, the three-dimensional learning, and anchoring phenomena were helpful to improve my understanding of these concepts and figure out the connections among them and relevance to my curriculum resources.

Support was crucial for successfully navigating the difficulties of creating anchoring phenomenon-based curricular resources. The feedback from my committee and the use of resources, such as templates, examples of curriculum resources, and AI

was of great help for the process. The theme of *final products* encompasses the culmination of the journey and the outcomes: the resource development guide, anchoring phenomenon-based curriculum resources, and this research. Throughout the process, the meetings with science experts to talk about western tiger salamander migration in Laramie was a key component. These discussions helped me to understand the migration, status of conservation of salamanders, challenges they face during their lifecycle, and the effects of these challenges on their lifecycle and populations.

Table 1. Themes and Codes Elicited in this Self-Study

Themes	Codes	Quotes	Reasoning/Explanation
Content Development	<i>Adapt Vocabulary, concepts, curriculum resources, Instructions, NGSS standards, outcomes and public, stations, storyline, summarize, three-dimensional learning, unpacking, visuals, and writing</i>	On March 15, 2024, I wrote: “Write the instructions for the bends and stations of the rally, add resources, and keep working on comments of chapters 1, 2, and 3.	This theme encompasses the process taken while I was working on the curriculum resources.
Process and Methodology	<i>Analysis, coding, drafts, looking for theories or resources, reading, rewrite, writing</i>	On February 5, 2024, I wrote: “Keep working in chapter”.	Under the theme are included codes related to my process. All of them are the steps throughout my journey. From understanding ‘what is a phenomenon?’ to starting the analysis.
Personal Reflection	<i>Emotions, questions</i>	On January 23, 2024, “I have a better understanding of which concepts might be helpful and what the anchoring phenomenon, disciplinary core ideas, crosscutting concepts, and science and engineering practices are”.	This theme includes all the codes related to my emotions, reflections, and questions regarding my process in the development of the artifacts. These codes reflect how confident I was feeling with my process and which are the things I was struggling with or needed help.

Table 1, cont.

Themes	Codes	Quotes	Reasoning/Explanation
Support	<i>AI, feedback, meetings, templates or examples, workshop, writing center</i>	On January 24, 2024, I wrote “Before the meeting, I was feeling stuck about what I should be doing. During the meeting, they gave me instructions on what I need to do during the week and how unpacking the standards would be helpful to find out which one is the better fit for my project”.	Under this theme are included the codes related to external resources, meetings, and support from others who guided me or helped me with feedback.
Final Products	Research paper, resource development guide, and anchoring phenomenon-based curricular resources	On November 16, 2023, “Defining the products of my master’s project paper and graduate assistantship. I am going to develop the thesis, a guide, and resources. The theories selected for my theoretical framework are social constructivism, place-based education, and problem-based learning”.	Under this theme are included the codes related to the outcomes of my research.

Content Development

This theme mainly focused on how I developed the anchoring phenomenon and theories involving the process of creating curricular resources for middle school students. The work involved researching and identifying standards, selecting the grade level, and similar works to mine or templates from others.

This theme is tied to the self-study because it explains my process in developing the curriculum resources. This started, with finding the scenario for the phenomenon and educational theories embedded within them, unpacking the standards, and aligning my curriculum resources with the three-dimensional learning of the NGSS. It culminated with creating the educational rally event, its storyline “bends” used to create stations, and selecting the resources to use within each station, finally adapting it for a younger public group that attended the Western Tiger Salamander weekend day event.

To find the scenario for the phenomenon I looked at the resources the Biodiversity Institute already had and did a list of species with few or not educational resources and need attention from the general public. The educational theories were selected based on the desired outcomes and ways to involve the public. I identified relevant standards and unpacked them into learning objectives. The educational rally, storyline “bends”, and stations were designed based on the performance expectations from the selected standard and the concepts of importance for the standard and my phenomena. Within each station, I carefully selected resources such as videos, notes from local news, maps, tables, and pictures that illustrated and helped to explain the phenomenon. Finally, I created an assessment to measure students’ comprehension of the phenomenon and piloted the rally during Salamander Saturday. The adaptation

for younger audience in Salamander Saturday required simplifying the language and creating activities (maze, word search puzzle, and crossword).

Finally, in the appendix you will find the draft of the resource development guide produced for the Biodiversity Institute with more details about the previous steps mentioned.

Process and Methodology

This theme included the actions of my journey, from looking for resources, reading, writing, summarizing, to analyzing the journal. It included rewriting the sections to improve the flow and connections among the sections and chapters.

The most repeated steps in the process were classified as codes under this theme. These were: reading, writing, looking for theories or resources, brainstorming, flow, summarizing, rewriting, and concepts. Throughout my process, most of the time I worked on the education theories and framework, which is reflected in the analysis as it is the code with the highest frequency (153).

Despite the overlap between the two the *process and methodology theme* differs from the *content development* one because this theme described the general processes that capture all the aspects of my work, while the *content development* theme encapsulated the process of content development.

