Understanding Ontario Elementary Teachers' Experience Of Interdisciplinary Education Through An Integrative Lens

Linh Hoang

Thesis submitted to the University of Ottawa

in partial Fulfillment of the requirements

for the degree of

Master of Arts in Education

Faculty of Education

University of Ottawa

Abstract

Interdisciplinary education equips young minds with the critical, multi-perspective, and global thinking needed to tackle the vast challenges of the modern world. In Ontario, while the Ministry of Education encourages interdisciplinary education, it lacks clear implementation guidelines and has made budget cuts resulting in the cancellation of many long-standing interdisciplinary programs. This study uses a qualitative approach with a reflexive thematic analysis method to investigate how five elementary Ontario teachers understand and practice interdisciplinary teaching and learning in their classrooms. The study is framed by sociocultural learning theory, using Mansilla's (2017) pragmatic-constructionist interdisciplinary learning model as the analytic lens through which to understand the nature and process of interdisciplinary integration.

The findings reveal that participants initiated interdisciplinary education with a focus on students' interests and learning, placing less emphasis on strict adherence to the curriculum. They employed diverse teaching methods, known to facilitate interdisciplinary learning. Consequently, interdisciplinarity emerged organically from student interest and learning; yet it also ultimately enabled teachers to meet curriculum standards. This contradicts curriculum integration literature, which emphasizes the need to develop interdisciplinary units by carefully integrating multiple subjects' contents and purposefully connecting curriculum standards. This literature assumes that starting this way, with planned interdisciplinary units, will lead to effective teaching and learning. By contrast, this study indicates that focusing first on authentic, effective teaching and learning is what fosters interdisciplinarity in elementary schools. The study suggests reassessing curriculum integration frameworks in the direction of more emergent frameworks such as Mansilla's (2017).

Acknowledgement

First and foremost, I extend my heartfelt gratitude to the participants of this study. Your passion for teaching, your dedication to your students, and your willingness to share your inspiring stories have been the cornerstone of this research. Without your contributions and trust, this work would not have been possible. Thank you for allowing me to learn from your experiences and for your tireless devotion to the field of education.

I wish to express my deepest gratitude to Dr. Angus McMurtry, for your consistent encouragement and open-mindedness throughout this journey. Your steady guidance empowered me with confidence, while your deep insights into the nuances of the research process enriched my learning experience profoundly.

I am immensely grateful to Dr. Barbara Graves, a member of my thesis committee, for your invaluable wisdom and insights. You have been a constant source of inspiration, holding me to the highest standards while your steadfast support made me feel empowered throughout my research.

Special thanks are due to Dr. Tasha-Ann Ausman, a member of my thesis committee, for your critical perspective and deep engagement with my work. Your encouragement to push boundaries and your support in fostering deep analytical thinking have been crucial in shaping this thesis.

I am profoundly thankful to my family. To my parents, who have always been there for me, offering a listening ear and taking a keen interest in my studies. To my husband, thank you for being my rock, believing in me, and providing unwavering support. To my daughters, your grace and understanding in allowing me the space and time to focus on my work have been deeply appreciated.

Finally, I extend my deep appreciation to all those who have supported me in various capacities throughout this academic endeavor. And lastly, I want to acknowledge myself for persevering through one of the most challenging endeavors I have undertaken.

Table of content

List of Tables and Figures

List of figures

List of tables

Chapter One: Introduction

Purpose of the Study. The objective of this study is to investigate how self-identified interdisciplinary elementary teachers in Ontario understand and practice interdisciplinary teaching and learning in their classrooms. By exploring the lived experience of teachers, I seek to identify possible pathways for enacting interdisciplinary education and addressing current reported challenges to such approaches.

Significance of the Study. This investigation holds significance due to the lack of clear guidelines, resources, and understanding of integrated educational approaches in Ontario, despite widespread calls from policymakers and scholars. The study contributes to the literature in several ways. First, it deepens our understanding of how teachers enact interdisciplinary education, particularly addressing the relatively limited empirical literature on this topic in Ontario, Canada. Second, it pioneers connections between disparate discourses regarding interdisciplinary education at the K-12 level, bridging scholarship on interdisciplinary studies and curriculum integration through the lens of progressive education and sociocultural learning. Last, it proposes pathways to support stakeholders, including teacher educators, school administrators, teachers, and scholars of interdisciplinary education, in advancing the enactment of interdisciplinary education in the classroom.

Context of the Study. Education policymakers call for an interdisciplinary approach to education in the face of increasing pressure from society to help young people develop the competencies and dispositions needed to navigate in today's complex world. The OECD (2020) report, *Curriculum Overload: A Way Forward*, suggests introducing "connecting topics/ themes or competencies across learning areas" to "reinforce content and deep learning" and combat the problem of learning that is "mile-wide, inch-deep" (p. 7). In Ontario, the provincial curriculum

statement encourages an integrated approach, which is defined as "working towards meeting expectations from two or more subjects within a single unit, lesson, or activity," to provide students with "a rich learning experience that helps them make connections across subjects and brings the learning to life" (Government of Ontario, 2024, para. 1).

Numerous scholars advocate for an interdisciplinary approach to K-12 education, claiming that it is conducive to deep learning and equips students with global competencies to tackle complex, real-world problems (Beane, 1995; Lenoir & Hasni, 2016; Mansilla, 2017). Empirical studies indicate that interdisciplinary education positively impacts student engagement, student grades, students' attitude toward mathematics, students' understanding of the interconnectedness of subjects, and students' higher-order thinking (Kokko et al., 2015; Le et al., 2023; Spintzyk et al., 2016; Yeşilkaya et al., 2021).

Despite its potential benefits, studies on interdisciplinary education in Ontario remain limited. Slomka (2019) reports that a lack of clear guidelines for the curriculum development, assessment, and teaching of interdisciplinary science courses in Ontario leads to ineffective implementation. Clausen & Drake (2010) identify several exemplary interdisciplinary programs in Ontario but they "were rarely heralded and quietly existed" (p. 98). Programs of significance include environmental studies programs such as the Bronte Creek Project at the Halton District School Board, global education programs such as the semester abroad program at the Simcoe District School Board, the intermediate-level interdisciplinary planning initiative at the Blue Water District School Board, themed elementary programs at Bishop Strachan School, and the double-credit block program, where students can choose among five interdisciplinary combinations, at Toronto District Christian High School (p. 98-99). Unfortunately, many environmental studies programs in Ontario, such as the Bronte Creek Project, have been

canceled due to financial constraints (Bronte Creek Project, 2023). Recently, McKillop (2023), one of the original founders of the Bronte Creek Project, published a book chapter to document the history, philosophy, and operations of the program. However, he asserts that the program has never been studied formally (p. 277). Similarly, very limited academic research can be found on other programs. While several studies on interdisciplinary practices exist in Quebec (Hasni & Lenoir, 2015; Lenoir et al., 2000; Lenoir, 2010), systematic exploration of interdisciplinary education in Ontario is lacking.

I will employ a qualitative approach, using interviews with teachers as the primary data, and a reflexive thematic analysis method to explore how Ontario elementary teachers conceptualize and implement interdisciplinary teaching and learning in their classrooms. I will unpack the teachers' beliefs, their pedagogical strategies, and their social and personal contexts to understand how they make decisions regarding interdisciplinary practices and which factors enable their decisions. Findings can contribute much-needed insights into the state of interdisciplinary education in Ontario.

Positionality. I grew up in a rapidly expanding urban environment in Vietnam, shaped by a neoliberal mindset that views education as a means to economic gain and power. In this context, a pervasive culture of performativity dominates Vietnamese schooling, where the emphasis is on preparing for tests to progress to higher levels. While this approach has produced students who excel in exams and possess strong theoretical disciplinary knowledge, the limitations of the Vietnamese education system become apparent as college graduates fall behind their Southeast Asian counterparts by large measures. Statistically, Vietnam's labor productivity is among the lowest in Southeast Asia (Le et al., 2023). Having worked extensively with college graduates from Vietnam as well as regional peers like Thailand and Indonesia, I realize that our

college graduates lag in critical thinking, communications, problem-solving skills, as well as the ability to apply knowledge in real situations – such as using mathematical, literacy, and social studies skills to design a market research survey.

I have experienced the Vietnamese education system as a student, a professional, and a parent. I believe the problem of our workforce stems from as early as our basic education, where students are stripped of the opportunity to engage in learning that connects to their lives, subjects are taught in silos, and students rarely experience how disciplines might come together to solve complex problems. The study I am undertaking aligns with my beliefs about the importance of fostering genuine and meaningful education, preparing students to integrate diverse knowledge sources into "coherent wholes" to address complex cultural and environmental challenges.

I have chosen to conduct the study in Ontario as I am pursuing my research career here and my children are currently enrolled in the Ontario education system. Additionally, I wish to add a fresh perspective to my professional educational experience, which has primarily been situated in Vietnam. I believe that the insights gained through this research will not only contribute to the understanding of interdisciplinary education in Ontario but also help inform my broader perspective about potential solutions to challenges in Vietnamese education.

Chapter Two: Literature Review

The literature review is organized into three sections. The first part reviews theoretical developments in interdisciplinary education scholarship, outlining three trajectories pursued by researchers to provide possible frameworks for understanding interdisciplinary educators' experiences. The second section examines the enactment of interdisciplinary education, discussing empirical studies on classroom practices of in-service as well as pre-service teachers. This research body encompasses concepts such as integrated curriculum, interdisciplinary studies, and related approaches such as STEM, inquiry-based, and project-based learning. This section enables me to assess the alignment or divergence of participants' experiences from existing empirical evidence. The last section offers an overview of the historical evolution of interdisciplinary education in North America and Ontario in particular, along with a review of several empirical studies on interdisciplinary education conducted in the region. This section provides the context for my study and helps identify gaps in the literature.

Theories of Interdisciplinary Education

Theories of interdisciplinary education at the K-12 level have evolved along three major paths. One popular model is Jantsch's (1972) hierarchy of typologies, from multi-, pluri-, cross-, inter-, to trans-disciplinary education (as cited in Newell, 2013). Various typology models were further introduced by curriculum design experts at the K-12 level (Brandt, 1991; Drake & Reid, 2019, 2020; Fogarty 1991; Jacobs, 1989, 1998; Perkins-Gough, 2003). Scholars and practitioners often refer to this approach under the name curriculum integration. To understand the curriculum integration approach, examples will be helpful. In multidisciplinarity, subjects are taught separately, around a common theme, usually at topical level such as "Water" or "The

Renaissance." In interdisciplinarity, subjects are connected more explicitly and strongly, also around common themes but usually at a more conceptual level such as "Sustainability" or "Identity." In transdisciplinarity, subjects are no longer the driver, and students start with examining an "authentic real-world" issue or problem and call upon appropriate subjects to help achieve the learning goal (Drake & Reid, 2020, p. 2). One critique of a spectrum-oriented approach is that it could lead administrators and practitioners to believe that merely rearranging departments or restructuring the curriculum can promote integration. Organizational and curricular changes alone are not enough; true integration also requires shifts in mindset and cognitive practices (Newell, 2013). Nevertheless, the goal of achieving "real" curriculum integration has prompted numerous efforts from curriculum experts. They have developed various tools and frameworks to assist teachers in designing robust, interdisciplinary units. For instance, one framework employed in some teacher colleges is the concept-based curriculum and instruction (Erickson et al., 2017; see also Dack, 2020; Moser et al., 2019). This approach introduces knowledge structure, distinguishing between the conceptual-level and topical-level knowledge. It promotes the "integration of thinking" as well as "the transfer of learning" (Erickson et al., 2017, pp. 15-17). Integration of thinking "can occur in inter- or intradisciplinary contexts" and refers to "conceptual understandings that transfer through time, across cultures, or across examples" (pp. 15-17). An example of transfer of learning is "using one's knowledge of how electrical systems work to facilitate an understanding of the network of arteries and veins in the circulatory system" (pp. 15-17).

Another path saw integration, rooted in John Dewey's ideas of authentic, experiential learning, materialize through initiatives such as the Middle School movement, with James Beane a notable advocate. Critical of the typology model where merely teaching separate subjects

around a shared theme is called curriculum integration, Beane conceptualized “real” curriculum integration as promoting personal and social cohesion through a curriculum structured around real-world issues without regard for subject-area boundaries (Beane, 1995; Beane, 1997 as cited in Harrison et al., 2020, 2005, 2007). The Middle School movement placed integrating “life” into the curriculum as a defining factor, moving away from the Junior High model which focused on cognitive development within distinct subject areas. Instead, it centered on students’ affective and cognitive development, utilizing an integrative curriculum implemented by interdisciplinary teams of educators (Harrison et al., 2020).