Support

A vital component of the process was concurrent meetings and getting feedback from my committee members to improve the present research and curriculum resources. Having recurring meetings with the salamander experts and being able to

reach out to them with my questions helped me to get a better understanding of the salamander migration in Laramie and they shared resources with me. I used templates and models of similar works as resources to help me navigate the process. In addition, the meetings with my committee and using AI tools like ChatGPT and Gemini to unpack the standards were valuable. I used them to unpacked the standards using prompts such as elaborate major ideas in the element, describe the practice and its components, and identify substantive intersections with science practices and disciplinary core ideas. AI tools were also helpful to simplified the vocabulary for younger audiences. The biggest changes I noticed while I was working on my outcomes after getting support are reflected in the drafts of the framework and literature review chapter and the resources I did. Here are some examples about how external support was meaningful and for which tasks.

“Motivated about how can I use AI to develop my project. The more I know about AI, I found it helpful but also scary” January 31, 2024

“After the meeting with my committee members, it was of great help the feedback they gave me on the connections between the concepts and how can I start thinking of the takeaways of students” February 16, 2024

Personal Reflection

This theme described my feelings, reflections, and questions during the process. My feelings throughout this process ranged from feeling tired, confused, and frustrated at times, to feeling motivated, inspired, and confident at other times. Sixty-four percent of the time I had positive emotions and 35% of the time, they were negative. This was unexpected for me as most of the time I felt concerned about deadlines and graduation,

finding motivation for certain tasks, and making connections between the sections and theories of my research. However, they also showed how I navigated the challenges and found confidence with the guidance and support of others. Working on the educational theories and framework and analysis were the steps of the process that made me feel more frustrated and anxious. The content development, curriculum resources, and Salamander Saturday made me feel confident and satisfied with my progress. During the second cycle of the analysis, I noticed this project was driven by my curiosity, passions, and emotions. So, in the third cycle, I break the emotions into positive and negative.

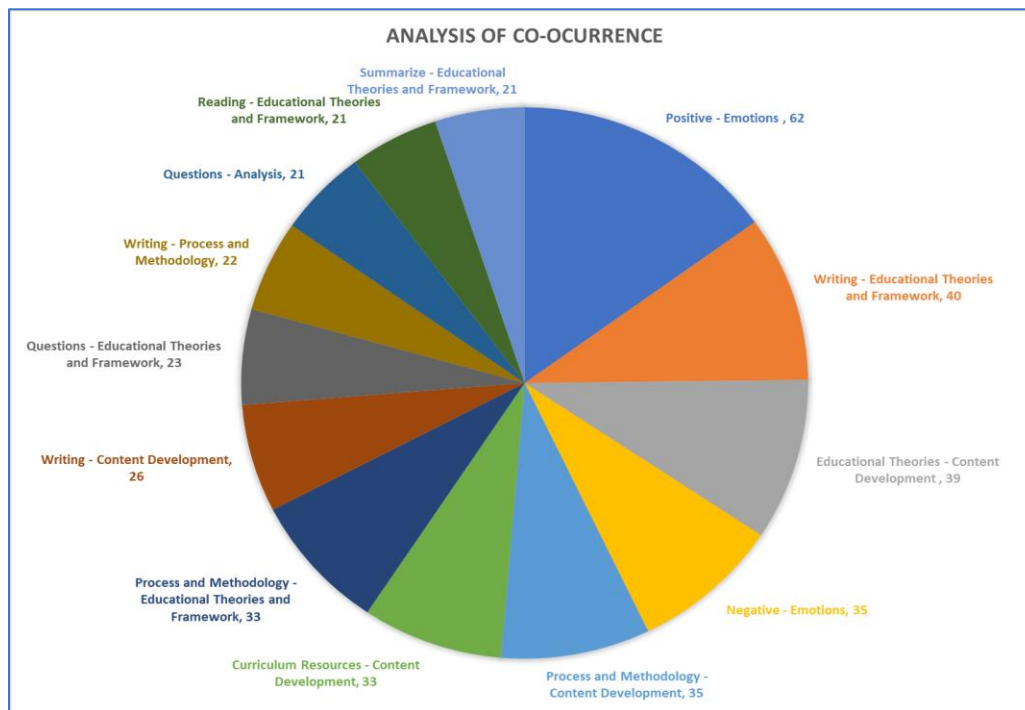
Final products

This theme was about the final products of my Plan B research project which are the project paper, the curriculum resources, and the resource development guide. For this group, I mainly describe the outcomes and how I was wrapping them up. For example, on March 15, 2024 I wrote that I would “Write the instructions for the bends and stations of the rally, add resources, and keep working on comments of chapters 1, 2, and 3” and how was helping to have “Having all set for Salamander Saturday and defense of my research paper. Another example with a similar structure can be found on March 27, 2024. This example details how I approached the final steps of writing this paper and the analysis of my journal. That day I wrote that I was doing “Install atlas ti, make edits to chapter 3, improve the survey and crossword puzzle for salamander Saturday” and it was helping “Moving towards salamander Saturday and the defense”.

Analysis of Co-occurrence

In qualitative data analysis, co-occurrence is the tendency for certain codes to appear together frequently. In this case, the analysis of co-occurrence helped me to identify the conjunction of codes (Figure 3), some of these concurrences were obvious such as educational theories - content development but others revealed intriguing insights about my process, for example, questions - analysis, emotions - negative, emotions - positive (Table 2).

Figure 3. Analysis of co-occurrence among the codes



Insights from the codes with the highest co-occurrence

There was an interesting connection within the *emotions* code. At the beginning of the project, I was feeling confused about the educational theories and content development which was reflected in the emotions (emotions-negative). As I kept working, I felt more confident with my progress and there was a switch to positive

emotions (emotions-positive). The co-occurrence of questions-analysis suggests a connection between the encountered challenges of the analysis. Table 2 shows some of the main co-occurrences with quotes and examples from this process.

Table 2. Codes with key co-occurrences

Co-occurrence	Quotes	Reasoning/Explanation
Educational theories - content development	<p>“The fact that I am working in the theories and resources at the same time is giving me a better idea about how my theories connect to the resources” February 2, 2024</p>	<p>At the beginning of this research took me a while to understand the theories and how can I incorporate them to the curriculum resources. In fact, I got a better understanding of the theories once I start working on the content development.</p>
Questions - Analysis	<p>“How do you analyze a journal?” Nov. 11, 2023</p> <p>“How can I do a qualitative analysis”? Dec.12, 2023</p> <p>“How might the analysis of this journal will look like?” February 23, 2024</p> <p>“When I will get Atlas ti and start the analysis of the journal” March 7, 2024</p>	<p>This is one of the co-occurrences I didn’t notice until the analysis. Without realizing it, I was thinking and wondering about the analysis all the time.</p>
Emotions - negative	<p>“Confused about the steps of my project and theories I need to apply.” October 24, 2023</p> <p>Frustrated. I do not find information November 27, 2023</p>	<p>Confusion and frustration were two of the most recurrent emotions throughout the project.</p>
Emotions - positive	<p>“More confident about the direction of my research project.” January 25, 2024</p> <p>“This draft is better than the one from last semester, so I feel more confident, and hopefully will get a green light.” March 5, 2024</p>	<p>As I walked down the path of this journey, my knowledge and comprehension improve as well as the way I was knitting together all the pieces and artifacts of this project.</p> <p>Getting back to our meetings with Ana, in a couple of them she said this metaphor: Imagine yourself as when you clean your room and have all the messy piles of random objects, but now you are rearranging and putting together all the elements.</p>

Chapter 5

Discussion and Conclusion

Interpreting and Contextualizing the Results

The results of my study add to the existing literature already available on the creation of scientific curricula and the application of the NGSS (2013) by bringing on the alignment of non-formal education with the three-dimensional learning, educational theories, and bridging the gap of researchers and communication with the general public to improve science education and wildlife conservation. The anchoring phenomenon-based approach I used in designing my curriculum resources is based on the principles of social constructivism, place-based education, and problem-based learning, as espoused by other authors (Vygotsky 1933; Sobel 2004; Barrows 1968). By situating the learning within a relevant and engaging local context, my curriculum resources aim to foster students' active construction of knowledge and their connection to the natural world by echoing the principles of these educational theories.

Broader Implications and Applications

When appropriate, we might employ strategies that involve members of the community in scientific issues that naturally engage with their interests. According to Strand et al. (2003), community-based research aims to solve community problems and promote social constructivism change by concentrating on a topic that is relevant to the community, with equal involvement of community members and researchers to produce favorable results. Science communication can be seen as a vehicle to improve the understanding of and support for science through the lenses of scientists and science organizations as well as participants in public communication (Simis et al., 2003). The

prevalent and unyielding deficit (knowledge transmission) paradigm in scientific communication underscores the restricted impact of science communication research on practical applications. The operationalization of scientific communication studies requires relationships between researchers and practitioners (Seethaler et al., 2019).

Given this, the curriculum resources and resource development guide I created through this research project have the potential to be a bridge within the fields of outreach and non-formal education and biodiversity conservation. My work could be a useful model (Figure 7) for other educators and curriculum creators who want to apply anchoring phenomenon-based curriculum and research-based science education aligned with the NGSS to their work in this field.