A third, major trajectory aimed to establish a broader definition of interdisciplinarity. It expands beyond education to any professional and research contexts that deal with complex issues requiring expertise from various disciplines. Early definitions emphasized the integration of insights from two or more disciplines (Mayville, 1978; McGrath, 1979; Newell & Green, 1982 as cited in Newell, 2013). Klein & Newell (1997) expanded this definition to describe interdisciplinary studies as a cognitive process, aimed at solving complex, multifaceted problems, and often resulting in multi-perspective outcomes. Today, scholars belonging to this trajectory concur on many of the key attributes of interdisciplinary education. It should serve a specific purpose, usually centered around solving broad and complex issues. It must be firmly rooted in disciplinary knowledge. Integration, which may take the form of metaphors, analysis, synthesis, and complex explanations (to name a few), is an integral part. Finally, it should help advance understanding and create new knowledge, potentially yielding creative products, innovations, or fresh theories (Mansilla 2017; Newell, 2013; see also Leonard, 2012; Repko, 2007).

The Enactment of Interdisciplinary Education

Just as interdisciplinary studies encompass a wide range of theoretical models, empirical studies on interdisciplinary education employ a variety of practical frameworks. These include the STEM approach (Deniz et al., 2019; Johnson et al., 2021; Sevimli & Ünal, 2022; Županec et al., 2023), problem or project-based inquiry approach (Goovaerts et al., 2019; Morrison et al., 2021; Weinberg & Sample McMeeking, 2017), concept-based learning and instruction (Dack, 2020; Moser et al., 2019), teachers' knowledge (Niemelä, 2022; Niemelä and Tirri, 2018; Ryu et al., 2019), curriculum integration (Applebee et al., 2007; Gero, 2017), team teaching and community of practice (Hardré et al., 2013; Kodkanon et al., 2018).

These studies also explore a range of topics within interdisciplinary education. Some focus on student outcomes, reporting that the interdisciplinary approach leads to a positive attitude toward mathematics (Kokko et al., 2015), higher grades and improved self-efficacy (Yeşilkaya et al., 2021), growth in knowledge (Spintzyk et al., 2016), improved quality and retention of understanding (Županec et al., 2023), and increased higher-order thinking and career interest (Le et al., 2023). Other studies focus on the teacher's enactment of interdisciplinary learning. These studies find conditions favorable to integration, including student-centered and authentic pedagogy (Kodkanon et al., 2018; Morrison et al., 2021), supportive student-teacher and teacher-teacher relationships (Hardré et al., 2013; Kodkanon et al., 2018; Morrison et al., 2021), and flexibility and a willingness to embrace ambiguity (Applebee et al., 2007).

The studies also highlight challenges that could inhibit the effectiveness of interdisciplinary education. First, there are the structural boundaries placed around teachers, including the need for curriculum coverage, fragmented school schedule and timetable, lack of time, and lack of support and training (Applebee et al., 2007; Gürkan, 2018; Weinberg & Sample

McMeeking, 2017). Second, a recurring challenge reported by teachers is the difficulty of integrating subjects and finding connections between them (Braskén & Pörn, 2021; Cassidy & Puttick, 2022; Goovaerts et al., 2019; Moser et al., 2019; Sevimli & Ünal, 2022). Some studies mentioned the need to help teachers develop a specific type of knowledge known as integrative or interdisciplinary pedagogical content knowledge (Niemelä and Tirri, 2018; Weinberg & Sample McMeeking, 2017).

Niemelä and Tirri (2018) propose that effective interdisciplinary education requires teachers to have adequate content knowledge, pedagogical approaches suited to all the disciplines involved, and a broad enough curriculum knowledge to establish connections with prior or future knowledge. They recommend that teacher education programs should offer first-hand experience through interdisciplinary courses, explicitly teach how to build "conceptual bridges" between subjects in method courses, and develop a rich database of reference materials to demonstrate these "conceptual" connections (Niemelä and Tirri, 2018). Multiple studies show that preservice teachers feel inadequately prepared for interdisciplinary teaching – feeling the lack of a disciplinary knowledge base (Ryu et al., 2019), role models (Ryu et al., 2019), and, repeatedly, finding it difficult to identify interdisciplinary connections between and within subjects (Moser et al., 2019; Johnson et al., 2021; Ryu et al., 2019). Studies report that effective teacher education programs are able to demonstrate how to construct shared conceptual understandings and forge meaningful connections between subjects (Dack 2020).

Mirroring theoretical research, empirical studies at the K-12 level also highlight the issue of integration, reporting teachers' challenges in integrating subjects and building connections among disciplines. However, very few studies employ theoretical advancements in interdisciplinary studies that examine integrative strategies in depth, as discussed in the third

trajectory. Understanding teachers' interdisciplinary work through this lens could be illuminating.

Interdisciplinary Education in Ontario

Integrated and interdisciplinary education has a long history in North American education. In the United States, integrated learning in the formal schooling context took shape during the 1930s in the Progressive Era, led by prominent figures such as John Dewey. This period emphasized child-centered learning, where education should be authentic and help children integrate what they learn in school and their lives outside. After this period, integrated learning became marginalized. At times, practical courses such as home economics and communications were labeled as interdisciplinary but often did not integrate very deeply. From the 1950s to 1990s, socio-political events such as the space race, the economic race, and globalization, shifted the focus to standardization, achievement, and accountability, which now define our schooling. Despite this shift, some educators held on to the integrated tradition of the Progressive Era, albeit on a smaller scale. Currently, it is increasingly recognized that interdisciplinary approaches are required in preparing a new generation of learners to face complex global issues such as environmental disruptions, technological transformations, and global migration (Mansilla & Lenoir, 2010).

Ontario is influenced by trends across Canada and the United States. Interdisciplinary practices in Ontario are characterized by a rather rapid pace of pendulum swing between accountability and authenticity, mirroring the pace of change of political parties in power. A notable moment of progressive education occurred during 1967-1974 when broad areas of study with “melted subject boundaries” were introduced, teachers were encouraged to work in teams,

and students were viewed as co-collaborators in planning. Recent decades witnessed a more balanced approach, valuing accountability and rigor while introducing specific interdisciplinary programs such as environmental education (Clausen & Drake, 2010). However, the swings, typically occurring in short periods of five to ten years, mostly stayed at the policy level. Teachers and practitioners found it challenging to adapt to the frequent shifts, and instead often resorted to practices influenced by peers and supported by their local schools (Clausen 2001). Similar to the United States, interdisciplinary efforts in Ontario remained sporadic and dependent on individual teachers (Clausen & Drake, 2010).

To locate studies on interdisciplinary education in Ontario, I employ search terms such as "interdisciplinary education," "interdisciplinary teaching," "interdisciplinary learning," "integrated curriculum," "integrated learning," and "curriculum integration." Of the eleven studies I found, five examine interdisciplinary education at the high school level (G9-12) in Ontario. McKillop (2023) describes the Bronte Creek Project, an interdisciplinary outdoor education program from 1981 to 2019, noted for its testimonials but lacking formal outcome studies. Matheson et al. (2020) highlights how reorienting to transdisciplinary, student-led learning significantly enhanced experiences in personal finance education. Valkova (2017) reports that students consistently view the Outdoor ICP program as positive and impactful even after graduation. Jacobs et al. (2015) detail the Dandelion Evolution Outreach Program, which successfully engaged Grade 11 students in inquiry-based evolution learning. Slomka (2019) analyzes Ontario's curriculum documents and finds they lack clear guidelines on implementing interdisciplinary science models for Grades 11-12.

Four studies focus on interdisciplinary education at the elementary level (G1-8). Docherty-Skippen et al. (2020) find that hands-on, inquiry-based science and technology

education boosts pre-service teachers' confidence in teaching these subjects. Clausen (2001) reveals that Ontario's education system sees curriculum integration, especially at the Grade 7-8 level, as a luxury. Ryan (2021) highlights ample opportunities for problem-based learning in Ontario's new primary Health and PE curriculum. Lepone (2016) examines Ontario's 2006 Language curriculum, noting that while it does not explicitly state Drake and Beane's integration approaches, it reflects similar methods and aligns with Beane's desired student outcomes.

Lastly, two studies address interdisciplinary education at the kindergarten level. McLennan (2019) describes using the number talks approach to engage kindergarteners in joyful and flexible math learning. Macdonald & Breunig (2018) explore student experiences in an outdoor, inquiry-based schoolyard pedagogy, highlighting student-led activities, outdoor lessons, and challenges to learning.

Most of these studies explore interdisciplinary education under the lens of curriculum integration, especially utilizing the curriculum spectrum categorization. None of them uses interdisciplinary theories situated in the third trajectory, as perhaps this theoretical stream has been more geared towards higher education and beyond. As well, the experiences of in-service teachers are underrepresented in these studies. Of the 11 studies, three studies specifically examined teachers' experiences. However, one focuses more on students' experiences (Matheson et al., 2020), one examines pre-service teachers (Docherty-Skippen et al., 2020), and one was conducted more than 20 years ago and is in need of updates (Clausen, 2001).

This study aims to contribute to the literature in two ways. First, it uses an analytical framework that is rooted in the third trajectory as described in the *Theories of interdisciplinary education* section, centering on understanding the integration process to advance understanding (Mansilla, 2006, 2017; Nikitina, 2006; Nikitina & Mansilla, 2003; Klein & Newell, 1997). While

many empirical studies acknowledge integration as a challenge, very few of them employ interdisciplinary frameworks that use integration as the primary analytical lens. Second, this study focuses on Ontario elementary teachers and seeks to contribute insights to the limited literature on their experiences with interdisciplinary education.

Chapter Three: Research Questions

The overarching research questions of this study are:

1. **How do self-identified interdisciplinary elementary teachers in Ontario understand and practice interdisciplinary education?**
2. **What is the nature and process of interdisciplinary integration in these teachers' practices?**

Self-identified interdisciplinary teachers are teachers who self-identify as teaching or having taught courses or content that deal with complex issues requiring knowledge and insights from two or more disciplines. The first question examined how teachers define interdisciplinary education and delved into their pedagogical strategies, their growth and learning process with respect to interdisciplinary practices. It also examined numerous samples of interdisciplinary lessons to determine what type of practices best foster interdisciplinary learning.

The second question investigated the process through which the participant teachers were able to enact interdisciplinary integration in their classroom. I sought to understand the nature of this integration, including what type of cognitive or knowing transformation took place, as well as how it happened.

Chapter Four: Theoretical Framework

To answer my research questions, I adopt a sociocultural lens as the overarching theoretical framework to understand the teachers' experiences. Additionally, I use Mansilla's (2017) interdisciplinary learning framework, a development belonging in the third theoretical trajectory, as the lens to understand the interdisciplinary learning process and the nature of interdisciplinary integration.

Sociocultural theory's most important contribution is how learning is always social and development is rooted in social activities. Vygotsky (1978) suggests,

> Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formulation of concepts. All the higher functions originate as actual relations between human individuals. (p. 57)

This means that learning is nurtured and developed in a social context, where individuals learn through interaction and collaboration (see also Adam, 2006; Davis et al., 2015). More profoundly, it implies that learning occurs in a social context through interaction with a more knowledgeable other, who guides the child until the skill or knowledge is internalized and can be performed independently (Vygotsky, 1978; Wertsch, 2008). Wertsch (2008) describes this progression as starting with direct adult instructions, transitioning to self-guided "self-talk," and eventually leading to automatic, internalized processes—that is, thinking. The process through which an adult helps a child learn by explaining, giving directives, and responding to the child's questions is one form of what Vygotsky called mediation. Vygotsky's students and other

sociocultural researchers, such as Engeström (1987) and Leontiev (1981) (as cited in Hardman & Corte, 2023), and Wertsch (2008), have further developed this notion. Scholars in this field now recognize that our understanding of the world is mediated by not only the people in our social environment but also "psychological and cultural tools" like language, counting systems, mnemonic devices, art, writing, diagrams, maps, and more (Lattuca, 2002, p. 715). These tools shape our meaning-making processes, contributing to what is “learnable, thinkable, and doable” (Davis et al., 2015, p. 134; see also Lattuca, 2002).

The sociocultural lens is suitable for this study because it aligns with interdisciplinary studies in viewing knowledge as a socially constructed tool that evolves through interaction and context, promoting diverse perspectives and dynamic understanding (Lattuca, 2002; McMurtry & McMurtry, 2016; Vygotsky, 1978). Through this lens, I aim to understand how interdisciplinary learning is mediated through classroom interactions among teachers and students, by cultural tools such as classroom set up, language, subjects, and by the contexts in which teachers and students are situated.

To deep dive into the process of interdisciplinary learning and the nature of integration, I use Mansilla’s (2017) pragmatic-constructionist theory of interdisciplinary learning, a theory built on the tradition of interdisciplinary studies, the third theoretical trajectory. This framework focuses on the integrative nature of the interdisciplinary learning process. It asserts that interdisciplinary learning starts with a defined *purpose*, draws upon diverse *disciplinary insights***,** and employs various *integration* techniques or tools (e.g., metaphors, aesthetic interpretations, predictive integrative models), all of which must align with the purpose. Finally, it entails a *critical review and reflection* on the gained understanding. The entire process is *iterative*, with each component influencing and refining the others to achieve a “*reflective equilibrium***,**”

characterized by *coherence*. The model embraces pluralism, is receptive to different disciplinary viewpoints, offers relevant explanations for the learning process, and prioritizes quality (Mansilla, 2017). See Appendix A for the original illustration.

Echoing scholars within the third trajectory who view integration as central to interdisciplinary work (Klein, 1990, 2012, 2013 as cited in Klein, 2018; Newell, 2001; Repko, 2007), Mansilla's (2017) framework prioritizes the cognitive demands of interdisciplinary integration. Mansilla's conception of integration is rooted in insights from Harvard's Project Zero's Interdisciplinary Studies project, which examined exemplary interdisciplinary practices at collegiate, pre-collegiate, and professional levels in the US, with Mansilla as one of the principal investigators (Mansilla, 2006; Nikitina, 2006; Nikitina & Mansilla, 2003; see also deLusé, 2009). According to this body of work, three integrative strategies were identified in interdisciplinary teaching, namely contextualizing, conceptualizing (initially termed essentializing), and problem-centring (Nikitina, 2006; Nikitina & Mansilla, 2003). Contextualizing embeds concepts within historical, cultural, and personal contexts, like exploring evolution through its historical and philosophical significance. Conceptualizing, on the other hand, identifies core concepts that bridge disciplines, for example, linking the concept of change across biology, chemistry, and mathematics. Finally, problem-centring invokes knowledge from various disciplines to tackle real-world issues. The way knowledge is generated differs between these strategies due to their varying epistemic goals. Contextualizing is often seen in humanities programs, conceptualizing is a method used in more science-oriented programs, and problem-centring is found in more applied programs (Nikitina, 2006). However, these are not the only contexts where these strategies can be employed, their use is not strictly confined to specific program types, and

educators can choose an optimal strategy or design hybrid approaches that build on the strength of multiple strategies (Nikitina & Mansilla, 2003).

Building on this groundwork on integrative strategies, Mansilla (2017) later outlines strategies for integration, one of the four iterative components of her proposed model for interdisciplinary learning. These strategies include aesthetic interpretation, comprehensive explanation, predictive integrative models, informative contextualization, and practical problem solving (p. 268).

Applying interdisciplinary learning frameworks, such as Mansilla's (2017), that emphasize integration processes when examining teachers' practices helps to shed light on the nature of integration in their approach. This includes, for instance, how disciplinary insights are drawn upon, the type of integration strategies used, and whether such practices align with their purposes. It should be noted that the purpose is not to critique teachers' knowledge by comparing it to pre-set criteria but rather to deepen understanding of teachers' interdisciplinary practices.

Chapter Five: Methodology

For my study, I have selected a qualitative approach, wherein I seek to understand how my participants "interpret their experiences," how they "construct their worlds," and "what meaning they attribute to their experiences" (Merriam, 2009, pp. 22-24). An epistemology, or theoretical framework, influences the choice of methodology (Carter & Little, 2007). A qualitative research methodology is compatible with my theoretical framework of sociocultural learning. The key epistemological assumption underpinning qualitative research is that knowledge is located and contextual, that our "reality is socially constructed," and that there is no single truth (Merriam, 2009, p. 8; see also Cresswell, 2014, p. 16-18).

Among qualitative research designs, thematic analysis is an "open, exploratory, flexible and iterative" approach (Braun & Clarke, 2019, p. 593). Braun & Clarke's (2019) approach to thematic analysis involves focusing on "meaning and meaning-making," and viewing these as always "context-bound, positioned and situated" (p. 591). In their view, thematic analysis is about "telling stories, interpreting, creating, not discovering the truth" (Braun & Clarke, 2019, p. 591). Furthermore, thematic analysis can also provide a rich and detailed, yet complex account of data (King, 2004, as cited in Nowell et al., 2017). Thematic analysis also proves valuable in exploring the viewpoints of research participants, highlighting similarities and differences, and producing unanticipated insights (Nowell et al., 2017). As my research is an exploratory study that seeks to understand and situate the experiences of teachers, thematic analysis is a suitable choice of method that is internally consistent with sociocultural epistemology as well as a qualitative methodology.

Participants

I was able to recruit five research participants. Table 2 provides the list of participants. The teachers' names have been changed to ensure confidentiality.

Table 1

List of participants

No	Pseudonym	Grades	Teaching role	Experience	School board
1	Allison	K, 4,5	Classroom teacher	18	SB1
2	Finley	Grades 1-6	Specialist teacher, science	10	SB2
3	Sara	Grade 4	Classroom teacher	19	SB3
4	Lynn	K-8	Coach primarily working with K-8 teachers Classroom teacher primarily Grades 7-8	27	SB3
5	Carol	K-8	Classroom teacher primarily Grades 4-6 Teacher librarian supporting K-8 classroom	10	SB1

All participants are teachers in public school boards in Ontario. Allison started her teaching career as an early childhood educator and was heavily influenced by her training in inquiry-based teaching which characterizes kindergarten education in Ontario. She later moved to become a Grade 4 and 5 teacher and continued to apply the inquiry-based approach to her teaching. Allison is passionate and knowledgeable, always looking for materials and resources to serve as provocatives for her students' inquiry. She immediately said "yes" when I extended my invitation to join the research, mentioning that she loves talking about the topic.

Finley has a passion for nature and the sciences. During her university years, she worked at a daycare and discovered that she enjoyed working with children. She became a specialist science teacher to combine her passions. She calls herself the “fun aunt” to her students, who would go to her class to have fun and then return to their homeroom. She has recently stopped teaching to pursue a PhD degree full-time.

Sara has always loved working with children and has had multiple jobs working with youth since she was 12. She described herself as “competitive” in the sense that when she saw teachers doing great work, she wanted to be able to do the same. She loves to travel and learn about other cultures. Every summer, she takes a teaching job in a foreign country to travel and learn about a new culture, then brings this world back to her students in the school year. Currently, besides her full-time teaching job, she coaches sport teams, dance, and robotics. She is a force of nature with a thirst for learning and strives to be better every day.

Lynn in her career has held multiple roles, including classroom teacher, counselor, and a process coach for her school board. Lynn became an educator to “share knowledge with students and to empower them to make changes in our world [...] to let them understand that they can explore whatever it is they are interested in.” Describing herself as a creative person, she centers her teaching on bringing joy back to the classroom.

Carol is passionate in inquiry-based learning and described herself as very “techie” and “creative.” She has developed an expertise in leveraging technology in teaching, and she also designs her own learning materials with a unique art style. She runs an active social media profile and a blog that discusses teaching, shares materials, and acts as a platform to develop collaborations with other teachers.

While the other four teachers have direct experience teaching Grades 1-6 classrooms, Lynn has more experience teaching Grades 7-8. However, as a coach she has designed multiple learning units for Grades 1-6 and works directly with teachers in Grades 1-6 to implement these units. Therefore, her background aligns well with the focus of this study (teaching students in Grades 1-6) and her role as a teacher coach could provide additional valuable insights, enhancing the depth of the research.

Two of my participants are acquaintances with whom I have developed friendships through social connections. Through our conversations, I have gathered that their teaching approach is integrated and interdisciplinary. The other three participants are educators whom I recruited during an education conference in Ontario. All of them were speakers at the conference, and from their sharing, I learned that their approach to teaching is interdisciplinary. I took the initiative to engage them, share details about my research, and invite them to participate.

I encountered challenges when attempting to recruit participants through planned channels such as social media and snowball sampling. Despite reaching approximately 50 individuals through recruitment posters and messages, I received minimal response and ultimately failed to secure any participants. The feedback I received suggested that teachers either were too busy with their existing commitments or lacked interest in participating. It is possible that the term "interdisciplinary education" is unfamiliar to many teachers, and consequently, it failed to evoke the emotional resonance necessary to compel them to share their experiences.

My face-to-face interactions with teachers at the conference provided opportunities to engage with them personally, explain the purpose of my research in greater detail, as well as

connect with the content of their presentations. As a result, participating in the study seemed more relevant and meaningful to them, increasing their willingness to get involved.

Ethical considerations

I submitted an application to the Office of Research Ethics and Integrity at the University of Ottawa and received approval before starting participant recruitment. The consent form, which was approved, allowed participants to decide whether to use their real names or remain anonymous. All participants opted to remain anonymous. To ensure confidentiality, I anonymized all working files, including interview recordings, transcripts, and any participant-related documents, using pseudonyms from the beginning. Before beginning analysis, I removed any personal details such as names, schools, and school boards from the transcripts.

Data Collection

Data collection was done primarily through one-on-one interviews. Teachers also shared artifacts from their classroom with me, to enhance their narratives. For teachers recruited from the conference, I obtained consent to use their utterances and materials (except for pictures of student works) that they shared during their conference sessions. They treated the interview as an extended conversation of our encounters at the conference and sometimes referenced materials or stories shared at the conference to illustrate a point during the interview.

The interview with Allison took place in person, while the other four interviews were conducted virtually. I observed no material difference between the two modalities, perhaps because I already met all participants in person prior to the interviews. The interviews were recorded using Microsoft Teams and transcribed using Microsoft Word Online.

Analysis

The method I chose was thematic analysis based on Braun and Clarke's framework (2006). The first step was to become familiar with the data. After obtaining the transcript, I played the recording while going through the transcripts and took notes of my first thoughts while listening.

The second step was to generate initial codes. The transcripts were imported for coding in NVivo software. Coding was done primarily in a semantic way. This means I went through each transcript line by line, and coded any item I thought was significant at the surface-level meaning that the data item conveys. For instance, the following statement from Allison was coded directly as "support from administrator."

> And so what I really appreciate about my principal is that we do not need long range plans. And she is like, it is going to be a flow because maybe something pops up and that is when we are going to address it.

The codes were roughly categorized within NVivo according to overarching categories such as teachers' beliefs, growth and learning journey, pedagogical practices, descriptions of interdisciplinary units, connections and integration, assessment practice, and challenges and enablers. This initial categorization was done to facilitate easier retrieval and analysis of specific participant utterances and qualitative insights from the large number of codes generated.

The third step was searching for themes. The codes were downloaded into an Excel spreadsheet for viewing and clustering. Clustering means putting codes that were related into the same "cluster," or potential themes or subthemes. During this process, I moved codes around and reorganized the clustering several times. As I clustered the codes, I thought about the potential

themes, subthemes, and overarching themes. While doing this, I kept in mind that the themes should avoid being mere summaries of categories (Braun & Clarke, 2006). Rather, they should be more interpretive and tell a story. It was during the third step that I practiced interpreting the meanings behind the codes. For instance, the code “self-assess” was initially placed under the category “assessment,” but further analysis revealed it also reflected “student empowerment,” which later constituted the theme “teachers' learner mindset.”

I found that I moved iteratively between the third (searching for themes), fourth (reviewing themes) and fifth steps (defining and naming themes). There were no clear boundaries as to where one phase ended and another began. According to Braun & Clarke (2006), “a theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning” (p. 82). My process for determining themes involved aligning them with the research questions, evaluating how each theme or interpretation helped answer these questions. Simultaneously, the process was informed by the chosen theoretical lenses, which helped me make sense of the participants’ experiences through. After identifying the themes, I reviewed each code to ensure the data supported the themes into which they were clustered.

Finally, I arrived at two broad categories and seven major themes. The first category consists of four themes, focusing on the experience of the participants with interdisciplinary education, from conceptualizing the meaning of interdisciplinary education to how they practice it. The second category consists of three themes, delving into the nature and process of interdisciplinary integration.

The next three chapters present the findings of the study and are structured as follows. Chapter Six offers brief descriptions of seventeen interdisciplinary units shared by the

participants. Chapter Seven delves into how participants understood and practiced interdisciplinary education, exploring four key themes. Finally, Chapter Eight presents the last three themes concerning the nature and process of interdisciplinary education.

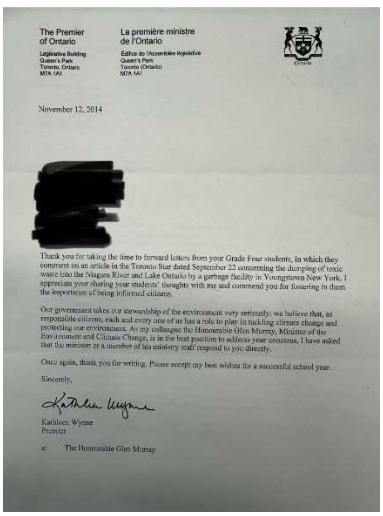
Chapter Six: Interdisciplinary Units

Overall, the participants recounted seventeen vignettes detailing diverse interdisciplinary learning units in which they engaged with their students. Here, I present a concise summary of each narrative in order to offer readers insight into the depth and diversity of the participants' experiences. These vignettes lay the groundwork for the findings and analysis presented in subsequent chapters.

Allison's interdisciplinary units

Vignette 1 (Allison): Advocacy for Lake Ontario

During a See-Think-Wonder activity, fourth graders became deeply engaged with water habitats. They explored the impact of water on animal habitats, sparked by a news article about toxic waste in Lake Ontario. Motivated to take action, they collectively wrote letters to Kathleen Wynne, the Premier of Ontario at the time, expressing concerns about their drinking water. Their efforts garnered responses from both Wynne and the Minister of Climate, demonstrating their ability to influence environmental discussions and integrate the science and language curriculums through practical engagement.