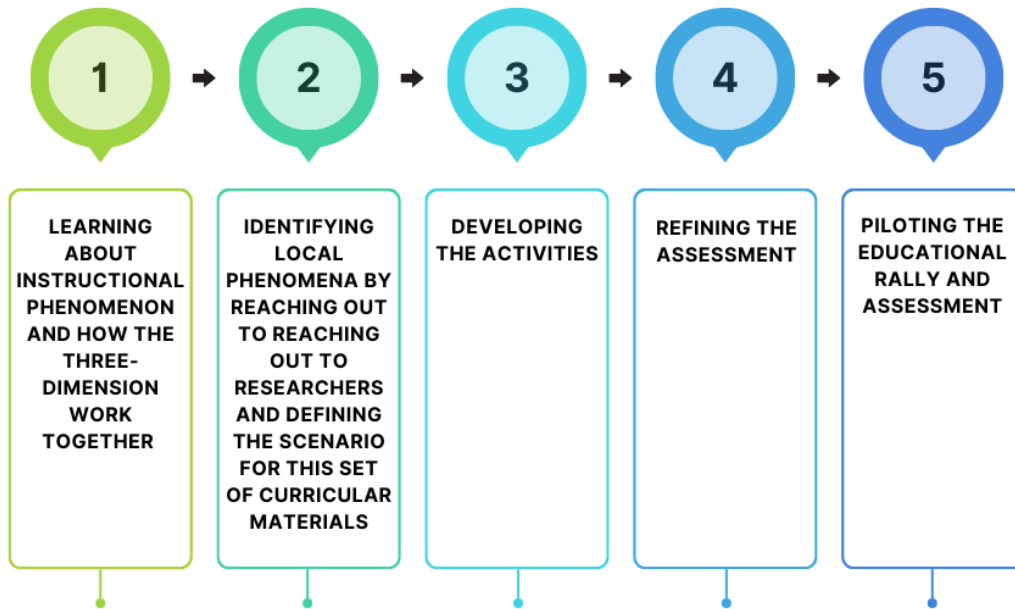
The resources also have wider adaptability as they were made to be modified for various grade levels and the interested public, which increases the likelihood of them being used. Other educators or professionals could follow the steps of my journey and its principles to create context-specific resources for their species of interest, classrooms, or school districts. They will only need to adapt or adjust the activities and context to fit the particular needs of their students and local environments. For example, people working in non-profits with conservation projects related to wildlife conservation can create anchoring phenomenon-based curriculum resources with the species they work aligned with the NGSS, even they might not have professional teaching experience. By providing a model on how to use anchoring phenomena and aligned with the NGSS, the guide can support non-formal educators in the creation of curriculum resources.

In addition, the research methodology and conclusions presented here might support the current academic and educational bibliography about successful approaches to developing species curricula and non-formal education development. The process of transferring my work with the scientists into a tangible educational resource can be seen as an interdisciplinary approach as biodiversity researchers and educators will work together towards increasing the awareness of species and their ecosystems that need more attention from the general public. Developing hands-on activities that directly connect students to the anchoring phenomenon will promote experiential learning. An inquiry-based learning will be boosted by encouraging curiosity using the driving and sub-driving questions, as well as prompting students to investigate and discover answers on their own.

I would like to make my experiences, struggles, and steps to inspire and guide others to make more anchoring phenomenon-based curricular resources in the context of wildlife as the anchoring phenomenon. The use of these resources has the potential to help improve connecting science education to conservation efforts.

Figure 7. The model to create anchoring phenomenon-based curricular resources

How to create anchoring phenomenon-based curriculum resources within the biodiversity context?



Iterative and Improved Process Through Self-Study

The inclusion of a self-study component helped me to identify how the creation of anchoring phenomenon-based curricular resources was an iterative process. The self-study and curriculum resources development worked together as I was able to track, define, and record my process, which also ended up being the *process and methodology* theme. The recurrent reflections improved my knowledge and ways of navigating the process, this can be seen under the theme of *personal reflection*.

The self-study and *content development* theme aimed to show educators how they can cultivate a deeper understanding of pedagogical theories, instructional strategies, and curriculum design principles. By incorporating these elements, they may be able to make better decisions that resonate with their students' community, learning needs, and interests. In the *support* theme, I recognized the value of having recurrent meetings with salamander scientific experts and my committee members to improve the curriculum resources and also using templates, AI tools, and previous examples from others. Consequently, the guide has references to many external resources I used.

In addition, the resource development guide would not have been possible without the self-study component. This guide is a summary of my self-study journey's observations and notes providing educators and curriculum developers with a road map to create more educational resources. People who might replicate my process may have an easier time making the anchoring phenomenon-based curricular resources because the self-study clarified the process I went through. The *final products* theme encapsulated the outcomes and last steps of the road map.

By engaging in this self-study, I feel more empowered in terms of how I can improve my teaching and I earned the ability to critique my process and find the areas of improvement. The areas of improvement are that now I am able to develop non-formal curriculum resources aligned with educational theories and the NGSS. Other educators, could benefit by using this methodology as it encourages a culture of innovation and continual improvement by adopting a self-study methodology in their professional practice (Aubusson and Gregson, 2008). This could ultimately enhance students' learning experiences.

In becoming an educator, one is continually accumulating knowledge, and reassessing how that knowledge plays a role in who they are and what they hope to teach. The struggle to define definitive teaching -this is what I want students to know, and this is how I want them to know it - is always precarious because we, as human beings, are constantly changing. What we hold to be true one day, might change the next. Teaching becomes a quest for self-knowledge. We begin to examine our own lives, and in turn, prompt the self-examination of the lives of the students we teach (Kaplan, 2002).