The Premier of Ontario
Legislative Building
Queen's Park
Toronto, Ontario
M7A 1A1

La première ministre de l'Ontario
Édifice du l'Assemblée législative
Queen's Park
Toronto (Ontario)
M7A 1A1

November 12, 2014

[redacted]

Thank you for taking the time to forward letters from your Grade Four students, in which they comment on an article in the Toronto Star dated September 22 concerning the dumping of toxic waste into the Niagara River and Lake Ontario by a garbage facility in Youngstown New York. I appreciate your sharing your students' thoughts with me and commend you for fostering in them the importance of being informed citizens.

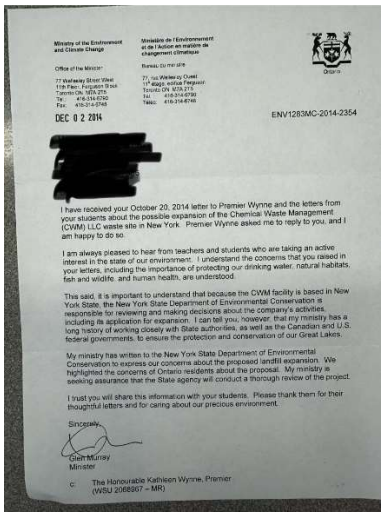
Our government takes our stewardship of the environment very seriously; we believe that, as responsible citizens, each and every one of us has a role to play in tackling climate change and protecting our environment. As my colleague the Honourable Glen Murray, Minister of the Environment and Climate Change, is in the best position to address your concerns, I have asked that the minister or a member of his ministry staff respond to you directly.

Once again, thank you for writing. Please accept my best wishes for a successful school year.

Sincerely,

Kathleen Wynne
Premier

c: The Honourable Glen Murray



Ministry of the Environment and Climate Change

Office of the Minister

77 Wellesley Street West
11th Floor, Ferguson Block
Toronto ON M7A 2T5
Tel: 416-314-6790
Fax: 416-314-6748

Ministère de l'Environnement et de l'Action en matière de changement climatique

Bureau du ministre

77, rue Wellesley Ouest
11e étage, édifice Ferguson
Toronto ON M7A 2T5
Tél. : 416-314-6790
Téléc. : 416-314-6748

DEC 0 2 2014

ENV1283MC-2014-2354

[redacted]

I have received your October 20, 2014 letter to Premier Wynne and the letters from your students about the possible expansion of the Chemical Waste Management (CWM) LLC waste site in New York. Premier Wynne asked me to reply to you, and I am happy to do so.

I am always pleased to hear from teachers and students who are taking an active interest in the state of our environment. I understand the concerns that you raised in your letters, including the importance of protecting our drinking water, natural habitats, fish and wildlife, and human health, are understood.

This said, it is important to understand that because the CWM facility is based in New York State, the New York State Department of Environmental Conservation is responsible for reviewing and making decisions about the company's activities, including its application for expansion. I can tell you, however, that my ministry has a long history of working closely with State authorities, as well as the Canadian and U.S. federal governments, to ensure the protection and conservation of our Great Lakes.

My ministry has written to the New York State Department of Environmental Conservation to express our concerns about the proposed landfill expansion. We highlighted the concerns of Ontario residents about the proposal. My ministry is seeking assurance that the State agency will conduct a thorough review of the project.

I trust you will share this information with your students. Please thank them for their thoughtful letters and for caring about our precious environment.

Sincerely,

Glen Murray
Minister

c: The Honourable Kathleen Wynne, Premier
(WSU 2068967 – MR)

Vignette 2 (Allison): Buy A Well

While studying ancient civilizations, the students became curious about how ancient societies managed to keep their water clean. A photo of a child drinking dirty water profoundly moved them, leading to a discussion on what actions they could take to address the issue of clean water access today. They brainstormed solutions, including fundraising to purchase a $350 well through UNICEF. They pitched a popcorn sale to their principal, applying their math skills to graph sales and analyze popular flavors. Their initiative successfully raised the funds for the well, allowing them to experience a profound sense of ownership and connection across their curriculum, and making a tangible impact on a global issue.

Vignette 3 (Allison): The Solar Eclipse

When faced with the imminent solar eclipse darkening their walk home from school, students brainstormed several solutions to address safety concerns. Their ideas included advocating for solar eclipse glasses and proposing alternative scheduling options: shifting the school day later, allowing for a half-day in school and a half-day online, synchronous learning from home, or implementing a PD day. Their proactive advocacy resulted in the school board ultimately scheduling a PD day, ensuring student safety during the eclipse and highlighting their impact on policy decisions within the school board.

Vignette 4 (Allison): World Population Density Map

Grade 4 students engaged with the population density map of Canada during their geography lessons. This exploration expanded when students, many with roots in India and Jamaica, expressed curiosity about their respective countries' population densities. Comparing Canada's population density with India's, they shared personal anecdotes about family visits and

observations. These discussions not only enhanced their understanding of mapping skills, such as interpreting legends and keys, but also deepened their insight into the diverse social and economic conditions worldwide.

Vignette 5 (Allison): Why Don't More People Live in Northern Canada?

An examination of the population density map of Canada prompted discussions on why fewer people reside in Northern Canada. Aligning with Grade 5's exploration of government levels and policies, and Grade 4's study of Canada's regions, they hypothesized reasons such as high living costs and limited agricultural viability. This led to a comparative study of grocery prices, integrating financial literacy into their social studies curriculum. They also examined government food subsidy programs for northern communities, exploring natural resources and sparking discussions on social justice and Indigenous rights. These conversations seamlessly integrated language arts, social studies, and math, enhancing their understanding of the complexity of the world they inhabit.

Vignette 6 (Allison): Food Drive

Upon being introduced to the UN sustainable development goals of poverty and hunger, the students were inspired to organize a food drive around Thanksgiving. They wrote persuasive letters to other classes, made daily announcements, and collaborated with a Kindergarten class to collect donations. The students then counted and categorized the food, creating graphs to visualize their contributions. A display board featuring a photo of the collected food and the students' efforts served as a reminder of their successful initiative and learning experience.

Vignette 7 (Allison): Clothes Production Map

During a discussion on environmental laws, a student noted that many products, including their T-shirts, were made in China. This observation led to an impromptu investigation where the class examined the tags on their shirts to identify their countries of origin. They then colored a world map to represent these locations and discussed the environmental regulations in each country. This student-initiated activity fostered global awareness and was showcased on a board alongside the sustainable development goals.

Finley's interdisciplinary units

Vignette 8 (Finley): Electric Race Car

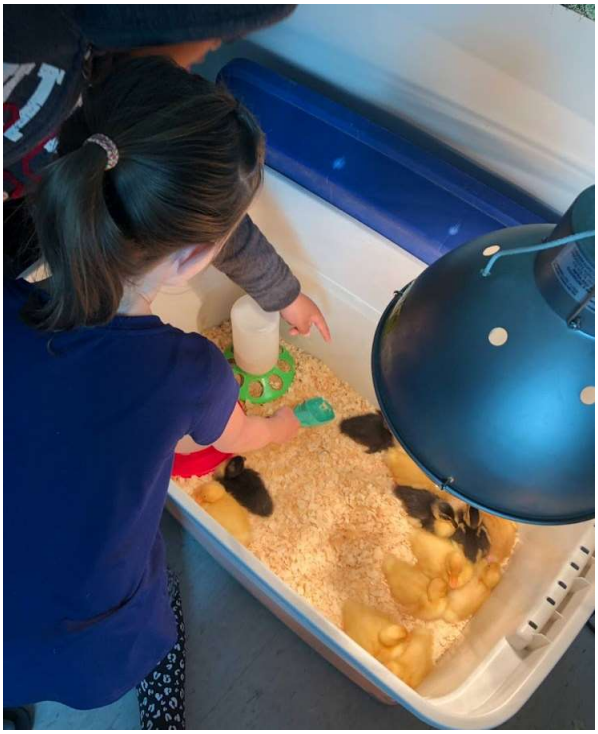
For a Grade 5 energy and matter unit, students were tasked with designing and building electric cars. Using the maker space, stocked with batteries, motors, and craft supplies, they followed a collaborative design-thinking process. This hands-on project enabled them to apply their knowledge of energy transfer practically. The culmination of their efforts was racing their cars in the hallway and presenting their projects to the entire school, integrating technological components and deepening their understanding of the subject matter.

Vignette 9 (Finley): Reducing School Garbage

In Grade 3, during the unit on soil, students explored the impact of waste sites and landfill garbage, discussing how their school's waste contributes to these issues. They brainstormed ways to reduce their school's garbage production, leading to a campaign involving daily announcements, weighing garbage, and sorting recycling. The project incorporated oral and written communication, art, and science, resulting in a comprehensive effort to measure and reduce waste, connecting environmental education with practical actions for sustainability.

Vignette 10 (Finley): Raising Ducks

A school-wide duck egg incubation project engaged students from various grades in meaningful and memorable ways. Each grade had specific responsibilities related to different aspects of the project. Grade 1 students learned basic concepts about what makes a duck a living being. Grade 2 predicted and monitored the life cycle stages. Grade 3 investigated their diet. Grade 5 explored habitats, determining how to mimic a natural environment for the ducklings within the classroom, while Grade 6 focused on biodiversity and the classification of ducks. Senior and junior kindergarten students also participated by caring for the ducks and learning about their needs. The project not only tied into the curriculum across different grades but also fostered a sense of responsibility, curiosity, and connection among students and staff, creating lasting memories and a sense of community throughout the school.



Sara's interdisciplinary units

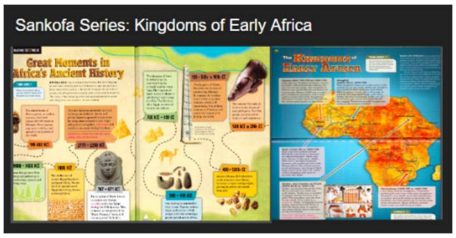
Vignette 11 (Sara): How Accessible Are Our Schools?

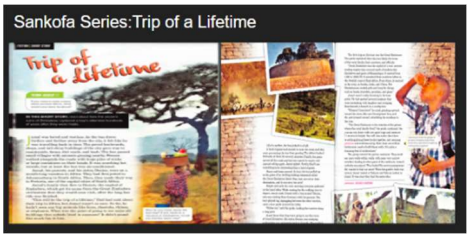
When a classmate could not attend school for a week due to a broken leg and the school's lack of accessibility, the students decided to investigate their school's accessibility. Using scooters, crutches, and tally charts, they assessed the barriers and found significant inaccessibility. Their inquiry broadened to include research across the school board, discovering that only one school was deemed truly accessible. Motivated to create change, they prototyped apps to map school accessibility features and pitched their ideas in a Dragon's Den-style presentation, integrating financial literacy. They also built and tested ramps with robots, blending math, science, and art, and partnered with a local organization to install a ramp in a nearby business, combining practical solutions with social justice.

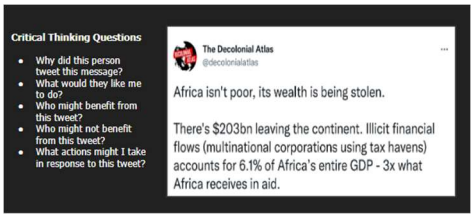
Lynn's interdisciplinary units

Vignette 12 (Lynn): How is Africa Rich?

Students explored Africa, identifying as geographers and using Google Earth to locate and describe landforms. Studying early African civilizations and modern resource exploitation, they reflected on Africa's contributions and challenges. They created passports and planned trips in Google Earth, presenting their favorite places. Activities included examining resource maps, oil company ownership infographics, and wealth distribution tweets, fostering critical thinking. Through readings and a creative trip presentation, students connected history, geography, and contemporary issues.



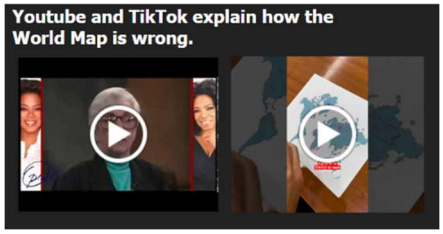




Vignette 13 (Lynn): How can we counter stereotypes of Africa

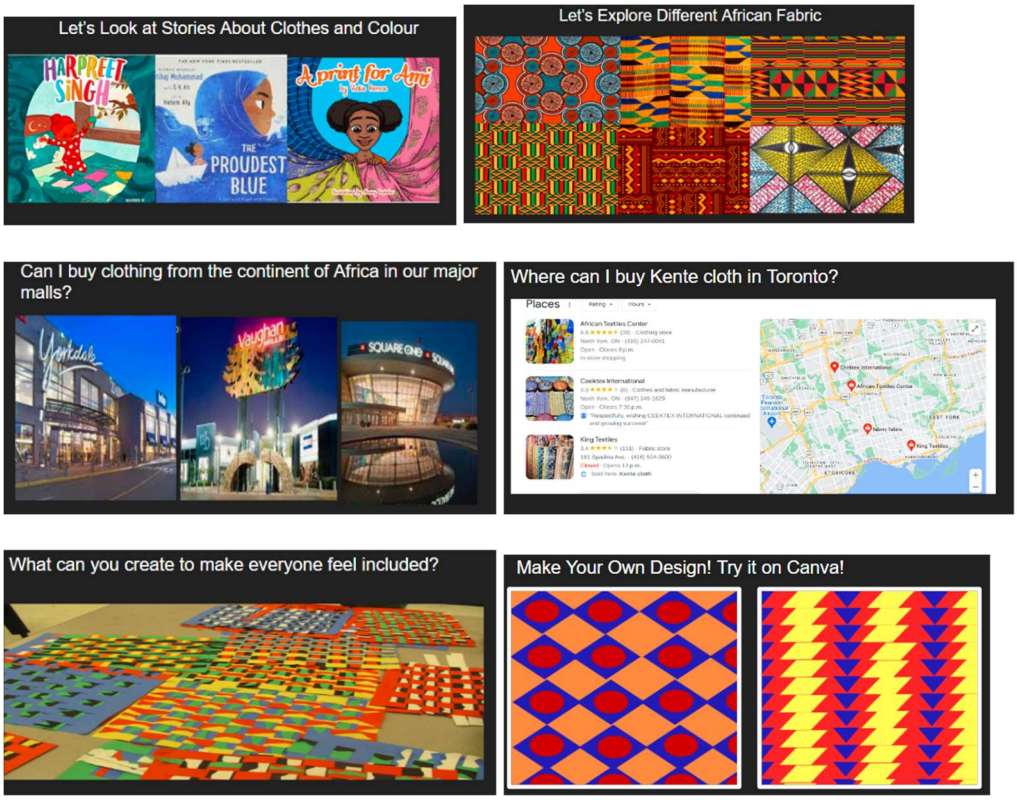
Students investigated Africa's true size, using ratios to illustrate its scale compared to other countries. Addressing misconceptions, they analyzed stereotypes about Africa and its diverse

nations, identifying historical and modern African rulers. Critically examining biased world maps, students explored their origins and implications. They created podcasts: a trivia show about Africa, discussions revealing map truths, and profiles on African leaders past and present. This integrated approach incorporated geography, math, media literacy, and language skills, fostering a deep understanding of Africa's complexity and significance.



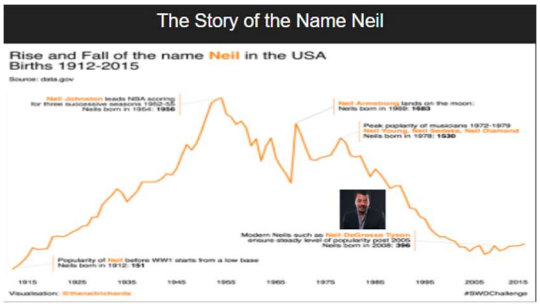
Vignette 14 (Lynn): Exploring African Fabric

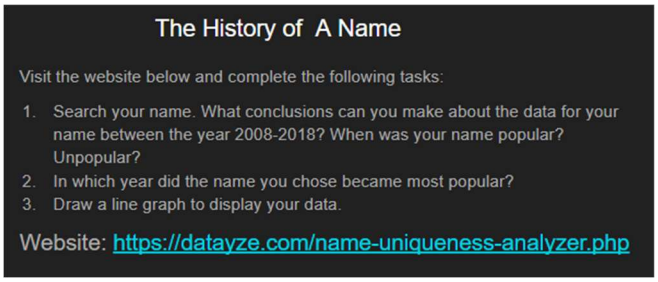
In this lesson, students explored fabrics and clothing as part of cultural heritage. They began by discussing favorite colors and emotional connections to clothing through picture book stories. Through hands-on activities, they identified shapes and explored symmetry in fabrics, while learning about diverse African textiles. They critically examined the availability of Kente cloth, a Ghanaian fabric, in Toronto, connecting this to economic factors in retail. To culminate, students created their own fabric designs, expressing personal style and creativity with colors, patterns, and shapes.



Vignette 15 (Lynn): My Name Is…

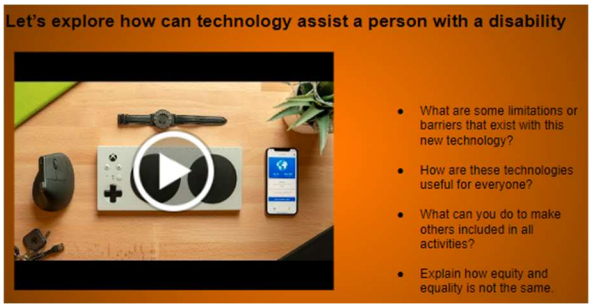
In this lesson, students explored the significance of names. They investigated their own name stories, researched meanings, and shared findings with peers. Using this information, they created bar graphs to visualize the popularity of their names over time, practicing math and data analysis skills. Discussions covered naming traditions across cultures and biases in how names are treated. Finally, students created infographics that reflected the meanings and personal connections of their names, integrating language arts with creative expression.

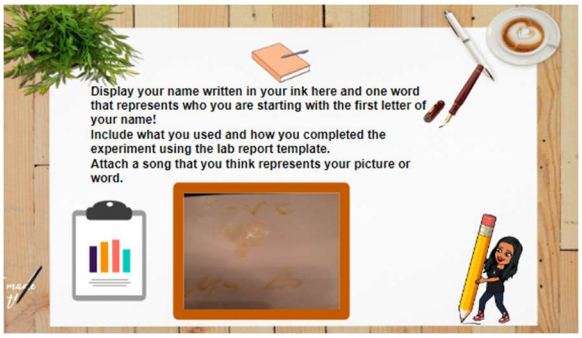


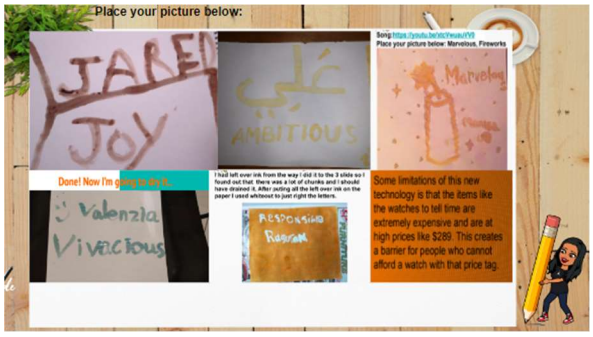


Vignette 16 (Lynn): Make Your Own Ink

In this activity, students engaged with identity and communication by creating their own ink. They explored the historical significance of paper and ink, particularly through ancient Egyptian practices. Through critical discussions, they identified obstacles faced by those who lack access to traditional writing tools and brainstormed solutions for inclusive communication methods. Ultimately, students expressed their personal identities by writing their names and a defining word using the ink they created, integrating skills in communication across various forms and media.







Carol's interdisciplinary units

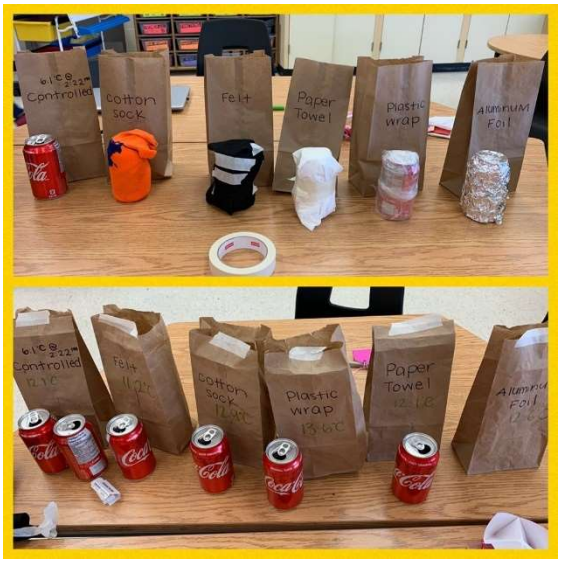
Vignette 17 (Carol): A Year-Long Inquiry

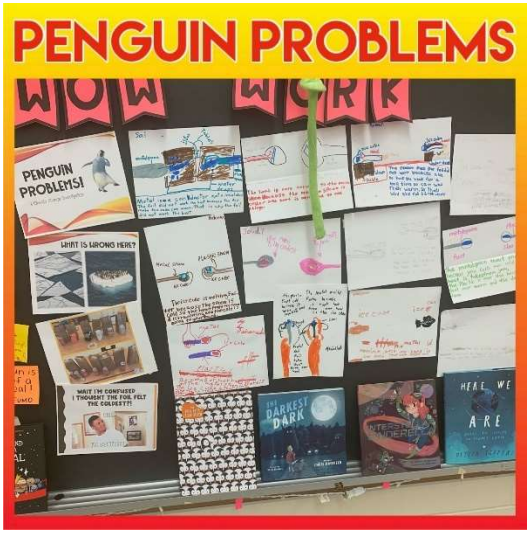
Phase 1

Students began their exploration with habitats, engaging in outdoor learning to observe and document their discoveries in the forest. Using microscopes, they closely examined samples and shared their observations. This hands-on approach sparked numerous questions about plants, animals, and their environmental interactions. As their inquiry progressed, they conducted experiments on plants, testing various liquids for watering and planting different seeds together to explore factors influencing plant growth and sustainability.

Phase 2

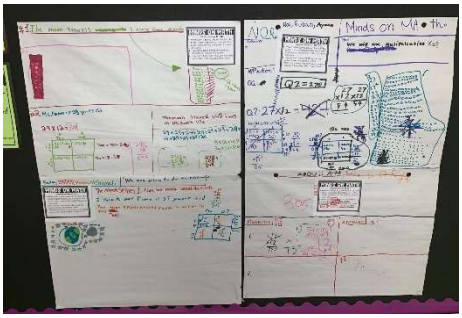
They shifted their focus from plants to penguins, exploring what these creatures need to survive. They delved into creating insulated homes for penguins, inspired by initiatives in South Africa due to global warming. Students researched different insulation materials to determine the best options for their penguin habitats, conducting experiments to test their hypotheses.

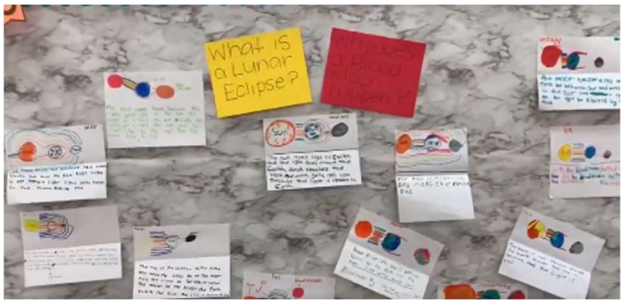




Phase 3

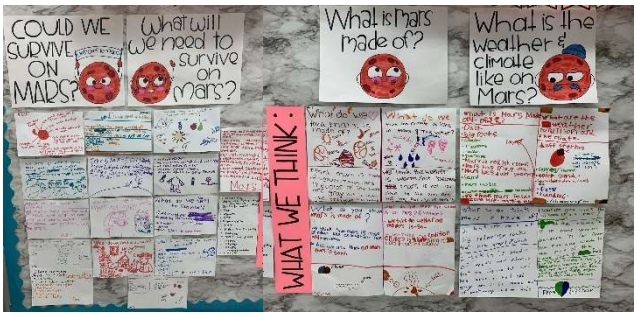
From their interest in penguins, the students began exploring broader questions about global warming. They delved into discussions about pollution and the role of the sun in creating heat, prompting further exploration into why the sun is crucial to everyday life. They read books and conducted research to understand the sun's significance. Additionally, the occurrence of a blood moon during that year sparked their curiosity, leading them to investigate the phenomenon and its causes in depth.

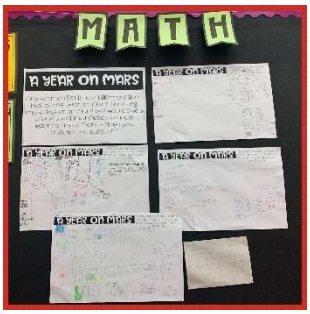


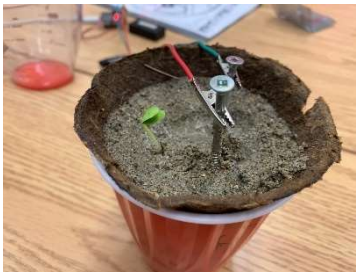


Phase 4

The students' interest in space led them to ponder relocating to Mars if Earth became uninhabitable due to global warming. They explored this by researching on the NASA website and studying Mars missions. They focused on essential survival needs, proposing a self-watering device to cultivate plants on Mars. They devised two methods: one requiring humans on Earth to trigger watering, and another that automated the process based on soil moisture. Their learning integrated math, robotics, coding, drama, and language arts to create innovative solutions addressing today's global challenges.






Chapter Seven: Experience with Interdisciplinary Education

This chapter discusses the first four of seven themes, which focus on teachers' understanding of and their experiences in practicing interdisciplinary education. First, teachers articulated their definitions of interdisciplinary education. Second, they implemented diverse pedagogical practices, often considered progressive, which were integral to their approach to interdisciplinary education. Third, teachers frequently integrated real-world issues and contextualized them according to students' interests to develop interdisciplinary units. Lastly, successful interdisciplinary teaching necessitated teachers adopting a learner mindset.