I included this quote, as it perfectly describes how I felt after this self-study. What we know today might not be enough for tomorrow, so as educators, we need to constantly reflect on our own teaching and how we can improve it for the benefit of our students, community, and in my case as somebody who loves being in the outdoors, also the biodiversity of our planet.

Limitations and Future Directions

The journal, although it was the primary tool of my self-study, was not started in parallel with this research. Therefore, I do not have journal entries for the first two months. This influenced my thematic analysis by not including the first steps of content development (reaching out to researchers and learning what is a phenomena). However, this self-study also helped me to notice that I am a paper-and-pencil person. There are so many things missing in the electronic journal but if you looked at my physical journal, there are notes in it starting at the beginning of my graduate assistantship and research. The notes from my physical journal are not part of the analysis but were used for the resource development guide's construction.

The curricular materials and resource development guide created as a result of this research study show promise for science instruction, but they are not without drawbacks. Since the materials were created in the context of middle school but applied in an open public event with children around 4 – 10 years old, more research and modification may be necessary to see how well they work in different settings or grade levels. Furthermore, because the development process is progressive and based on feedback, the finished resources will need to be tested and assessed after the completion of this study.

Future research could explore the long-term learning and impacts of the curriculum resources, as well as how well they support students' learning, engagement, scientific curiosity, and biodiversity curiosity. Studies that compare the benefits of the anchoring phenomenon-based approach to traditional education could also provide valuable insights. Additionally, the application and adaptation of this process by other

educators and researchers would strengthen the resource development guide and materials' relevance and impact by providing possibilities for improvement in the knowledge of students and biodiversity conservation.

Conclusion

The findings of this research project contribute to the ongoing efforts of outreach and non-formal education to improve their curriculum resources by providing a model for the development of materials that are aligned with the NGSS and adaptable to the needs of students and the local environment. This research has emphasized the importance of the process in developing anchoring phenomenon-based curricular resources. To ensure that the steps and materials produced by this project are efficient and meet the needs of educators and students future research needs to be developed. The future research needs to look at the outcomes and long-term learning of developing anchoring phenomena-based curriculum resources in the context of biodiversity and how this can help to improve science communication among the general public.

Bibliography

- Adams, P. (2006). Exploring social constructivism: Theories and practicalities. *Education 3-13*, 34(3), 243–257. <https://doi.org/10.1080/03004270600898893>
- Amineh, R. J., & Asl, H. D. (2015). Review of Constructivism and Social Constructivism. *Journal of social sciences, literature and languages*, 1(1), 9-16
- Amplify Science. (2019). What's so phenomenal about phenomena? An introduction to phenomenon-based learning. Berkeley, CA. The Lawrence Hall of Science.
- Ardoin, N. M. (2006). Toward an interdisciplinary understanding of place: Lessons for environmental education. *Canadian Journal of Environmental Education (CJEE)*, 112-126
- Ardoin, N. M., Bowers, A. W., Kannan, A., & O'Connor, K. (2022). Positive youth development outcomes and environmental education: A review of research. *International Journal of Adolescence and Youth*, 27(1), 475–492. <https://doi.org/10.1080/02673843.2022.2147442>
- Aubusson, P., & Gregson, R. (2008). Self-study, teacher-researcher, and action research: Three sides of a coin. *Teacher learning and development*, 195-208.
- Barrows, H.S. (1968). Simulated patients in medical teaching. *Canadian Medical Association Journal*, 98(14), 674-676
- Barrows, H.S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New directions for teaching and learning*, 1996(68), 3-12
- Beebee, T. J. C. (2013). Effects of Road Mortality and Mitigation Measures on Amphibian Populations. *Conservation Biology*, 27(4), 657–668. <https://doi.org/10.1111/cobi.12063>
- Bhurekeni, J. (2022). Enacting Environmental Ethics Education for Wildlife Conservation using an Afrophilic 'Philosophy for Children' approach. *Southern African Journal of Environmental Education*, 38. <https://doi.org/10.4314/sajee.v38i1.02>
- Brooks, J. & Brooks, M. (1993). *In search of understanding; the case for constructivist classrooms*. Alexandria, Virginia, USA: Association for Supervision and Curriculum Development.
- Brown, B. & Shorrock, S. (1998). Promoting access across the curriculum. In Littledyke, M. and Huxford, L. (eds) *Teaching the primary curriculum for constructive learning*. London: David Fulton
- Burns, T.W., O'Connor, D.J., & Stocklmayer, S.M. (2003). Science communication: a contemporary definition. *Public understanding of science*, 12(2), 183-202.