Theme 1: Defining interdisciplinary education

The participants of this study defined interdisciplinary education as “integrating different subjects,” “teaching different subjects through [other] subjects,” “intertwining [subjects] together,” “cross-curricular learning,” “incorporating different subject areas” and “using different disciplines within one activity or project.” Sara elaborated:

> Science is taught through language, social studies is taught through language, art is taught through language. Even science can be taught through drama. So if we are talking about report writing. I will introduce it in a language period, but then they actually write their science report, so it is integrated with what they are doing.

Additionally, the participants stressed that the purpose for integrating subjects was to make learning “more meaningful” through helping students to “understand connections between subject areas.” Carol explained,

> [It is about] the understanding of connections between subject areas.

> Understanding that math is literacy and literacy is science and science is social studies, and making sure that they are understanding that they all interweave between each other and just knowing how to connect them in a meaningful way.

Lynn used the metaphor of weaving a beautiful "fabric" to explain the sense of connections between the different subject and skill areas:

> We are intertwining things together to make a beautiful creation. I do not want to teach in isolation. I do not want to teach just math [or just] one particular subject area. Because everything is together in one. … Whatever you are teaching, you are not just teaching one particular skill. You are teaching so many different [skills] that fall within the different subject areas.

Articulating on integrating different subjects, Allison stressed that interdisciplinary education was where "students get to apply real-world learning because in the real world [we] do not have subjects in silos, but everything is combined together."

Participants also noted that interdisciplinary education could help students develop 21st-century competencies, enhance critical thinking, increase engagement, improve retention, and learn to apply knowledge in real-world contexts. Finley mentioned that interdisciplinary education was "a better representation of the real world," and therefore helped "set students up for success" in the real world. In Allison's words, interdisciplinary education was "more effective" for students, as well as "more exciting" for both students and teachers.

Summary of Theme 1. Participants defined interdisciplinary education as integrating different subjects to make learning more meaningful by understanding connections between them, emphasizing its role in developing 21st-century competencies and real-world application of knowledge. They viewed it as more effective, exciting, and reflective of the real world, setting

students up for success.

Theme 2: Practicing “good” pedagogies

The teachers in this study enacted interdisciplinary education through diverse teaching approaches, all of which feature progressive, authentic, and student-centered strategies. Allison, drawing on her Early Childhood education background, adopted an inquiry-based approach. Using the See-Think-Wonder framework, she structured daily inquiry sessions around thought-provoking questions or current issues, guiding students through understanding from multiple perspectives. The inquiry process culminated in actions aimed at addressing these issues. Influenced by her science training, Finley described her approach as project-based. Her teaching focused on hands-on activities, experiments, and exploration, often resulting in tangible products such as electric cars, reports on school garbage measurements, or hatched and raised ducks. Sara described her teaching as student-centered and driven by student interests, leaning towards a culturally relevant pedagogy framework that celebrates the individuality of her students. Lynn followed Dr. Gholdy Muhammad’s historically responsive literacy framework which centers learning on cultivating five different aspects in students: Identity, Skills, Intellect, Criticality, and Joy. Through the five pursuits, “classroom teachers and school leaders can authentically acknowledge, embrace, respect, and cultivate the diverse cultural identities that students bring with them every day” (Alharbi & Cataldo, 2024, p. 1286). Carol characterized her teaching as inquiry-based. She humorously mentioned saying "I don't know" a lot to her students, but she followed it up with "How can we find out?" She also incorporated technology, coding, and STEM in her lessons.

When asked how they considered their teaching approaches interdisciplinary, participants

shared that when they followed these approaches, they found that their lessons often called upon various disciplinary areas' knowledge and skills and necessitated the integration of different subjects to deepen students' understanding. Lynn elaborated on how using the five-pursuit framework led her to interdisciplinary teaching:

> When I first started to use the framework, I was more or less thinking about how am I incorporating those five pursuits … and from that, I think what has come out is the ways in which you make it interdisciplinary. Because if you are looking at joy, a lot of the joy comes from creation, [which involves] the arts, music, dance, drama. … When you are looking at the criticality and the intellectualism and the skills you are looking at, you know how you can incorporate your language, math, and other subject areas within that particular lesson.

Despite the diverse general approaches, the participants shared a few specific teaching strategies that directly supported interdisciplinary learning. These included mastering classroom management through establishing common structures and shared goals within the learning environment. Additionally, fostering a collaborative learning environment through dialogic discussions and learning communities strategies was emphasized. Providing scaffolds through deliberate teaching of disciplinary skills and knowledge was highlighted as an important foundation for interdisciplinary integration. Lastly, assessment using observations and anecdotes was underscored as important for effectively capturing students' development in interdisciplinary understanding.

Classroom Management. Participants described interdisciplinary teaching as granting students more freedom, enabling them to express diverse perspectives that can lead to expanded exploration of knowledge across multiple domains. They emphasized the importance of

mastering behavior management as a critical skill for new teachers. With increased freedom, it is essential that students exercise this freedom within a shared structure of conduct, expectations of behavior, and common goals. When asked about challenges she encountered when she first started as a teacher wanting to teach in an interdisciplinary way, Sara recalled behavior management as one of the biggest challenges. She elaborated,

> I have learned over the years that if you do not do behavior management at the beginning, the rest of your year is going to be quite miserable, and you cannot teach the way you want to because you are spending most of your time trying to get them to listen or to get them to just sit.

Finley echoed this sentiment,

> The management of behaviors is very intense and scary at first being a new teacher … because getting into [project-learning] and giving the children more freedom kind of comes with its own baggage … You absolutely need to have them on board and behave properly and be respectful and able to collaborate in a way that we can all learn and live together as a mini society.

Allison articulated that in approaches where students have more freedom, it might be most effective to let students co-construct the rules and structures. Allison highlighted the importance of students being involved in creating classroom guidelines and routines, fostering a sense of ownership over their learning space.

> This is more effective than me standing there…[declaring] these are the rules. They are telling me how they want our collective space. … The kids come in, they change the date on the board, they put up our daily schedule, they get their chairs out. … They love it because they feel a sense of ownership and a sense of

> belonging, … It is not my classroom. It is our classroom.

Learning Community. All participants underscored the significance of organizing learning communities such as discussions, collaborative projects, learning circles, or knowledge building circles. These spaces served as platforms for problem-solving and engendering ideas. Participants noted that during discussions or learning circles, students build upon each other's sharing, and together enrich their collective knowledge. Carol explained how students' diverse prior knowledge could help advance learning:

> So [when a student comes in with a question] I will ask the student to call our knowledge building circle. … We meet in a central location in the classroom, in a circle, and then we pose the question … to the whole class because I know maybe somebody in the class knows, or maybe they have seen something on TikTok, or they have seen something on YouTube, or they watch something on a TV show, or they heard their parents talking about it. So prior knowledge comes into play.

Utilizing collective knowledge and building upon each other's ideas were where interdisciplinary connections might occur. Allison recalled how her students made connections between geography (learning about population density) and social studies (understanding social conditions in different regions) during her class's daily learning circles called See-Think-Wonder. This connection led her class to apply their math skills (calculating average grocery prices for different regions) and reconnect the results back to social studies (understanding government programs and policies concerning Indigenous people).

> So, we started talking about [population density] and [the students] questioned Why don't more people live in Northern Canada? … And [someone] said, I think it is expensive to live up there. … [I said,] let us think about this. And so then

> they were like oh, it might be expensive because of fuel. It might be expensive because we cannot grow things. And so we then did a grocery comparison. [And] we were talking about government programs that subsidized food for northern communities. … And then it got into a discussion of social justice and what rights people should have and Indigenous people, with them being forced off their land.

Figure 1:

Allison's Classroom Set-up

Note. Allison's flexible classroom setup encourages student interaction, group work, collaboration, and active participation in discussions, thereby fostering interdisciplinary learning. The adaptable space also offers the necessary structure for students to explore freely within a safe learning environment. This freedom plays a crucial role in enabling

interdisciplinary learning.

Scaffolding and Deliberate Teaching. Scaffolding and deliberate teaching of disciplinary knowledge and skills was important for the participants' interdisciplinary classroom because only when students have the necessary skills or knowledge, can they progress to more integrative activities.

In supporting student learning, the teachers made sure to provide mini lessons on both content and skills necessary for projects, inquiries, or conceptual connections. Allison remarked that research skills are one of the skills she always taught deliberately to prepare students for their interdisciplinary inquiries.

> With interdisciplinary learning, there's certain things that I need to "front load" teach… I start September with research skills… [We talk about] how to source, paraphrase, and find a good website… So then as we get into the topics that… we want to do inquiries on, they are able to do it themselves.

Finley recalled providing mini "formal" lessons on closed and open circuits, so students were equipped with the knowledge to proceed with their car building project:

> I would have something formal … about closed and open circuits. What is an open or closed circuit? How do they differ? How do we build one? Then [we] go back to our material and build open and closed circuits with the knowledge that they just gained. [It is] kind of back and forth like that.

Sara gave an example of explicitly teaching a math skill so that her students could apply and proceed with their science projects involving building pulleys and gears.

> I have explicitly had to teach them how to use a ruler [and] the difference between

> centimeters and millimeters… Then now when… they are building something for pulleys and gears, they have to apply [the measurement knowledge] so that [the pulleys] actually work.

Lynn noted that within an overarching unit, there is usually a lot of "mini lessons" where teachers need to introduce or enhance the disciplinary knowledge or skills. Having this enriched knowledge provides students with the background to make connections and deepen their understanding in the bigger unit. She elaborated:

> There are different mini lessons that we do teach within the unit itself… For example, if you want students to be discussing the criticality and to be able to discuss … anti oppression, racism, discrimination. That is something that students are not well-versed in. So it's something [for which] you really have to give them the language so that they have an understanding of those words, how can they articulate their understanding of it and how can they be able to recognize it.

Carol noted that teaching a skill or a concept explicitly is needed when there is a gap in skill or knowledge that could prevent students from progressing productively with their current pursuits. She recalled teaching students measurement skills (math) to enable them to carry on with their science experiment.

> For example, when they were measuring water [they need 60ml of water each time they water their plants for their experiment], they did not know what measuring tools to use… They do not know that there are tools that we can use in order to measure 60 milliliters precisely. So at that point, I pause the learning. … I gave them measuring cups, measuring spoons, and little eye droppers they could use those to create 60 milliliters. At that moment I was like, they have this great

> idea, but all of the data they are going to collect is going to be skewed because they are not using the correct measuring tools or they are not being precise enough.

Assessment for Learning. A common theme among the teachers is their reliance on anecdotal observations and conversations with students to gain insight into their learning. This approach acknowledges that traditional assessment methods like paper-and-pencil tests may not effectively capture the connections that students might have been able to make. Carol noted, "There's so much other learning going on for the students that I teach [that] tests and quizzes don't necessarily reflect what they know." Echoing this, Sara uttered, "I found that if I just listen to them walk around and just eavesdrop and listen. That is when I know mostly that they have made that connection." Lynn recalled an instance when one of her students made a powerful connection while the class was examining why world maps usually depicted the size of the continent Africa as smaller than it should be when comparing to North America or Greenland:

> What I have been doing lately is recording students, recording their conversations and their voices. [During] that lesson Africa is not a country, I wish I had captured [at the time], the students were saying that, you know, "size carries power." So I have been moving towards now, looking at if students actually understand the concepts that we are trying to teach.

Summary of Theme 2. In enacting interdisciplinary education, teachers utilized diverse, progressive, and student-centered teaching approaches, which often required the integration of different subjects to deepen students' understanding. Specific strategies highlighted included mastering classroom management, fostering collaboration through dialogic discussions, providing scaffolds through deliberate teaching, and employing effective assessment methods to

capture students' interdisciplinary development.

Theme 3: Integrating life and students' interests

Participants typically drew from real-life materials or topics that interested students to develop interdisciplinary units. By focusing on real-world issues and situating them within the social context of the learners, rich interdisciplinary learning was fostered.

By incorporating real-world issues as well as empowering an action-oriented mindset, Allison was able to foster a rich interdisciplinary environment. Through tackling pressing concerns such as water pollution, local events like solar eclipses, and community food shortages, students gained deeper knowledge and made connections across multiple subject areas. For instance, upon discovering the lack of clean drinking water in Africa, the students conducted research and decided to organize a fundraiser through selling popcorn at their school and purchased a well for $350 through UNESCO. This endeavor involved developing knowledge and skills across disciplines, including social studies, financial literacy, math, persuasive writing, research, and project management.

In Finley's classroom, students tackled challenges directly relevant to their school life, such as quantifying the daily waste generated by their school, as well as participating in substantial hands-on projects like building electric cars or incubating duck eggs. In the school waste project, students integrated their learning in earth science and environmental science to understand the flow of garbage from their school to landfills, utilized their math knowledge to calculate how much garbage their school produces each day, and incorporated their language skills to craft daily morning announcements to persuade their classmates to reduce their collective waste output.