- Campbell Grant, E. H., Miller, D. A. W., & Muths, E. (2020). A Synthesis of Evidence of Drivers of Amphibian Declines. *Herpetologica*, 76(2), 101. <https://doi.org/10.1655/0018-0831-76.2.101>
- Chin, C., & Chia, L.G. (2004). Problem-based learning: Using students' questions to drive knowledge construction. *Science education*, 88(5), 707-727
- Cosentino, B. J., Marsh, D. M., Jones, K. S., Apodaca, J. J., Bates, C., Beach, J., Beard, K. H., Becklin, K., Bell, J. M., Crockett, C., Fawson, G., Fjelsted, J., Forsy, E. A., Genet, K. S., Grover, M., Holmes, J., Indeck, K., Karraker, N. E., Kilpatrick, E. S., ... Willey, A. (2014). Citizen science reveals widespread negative effects of roads on amphibian distributions. *Biological Conservation*, 180, 31–38. <https://doi.org/10.1016/j.biocon.2014.09.027>
- Dale, R. G., Powell, R. B., Stern, M. J., & Garst, B. A. (2020). Influence of the natural setting on environmental education outcomes. *Environmental Education Research*, 26(5), 613–631. <https://doi.org/10.1080/13504622.2020.1738346>
- Dewey, J. 1938. The determination of ultimate values or aims through antecedent or a priori speculation or through pragmatic or empirical inquiry. *Teachers College Record*, 39(10), 471-485
- Fick, S.J. (2018). What does three-dimensional teaching and learning look like?: Examining the potential for crosscutting concepts to support the development of science knowledge. *Science Education*, 102(1), 5-35.
- Fiorella, L., & Mayer, R. E. (2016). Eight Ways to Promote Generative Learning. *Educational Psychology Review*, 28(4), 717–741. <https://doi.org/10.1007/s10648-015-9348-9>
- Fisher, M. C., & Garner, T. W. J. (2020). Chytrid fungi and global amphibian declines. *Nature Reviews Microbiology*, 18(6), 332–343. <https://doi.org/10.1038/s41579-020-0335-x>
- Friese, S. (2019). Qualitative data analysis with ATLAS. ti. *Qualitative data analysis with ATLAS. ti*, 1-344.
- Glasson, G. E., Frykholm, J. A., Mhango, N. A., & Phiri, A. D. (2006). Understanding the earth systems of Malawi: Ecological sustainability, culture, and place-based education. *Science Education*, 90(4), 660–680. <https://doi.org/10.1002/sce.20148>
- Green, D. M., Lannoo, M. J., Lesbarrères, D., & Muths, E. (2020). Amphibian Population Declines: 30 Years of Progress in Confronting a Complex Problem. *Herpetologica*, 76(2), 97. <https://doi.org/10.1655/0018-0831-76.2.97>
- Hand, B., Chen, Y. C., & Suh, J. K. (2021). Does a knowledge generation approach to learning benefit students? A systematic review of research on the science writing heuristic approach. *Educational Psychology Review*, 33(2), 535-577

- Handrianto, C., & Rahman, M. A. (2018). *Project based learning: a review of literature on its outcomes and implementation issues. LET: Linguistics, Literature and English Teaching Journal*, 8(2), 110-129
- Henter, H. J., Imondi, R., James, K., Spencer, D., & Steinke, D. (2016). DNA barcoding in diverse educational settings: Five case studies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1702), 20150340. <https://doi.org/10.1098/rstb.2015.0340>
- Hmelo-Silver, C.E., Duncan, R.G., & Chinn, C.A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark. (2006). *Educational Psychologist*, 42(2), 99-107
- Houseal, A.K. (2016). A visual representation of three-dimensional learning: A model for understanding the power of the framework and the NGSS. *The Electronic Journal for Research in Science & Mathematics Education*, 20(9), 1-7
- Inouye, M., Houseal, A., & Gunshenan, C. (2020). Beyond the Hook: What is a phenomenon and how is it used? *The Science Teacher*, 87(9), 59-63.
- Jaramillo, J.A. (1996). Vygotsky's sociocultural theory and contribution to the development of constructivist curricula. *Education*, 117(1), 133-141.
- Jenkins, L. L. (2011). Using citizen science beyond teaching science content: A strategy for making science relevant to students' lives. *Cultural Studies of Science Education*, 6(2), 501–508. <https://doi.org/10.1007/s11422-010-9304-4>
- Jonassen, D.H., & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational Technology Research and Development*, 47(1), 61-79.
- Kaplan, J.S. (2002). A journey towards self-understanding: Reflections on a teacher educators' methodology. *Making a difference in teacher education through self-study*, 31
- König, H. J., Kiffner, C., Kramer-Schadt, S., Fürst, C., Keuling, O., & Ford, A. T. (2020). Human–wildlife coexistence in a changing world. *Conservation Biology*, 34(4), 786–794. <https://doi.org/10.1111/cobi.13513>
- Kuzmik, J. J., & Bloom, L. R. (2008). "Split at the roots": Epistemological and ontological challenges/tensions/possibilities and the methodology of self-study research. In M. L. Heston, D. L. Tidwell, K. K. East, & L. M. Fitzgerald (Eds.), *Pathways to change in teacher education: Dialogue, diversity and self-study. Proceedings of the Seventh International Conference on Self-Study of Teacher Education Practices*, Herstmonceux Castle, East Sussex, England (pp. 207-212). Cedar Falls, IA: University of Northern Iowa.

- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.
- Lin Hunter, D. E., Newman, G. J., & Balgopal, M. M. (2023). What's in a name? The paradox of citizen science and community science. *Frontiers in Ecology and the Environment*, 21(5), 244–250. <https://doi.org/10.1002/fee.2635>
- Martinez-Maldonado, R., Kay, J. & Yacef, K. (2012). Analysing knowledge generation and acquisition from individual and face-to-face collaborative concept mapping. In A.J. Canas, J.D. Novak, J. Vanhear, editors, *Concept Maps: Theory, Methodology, Technology Proc. of the Fifth Int. Conference on Concept Mapping* (pp. 17–24)
- McGuirk T. (2014). Drawing as situated knowing. In Almeida P. L., Duarte M. B., Barbosa J. T. (Eds.), *Drawing in the university today* (pp. 297–304). Research Institute in Art, Design and Society (I2ADS), Faculty of Fine Arts, University of Porto.
- Meadows, A. (2011). Wildlife Conservation Education and Programmes. *The Journal of Animal and Plant Sciences*, 21, 305-316
- Merritt, J., Lee, M. Y., Rillero, P., & Kinach, B. M. (2017). Problem-Based Learning in K–8 Mathematics and Science Education: A Literature Review. *Interdisciplinary Journal of Problem-Based Learning*, 11(2). <https://doi.org/10.7771/1541-5015.1674>
- National Research Council (NRC). 2007. Taking Science to School: Learning and Teaching Science in Grades K-8. Committee on Science Learning, Kindergarten Through Eighth Grade. Washington, DC: The National Academies Press.
- National Research Council (NRC). 2012. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>
- National Research Council. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/18290>.
- Nespor, J. (2008). Education and place: a review essay. *Educational Theory*, 58(4), 475–489. <https://doi.org/10.1111/j.1741-5446.2008.00301.x>
- Next Generation Science Storylines (2016). How does light help me see things and communicate with others [v1.1]. <https://www.nextgenstorylines.org/what-are-storylines>. Retrieved on May 1, 2024.
- Newman, M. J. (2005). Problem Based Learning: An Introduction and Overview of the Key Features of the Approach. *Journal of Veterinary Medical Education*, 32(1), 12–20. <https://doi.org/10.3138/jvme.32.1.12>

- NGSS Lead States. 2013. Next Generation Science Standards: For states, by states. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.
- NGSS For States, By States (2016). Phenomena. Creative Commons Attribution 3.0 Unported License. <https://www.nextgenscience.org/resources/phenomena>
- Nordine, J., Krajcik, J., Fortus, D., & Neumann, K. (2019). Using Storylines to Support Three-Dimensional Learning in Project-Based Science. *Science Scope*, 42(6), 86–92. https://doi.org/10.2505/4/ss19_042_06_86
- Ovens, A., & Garbett, D. (2020). Weaving self-studies through journaling: A systematic review. In C. Edge, A. Cameron-Standerford, and B. Bergh (Eds.), *Textiles and tapestries: Self-study for envisioning new ways of knowing* (pp. 332-341). Equity Press
- Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment*, 10(6), 314–317. <https://doi.org/10.1890/120007>
- Pinnegar, S. & Hamilton, M. L. (2009). Self-study of practice as a genre of qualitative research: Theory, methodology, and practice. Springer.
- Redpath, S. M., Bhatia, S., & Young, J. (2015). Tilting at wildlife: Reconsidering human–wildlife conflict. *Oryx*, 49(2), 222–225. <https://doi.org/10.1017/S0030605314000799>
- Richards, A. H., Ercan-Dursun, J., Suh, J. K., Hand, B., & Fulmer, G. (2023). Anchoring phenomena and summary writing working together to improve student learning. *Science Activities*, 60(2), 51–57. <https://doi.org/10.1080/00368121.2023.2168242>
- Roberts, T.G. (2003). An interpretation of Dewey’s Experiential Learning Theory. Retrieved from <http://eric.ed.gov/?id=ED481922>
- Roelofs, E., & Terwel, J. (1999). Constructivism and authentic pedagogy: State of the art and recent developments in the Dutch national curriculum in secondary education. *Journal of Curriculum Studies*, 31(2), 201–227. <https://doi.org/10.1080/002202799183232>
- Saldaña, J. (2021). *The coding manual for qualitative researchers* (4th ed.). Sage.
- Santos, H. P., Black, A. M., & Sandelowski, M. (2015).
- Schmidt, H. G., Rotgans, J. I., & Yew, E. H. (2011). The process of problem-based learning: what works and why. *Medical education*, 45(8), 792-806
- Seethaler, S., Evans, J. H., Gere, C., & Rajagopalan, R. M. (2019). Science, values, and science communication: competencies for pushing beyond the deficit model. *Science Communication*, 41(3), 378-388