Sara's students learned through exploring topics that were relevant to their life, such as their food, their culture, the stories of their names, as well as delving into issues directly affecting their school life, such as the level of accessibility of their schools. After learning that a friend missed school due to the lack of accommodations for temporary walking disabilities, her students conducted an inquiry into school accessibility within their district. This developed into a project where students developed an app to raise awareness about school accessibility issues in their district and pitched it as a business idea to school leadership. Students also learned to design ramps and conducted tests with robots to find out how steep ramps should be for someone in a wheelchair to be able to use. Overall, solving school accessibility problems provided a rich opportunity for interdisciplinary learning, integrating areas such as language, mathematics, coding, robotics, research skills, financial literacy, and media literacy.

Lynn prioritized "authentic" learning experiences that were rooted in her students' cultural identity, and this created an environment for interdisciplinary learning to thrive. For instance, in one unit, her students learned graphs and data biases through researching the global popularity of their names, integrating math and social studies. In another unit, they learned arts and geometry through designing Kente cloth (a type of Ghanaian fabric) patterns upon exploring the history and culture of Ghana and discovering that Kente cloth was not available in popular shopping malls in their area.

For Carol, inviting students to become co-constructors of their learning had the potential to promote interdisciplinary learning. Because students' interests and prior knowledge were so diverse, they provided a rich avenue for further exploration, which in turn necessitated the use of different disciplinary knowledge. She shared the story of how one day a student came in and asked about the blood moon, and because she listened to the student that as a class, they were

able to “push the learning further.” Initially, it was not directly related to what they were doing at the moment. However, as they pursued and inquired more into it, it connected to their current inquiry about penguins, global warming and the sun and transformed into a large space project of how to relocate to Mars if the Earth became unlivable. In this year-long inquiry, students integrated various subject areas, from biology, physics, chemistry to math, coding, robotics, social studies, language, media literacy, arts, and drama.

Summary of Theme 3. Participants in the study employed real-life materials and student interests to develop interdisciplinary units, fostering rich learning experiences by situating real-world issues within the social context of learners.

Theme 4: Learner mindset

It was clear that my participants had embraced a mindset of continuous learning, which contributed to their development in interdisciplinary teaching. First, the mindset of continuous learning was manifested in how teachers prepared themselves with knowledge of the curriculum as well as knowledge across a wide range of disciplinary areas in order to best support students in interdisciplinary learning. The teachers believed that having a solid knowledge of the curriculum is paramount in effective interdisciplinary teaching because this allowed them the freedom to pull upon different expectations from different subject areas. As Finley put it,

> As you get more comfortable within the job and more comfortable with the curriculum and what you want to do, … [this] lets you use that creative freedom and kind of apply everything in a better way, and that is what I had discovered through project based [interdisciplinary] learning.

For Sara, everything she had her students do in class can satisfy a curriculum expectation, “as

long as you know which expectation you are looking for." When Allison first transitioned from Kindergarten to Grades 4-5, during the first two years she "had the curriculum printed" and she would be "thumbing through it" constantly.

Besides knowing the curriculum, Carol taught herself and became an expert in incorporating coding, robotics, and technology in her teaching. Allison dedicated her free time to sourcing intriguing materials, articles, books, videos, to supply real-world topics for her classroom's discussions. She also conducted thorough research to equip herself for meaningful conversations with her students:

> I follow a lot of interesting science related topics … so even when I am not working, when I find something really neat, I am reading up about it. To not only connect it for the kids … but also so if that comes up in discussion, I can … answer in an appropriate and sensitive way that helps move the discussion along. I do not want a kid to say something and I am just like, I do not know and change the subject because that is when the best learning needs to happen.

Second, participants noted that "trial and error" was what characterized their interdisciplinary teaching, because it was often the case that the lesson could follow a completely different path than planned, based on what the students were interested in and the type of connections they made. Hence, Carol noted that it was important to "embrace failure," or "be okay with not knowing," because "the reality is you're never really going to know where [the learning] is going to go." Allison also underscores the significance of being comfortable with failure:

> Note that sometimes when you think [a topic to start off an interdisciplinary inquiry] is accessible for them, [the students] are not even going to care. I

> remember I got a book on wheels for kids. I read it to them. I am like, does anyone have any wonders? And they are like no. I am like, OK. Right. So being OK with that, it is not always going to work because you do not really know what they are going to be interested in.

Third, expanding on the notion of embracing failure, a slightly more nuanced aspect involved participants being vulnerable and honest with their students about what they did not know and open to learning with and from their students. Lynn talked about how being honest about what she did not know empowered students to bring what they knew to the classroom and this enriched the learning and could potentially expand the learning across different domains. She believed that "[Students are] more exposed to social media [...and that will] bring in another layer to the learning." For instance, during a lesson on stereotypes about Africa, Lynn's students brought up a Tik Tok clip illustrating the bias inherent in world map projections. This led to an exploration of how current maps are based on colonial renditions that exaggerate the global North, leading to rich discussions on power and politics. Allison echoed this sentiment: "[Teachers] should be OK with not always being in charge. … The kids can be in charge, too. They are good. They know what they are doing."

Summary of Theme 4. Participants in the study exhibited a mindset of continuous learning, which helped enhance their interdisciplinary teaching practices. This mindset involved thorough preparation in curriculum knowledge and diverse disciplines, embracing trial and error in lesson planning, and being transparent about areas of uncertainty, thus fostering mutual learning with students.

Chapter Eight: Interdisciplinary Teaching and Learning Process

This chapter discusses the last three themes, exploring the interdisciplinary teaching and learning process as described by participants. First, teachers noted the natural emergence of interdisciplinarity, as the integration of different subjects occurs organically within their lessons. Second, when I retrospectively applied Mansilla's (2017) learning framework to participants' interdisciplinary units, they demonstrated the presence of all four elements: a defined purpose, utilization of disciplinary insights, rich integrations in diverse forms, and a critical perspective. Third, the interdisciplinary teaching and learning process begins with students' interests, and curriculum connections emerge after.

Theme 5: Natural emergence of interdisciplinarity

Participants characterized the interdisciplinarity in their classrooms as inherently natural and organic to their teaching approach. They observed that their lessons frequently drew upon diverse disciplinary knowledge and skills, making it effortless to integrate subject areas, as well as to align classroom learning with curriculum requirements.

Allison asserted that "it's so easy to meld the different areas together." Reflecting on the Why Do Not More People Live in Northern Canada lesson, she remarked, "We were able to very easily connect language and social studies and math within … their See-Think-Wonder."

Sara discussed how the unit "How Accessible Are Our Schools?" could integrate multiple subject areas while meeting curriculum requirements:

> If you really look at it, everything connects back to the curriculum. When they are doing their Dragon's Den presentation, that's oral literacy. When they are creating their slides, that's media literacy. So that goes along with your media teaching.

> How do you design a slide so that it is not overwhelming that the writing is legible? When they are even just writing their proposal, that is a writing piece in itself, because now you need to talk about persuasive writing. Fortunately, it is easier than we think to knock off those curriculum expectations. So as long as you know which expectation you are looking for, you are always getting an expectation or reinforcing an expectation that you have already covered.

Lynn directly linked the implementation of Dr. Gholdy Muhammad's Five Pursuits framework to teaching in an interdisciplinary manner:

> So when I first [incorporated Dr. Gholdy Muhammad's framework] using science, I was thinking about, you know, the kids are going to be doing science, but they are also going to be doing the creation of an art. They are also going to be looking at math and measurement. So all of those different skills are right there within the lesson. So I think as educators, sometimes we do not realize that we are doing [interdisciplinarity]. We tend to want to teach in isolation… We are doing much more when we are teaching because there [are] so many other subjects. When you teach using the five pursuits, you are doing it all and you just have to kind of take a look and think about how it is being used in all those different areas.

Lynn discussed the unit "My Name Is…" which initially began with a focus on math but evolved into a comprehensive interdisciplinary unit through collaborative efforts with other teachers and aligning with students' interests:

> [It hits all those skills:] graph[ing], analyzing graphs, creating graphs, all of those different areas of the math curriculum. [You also have] your media literacy through creating those infographics. And you can also have the kids present

> themselves… So it was such a rich learning experience that hit all the curriculum [requirements]. The teacher wanted to teach graphing in math, but she also got her language mark from the presentation.

Carol elaborated on how her Grade 4 students' year-long inquiry seamlessly integrated all subjects and successfully fulfilled all curriculum strands:

> We did math. We did language. We have done multiple sciences now because they needed to create their motor so they need to understand pulleys and gears [...] We also connected it to light and sound because we were talking about the sun and the light that it creates. They talked about the weather on Mars and how they would need to send water up there because there was no water, but because it is cold, they needed to have water at a certain temperature so that it was still able to water without freezing. So we talked about how the sun lights [up] and creates heat. We also incorporated rocks and minerals because when we are sending earth plants, we figured out we cannot use soil because there is no soil on Mars, so they ended up using a specific type of sand from Home Depot that would be as similar to the surface of Mars as possible. … They were just doing a lot of writing and research. Math was connected to everything that we did. We did number sense, data management, measurement, financial literacy, coding … We also connected it to social studies because we were talking about natural resources in different regions of Canada and then we also learned about the resources that they had on the different planets, which is how they ended up deciding which planet to [relocate to]. Obviously, art was involved. We did drama as well because they did some coding … where they had to recreate sounds of planets … All of it stems

> from a nature walk that we did outside, we were looking at plants. And then by the end of the year, they were talking about whether or not they could repopulate Mars.

Summary of Theme 5. Participants described interdisciplinary learning as organic, noting how their lessons naturally incorporate diverse disciplinary knowledge and skills, as well as effortlessly align with curriculum requirements.

Theme 6: Interdisciplinary learning framework in action

To assess the nature of integration in the narrated interdisciplinary units, I retrospectively applied Mansilla's (2017) framework, examining its four components within each vignette provided by the participants. Acknowledging the brevity of the narratives and the lack of direct observation, I recognize that the accounts may not offer complete insights into the units' execution. Nevertheless, these snapshots offer sufficient material for considering the units within Mansilla's framework. Rather than critically scrutinizing each unit for its integration degree, my aim is to evaluate whether Mansilla's framework facilitates understanding of the integrations demonstrated by the participants' interdisciplinary units and to identify any recurring themes or patterns.

The analysis is presented in Table 2. As illustrated, all units demonstrate a clearly defined purpose or goal, aligning with Mansilla's (2017) framework, which underscores the significance of purpose in shaping the learning agenda and establishing an interdisciplinary approach (p. 268). Second, each unit mobilizes a diverse array of subjects and disciplinary insights. Thirdly, the type of integration varies across units. Some are oriented towards practical problem-solving, others towards creating a product, while some aim to foster a more comprehensive understanding

of a complex phenomenon. Additionally, some units provide contextualization or information, others focus on prediction, and some combine multiple forms. Fourth, although the criticality of the interdisciplinary endeavors was not always explicitly evident in the collected vignettes (except for some where criticality was inherent in the teacher's teaching framework and stated in the learning goals), all units possess the potential to cultivate a critical stance.

Table 2:

Analysis of Teachers' Interdisciplinary Units Using Mansilla's (2017) Framework

Vignette	**Teacher**	**Purpose**	**Disciplinary insights**	**Leveraging Integration**	**Critical Stance**
Vignette 1: Advocacy for Lake Ontario	Allison	To express advocacy for Lake Ontario against potential pollution	Biology, environmental science, persuasive writing	Practical problem solving	Raising awareness on environmental issues
Vignette 2: Buy A Well	Allison	To understand that clean water is not accessible to everyone and to provide clean water to children in Africa	Social studies, financial literacy, math, persuasive writing, project management	Practical problem solving	Raising awareness on social equity issues
Vignette 3: The Solar Eclipse	Allison	To suggest solutions to the timing of the solar eclipse falling exactly when students walk home	Science, persuasive writing	Practical problem solving	Learning to consider a multitude of solutions to a particular problem
Vignette 4: World Population Density Map	Allison	To understand the population density of the different countries where students come from	Mapping, math (to calculate density), identity	Informative, contextualization	Raising awareness on some sociopolitical issues such as resource allocation or urbanization

Vignette 5: Why Don't More People Live in Northern Canada?	Allison	To understand the situation and the reason for the particular population allocation in Canada	Natural resources, government policies, math (to calculate living cost), mapping, economics, politics	Informative, more comprehensive explanation	Raising awareness on some sociopolitical issues such as resource allocation or urbanization
Vignette 6: Food Drive	Allison	To help those suffering from poverty and hunger	Social studies, math, persuasive communication, presentation, leadership skills, project management	Practical problem solving	Raising awareness on social equity issues
Vignette 7: Clothes Production Map	Allison	To understand where our clothes are made and how goods travel across the world	Mapping, economics, social studies, environmental law	Informative, contextualization	Raising awareness on some sociopolitical issues such as resource allocation or urbanization
Vignette 8: Electric Race Car	Finley	To design and build an electric race car	STEM, project management, art	Creating a product	Thinking critically about car design and examine factors affecting car speed or efficiency
Vignette 9: Reducing School Garbage	Finley	To calculate the amount of garbage our school produce and to reduce it	Earth science, environmental science, STEM, persuasive communication, leadership skills, project management	Practical problem solving	Raising awareness about environmental issues, thinking critically about how effective the solutions are to reduce the school's garbage
Vignette 10: Raising Ducks	Finley	To incubate duck eggs and raise ducks	Biology, design, empathy, project management	Creating a product	Thinking critically about the incubation process, what could be done better, and what resources are needed to take care of the ducks as they grow