- Simis, M. J., Madden, H., Cacciatore, M. A., & Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication?. *Public understanding of science*, 25(4), 400-414
- Sinoradzki, K., & McKenna, T. J. (2021). Start With Phenomena: What's So Phenomenal About Animals?. *Science and Children*, 58(6), 86-90
- Soanes, K., Cranney, K., Dade, M. C., Edwards, A. M., Palavalli-Nettimi, R., & Doherty, T. S. (2020). How to work with children and animals: A guide for school-based citizen science in wildlife research. *Austral Ecology*, 45(1), 3–14. <https://doi.org/10.1111/aec.12836>
- Smith, G., & Sobel, D. (2010). Bring it on home. *Educational Leadership*, 68(1), 38-43
- Sobel, D. (2004). Place-based education: Connecting classroom and community. *Nature and listening*, 4(1); 1-7.
- Sterrett, S. C., Katz, R. A., Fields, W. R., & Campbell Grant, E. H. (2019). The contribution of road-based citizen science to the conservation of pond-breeding amphibians. *Journal of Applied Ecology*, 56(4), 988–995. <https://doi.org/10.1111/1365-2664.13330>
- Strand, K.J., Cutforth, N., Stoecker, R., Marullo, S., & Donohue, P. (2003). *Community-Based Research and Higher Education: Principles and Practices*. San Francisco, CA: Jossey-Bass Publishers.
- Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L., & Waller, R. W. (2004). Status and Trends of Amphibian Declines and Extinctions Worldwide. *Science*, 306(5702), 1783–1786. <https://doi.org/10.1126/science.1103538>
- Touitou, I., Schnedir, B., Krajcik, J. (2020). Incorporating Mathematical Thinking and Engineering Design into High School STEM Physics: A Case Study. In: Anderson, J., Li, Y. (eds) *Integrated Approaches to STEM Education. Advances in STEM Education*. Springer, Cham. https://doi.org/10.1007/978-3-030-52229-2_17
- University of Wyoming, Biodiversity Institute. (2024). Laramie Salamander Migration Initiative. <https://www.wyomingbiodiversity.org/index.php/community-science/laramie-salamander-migration-initiative>
- Vanassche, E., & Kelchtermans, G. (2015). The state of the art in Self-Study of Teacher Education Practices: A systematic literature review. *Journal of Curriculum Studies*, 47(4), 508–528. <https://doi.org/10.1080/00220272.2014.995712>
- Vygotsky, L.S. ([1933] 1978). In L.C. Moll, (ed.) *Vygotsky and education: Instructional implications and applications of sociohistorical psychology*. New York, NY: Cambridge University Press.

- Watson, J. (2001). Social constructivism in the classroom. *Support for Learning*, 16(3), 140–147. <https://doi.org/10.1111/1467-9604.00206>
- Wijnia, L., Loyens, S. M. M., & Rikers, R. M. J. P. (2019). The Problem-Based Learning Process: An Overview of Different Models. In M. Moallem, W. Hung, & N. Dabbagh (Eds.), *The Wiley Handbook of Problem-Based Learning* (1st ed., pp. 273–295). Wiley. <https://doi.org/10.1002/9781119173243.ch12>
- Wilder, S. (2015). Impact of problem-based learning on academic achievement in high school: A systematic review. *Educational Review*, 67(4), 414–435. <https://doi.org/10.1080/00131911.2014.974511>
- Williams, M., & Houseal, A. (2018). COMPOSTING: A Problem, Place, or Project? Using the PBL Trifecta (PBL³) in the Classroom. *Science Scope*, 41(6), 36-44
- Wright, D. S., Crooks, K. R., Hunter, D. O., Krumm, C. E., & Balgopal, M. M. (2021). Middle school science teachers' agency to implement place-based education curricula about local wildlife. *Environmental Education Research*, 27(10), 1519–1537. <https://doi.org/10.1080/13504622.2021.1960955>
- Wyoming Game & Fish Department. (2017). State Wildlife Action Plan 2017. <https://wgfd.wyo.gov/WGFD/media/content/PDF/Wildlife/State-Wildlife-Action-Plan-2017.pdf>
- Yemini, M., Engel, L., & Ben Simon, A. (2023). Place-based education – a systematic review of literature. *Educational Review*, 1–21. <https://doi.org/10.1080/00131911.2023.2177260>
- Yew, E. H., & Goh, K. (2016). Problem-based learning: An overview of its process and impact on learning. *Health professions education*, 2(2), 75-79
- Zheng, L., Tong, Z., Ma, C., Wang, F., Li, M., Yang, B., & Sun, Y. (2022). Effects of labeling on wildlife conservation education. *Global Ecology and Conservation*, 33, e01997. <https://doi.org/10.1016/j.gecco.2021.e01997>

Appendix 1

Appendix 1. The spreadsheet of my journal showing the questions and categories I recorded through my journal entries

	A	B	C	D	E	F	G	H	I	J	K
1	Day	What am I doing today?	How is it helping with this project?	How do I feel?	Frustration	Satisfaction	Confidence	Knowledge	What new questions do I have?	Which resources do I need?	What will I do tomorrow?
2											
3											
4											
5											

Appendix 2 Guide Overview

How to create anchoring phenomenon - based curriculum resources within the biodiversity context?

For a digital copy of the guide please email me to salkalex97@gmail.com