Vignette 11: How Accessible Are Our Schools?	Sara	To understand how accessible schools in our school board are and raise awareness about school accessibility	Math, research, technical design (application prototype), media literacy, financial literacy, persuasive communication, robotics, engineering	Practical problem solving	Thinking critically about the impact of the level of school accessibility to students, how their action (installing a ramp) can be sustained, how effective at raising awareness was their campaign...
Vignette 12: How is Africa Rich?	Lynn	To understand the richness of continent of Africa and how resources are being exploited unjustly	Geography, history, media literacy, language arts, economics, art	Informative, contextualization	Thinking critically about how resources are being exploited, and re-examine own biases
Vignette 13: How can we counter stereotypes of Africa	Lynn	To understand the various stereotypes of Africa, especially through learning about how biased the world map can be	Geography, history, media literacy, language arts, art	Informative, contextualization	Thinking critically about why the world map is made to be biased, and why no one is changing it and what can be done/ critically evaluate the effectiveness of their podcasts in terms of raising awareness
Vignette 14: Exploring African Fabric	Lynn	To explore how clothes are related to identity and culture, and to understand the richness of African culture through exploring its fabrics	Math (shapes), economics, art, cultural studies	Creating a product, practical problem solving	Thinking critically about resource allocation (how some goods are not available at certain location), critically think about what action can be taken to fill the need for Kente cloth in Ontario
Vignette 15: My Name Is…	Lynn	To explore names and culture, and understand what biases data about your names can convey	Math (graphs, data management, data bias), language arts, art, media	More comprehensive explanation	Thinking critically about data bias and the reason for it

Vignette 16: Make Your Own Ink	Lynn	To create an ink that represent who you are and to understand how important it is to be able to communicate	STEM, art, media literacy, history	Aesthetic interpretation, contextualization	Thinking critically about how some people are unable to communicate and what can be done to accommodate, understanding own privileges
Vignette 17: A Year-Long Inquiry	Carol	To understand what plants need to grow To protect penguins from global warming To test the feasibility for human to relocate to Mars if the Earth dies	Biology, physics, chemistry, math, coding, robotics, social studies, language, media literacy, arts, drama	Practical problem solving, predictive integrative model, creating a product	Thinking critically about resources needed to sustain life. Re-examine the experiment process (what to water plants with, what insulation materials work best to keep penguins cool, how can plants grow on Mars sand, ...) and the potential impact of the findings (e.g., what other environment impacts might the best insulation materials have on the life of penguins...)

To further understand the integration strategies used in the units, I categorize them according to the three strategies for integration in interdisciplinary teaching defined by Nikitina & Mansilla (2003) and Nikitina (2006). The three strategies are contextualizing, conceptualizing, and problem-centring. Most units primarily use either a contextualizing or problem-centring integrative approach. Units using a contextualizing approach such as Allison's "World population density map" and "Clothing production map," Lynn's "How rich is Africa?" and "How can we counter stereotypes of Africa?" examine phenomena through understanding the historical, cultural, and social contexts in which they occur. The majority of the units focus on solving a particular problem through building a product or improving the health and wellbeing of the community. Examples include advocating against the pollution of Lake Ontario, raising

awareness, and solving the problem of school accessibility, or building a working electric vehicle.

Two observations can be made. First, the units do not exclusively rely on one approach. Instead, teachers employ a hybrid of contextualizing and problem-centring strategies at different stages of the learning journey. For example, in Sara's "How accessible are our schools?" unit, while problem-solving is the primary mode, she incorporated contextualizing elements. This is evident when she introduced the history of assistive devices, such as hearing aids, and explored the inventors and their motivations. By providing this social context and the philosophical beliefs behind these inventions, Sara helped students understand the driving forces behind scientific progress and its role in serving community well-being.

Second, the absence of the conceptualizing approach is notable. Conceptualizing, an integrative strategy often found in subjects like mathematics and the sciences, focuses on internal integration among mathematics and the sciences, or among sub-fields within one discipline (Nikitina & Mansilla, 2003). In contrast, contextualizing and problem-centered strategies emphasize external integration (Nikitina & Mansilla, 2003). According to Nikitina (2006), “conceptualizing is an integrative strategy designed to take scientific and mathematical thinking beyond the facts and singular theories to the level of the underlying concepts” (p. 261). Examples include how the flux concept in calculus and magnetic waves in physics are essentially the same or how equilibrium can be understood in both economics and biology (Mansilla, 2006; Nikitina & Mansilla, 2003). Since conceptualizing is an internal strategy within mathematics and the sciences, participants' narrative accounts may lack the detail to discern this approach. For instance, when Carol’s students learn about exponents, they might use this understanding to calculate the size and distance of the sun from Mars and determine if they have enough sunlight

to sustain life on Mars. This potential exploration of concepts could be fertile ground for conceptual integration, but it is not clearly evident from the narratives.

Summary of Theme 6. Two conclusions emerge from this analysis. First, the units implemented by the participants in this study embody the hallmark qualities of interdisciplinary learning – having a clear purpose, using diverse disciplinary insights, varying in their integration approach, and possessing potential for cultivating a critical stance (Mansilla, 2017). Second, integration predominantly follows a contextualizing or problem-centered strategy, with conceptualizing serving as a potential yet not visibly employed strategy.

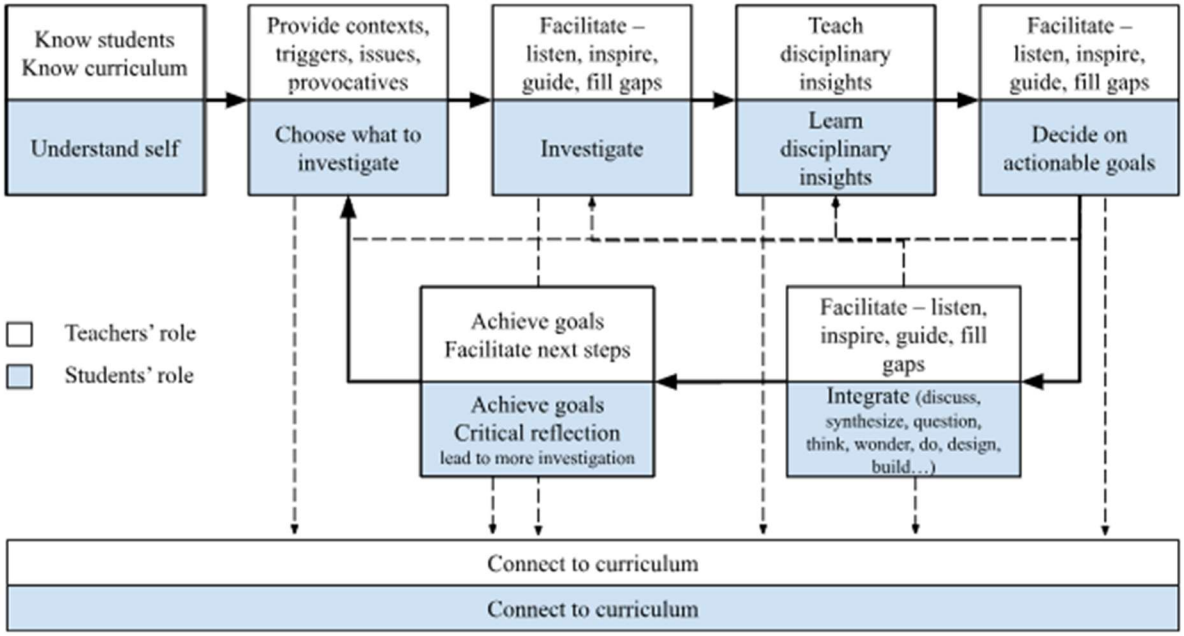
Theme 7: Interdisciplinary process begins with students, curriculum connections come after

The final theme explores the process employed by teachers in this study to foster interdisciplinary learning. Drawing from the teachers' narratives, I developed a visual model to illustrate this process, as depicted in Figure 1. Teachers began by familiarizing themselves with their students and aiding them in developing a deeper understanding of themselves as learners and community members. Likewise, students commenced the process by gaining self-awareness.

The subsequent step involved teachers presenting students with information that could spark their curiosity, prompt wonder, or evoke emotions. During this phase, students selected topics they were interested in exploring further. For example, Allison initiated See-Think-Wonder sessions to kickstart students' exploration, while Finley encouraged daily tinkering. Sara and Lynn introduced topics relevant to students' lives, and Carol let her students explore their interests outdoors.

Figure 2

Interdisciplinary Teaching and Learning Process



Following this, students embarked on investigating the issues that pique their interest. They asked questions, conducted inquiries, and researched. The teacher's role during this phase was primarily that of a facilitator. During this process, students might encounter concepts or knowledge they are not familiar with, rendering them unable to move forward. The teacher's role at this point was to provide students with knowledge or skills necessary to advance the investigation. Often, teachers perceived their role here as co-learners, engaging in parallel learning with students. As students gained insights into the issues they were investigating, they eventually decided on actionable goals to address the problem.

After deciding on the actionable goal, students continued to seek the knowledge and skills needed to achieve it. Typically, to comprehend a complex issue or solve a real-world problem, students needed to perform some forms of knowledge integration—such as offering a solution, creating a product, synthesizing information, making interpretations, or predictions

(Mansilla, 2017, p. 268). This is where interdisciplinary integration occurred. For instance, in Allison's Food Drive unit, integration took the form of practical problem solving. Running a food drive was the solution to the problem of hunger in the community. This food drive demanded that students integrate different disciplinary insights: understanding of hunger as a social problem (enough to communicate to others), mastery of language tool to articulate the issue in a persuasive essay, mastery of mathematical tools such as tallying or charting to manage food collection, collaborative and leadership skills to coordinate with students in other classes. Note that integration was not a one-time event but rather a gradual process as students built their understanding and accumulated disciplinary knowledge.

Finally, as students achieved integration—whether through a solution, a product, or deepened understanding—they took steps toward their goals. This might entail sending advocacy letters, presenting a finished product, or documenting and reporting experiment results. Meanwhile, both students and teachers engaged in reflection on the process. Occasionally, this reflection sparked new interests or problems to be addressed, and the cycle continued. This was exemplified in Carol's students' year-long inquiry. Their experimentation to find the best insulation materials to keep South African penguins cool in the face of global warming led to an interest in the sun, subsequently sparking a significant inquiry into space.

The interdisciplinary learning process exhibits a few notable characteristics. First, the process started with the students, based on what teachers knew about them and what students knew about themselves, rather than focusing on curriculum requirements. All teachers indicated that they "tried to go off of what students were interested in" to begin with. Integration of knowledge, as well as connections to the curriculum, could be made at every step of the process, as each step was a learning process. Usually, curriculum connections were made after or as the

learning unfolded because the learning was not driven by the curriculum but rather by students' interests. As Carol put it,

> [We need to] fit the students' interest into the curriculum as opposed to trying to fit the curriculum into the students. [This meant] retraining my brain to look at what I have done with the students and fit it into the curriculum as opposed to thinking of I have to teach this and I have to teach this and I have to teach this.

Second, the steps in the process were not linear; rather, they were iterative. For instance, after deciding on actionable goals, students might realize they need deliberate learning of certain skills. So, the deliberate teaching and learning of disciplinary insights could happen after every step of the process. For example, in the "Buy A Well" unit, after researching drinking water in Africa and discovering UNESCO's "Buy A Well" program (deliberate learning of research skills), the students decided to purchase a well (deciding on actionable goals). After this, they learned how to fundraise (an integrated activity) through deliberate learning of financial literacy, persuasive communication, project management skills, and so on, to achieve the goal.

Third, teachers still needed to plan carefully, as well as be able to react quickly and develop the ability to engage in "planning as learning" – planning lessons, materials, and resources in response to what was happening in the learning in their classroom. As Allison implied, teachers usually had to plan for potential ways in which learning could occur. When students' interests aligned with a potential pathway, it was the teachers' responsibility to listen and guide them.

> There are things that I like to listen for and once somebody says [something that could lead to deeper learning] then I am like ooh let us think about that. So it is still coming from [students] but … it is leading to where I am hoping. So [I would

> say to the students], let us think about this.

Carol emphasized the ability to "act quickly" upon a learning opportunity. Throughout the year-long inquiry, she provided students with resources to deepen their learning. In the initial phase, when they were exploring habitats, plants, and animals, she allowed them to read "Cece Loves Science," which inspired them to conduct experiments feeding plants different liquids. When they were investigating the sun, she provided books on the sun and space. Similarly, during the accessibility unit, Sara exposed her students to the idea of building things to help people, prompting them to want to design an app to raise awareness of their school's accessibility:

> We talked about how people design things to help other people. So we read biographies of people who designed hearing aids [for] hearing loss. We talked about prototypes, and who designed the crutches because that helps people walk when they break their legs. So we kind of talked about how people would build things to help people.

Summary of Theme 7. The interdisciplinary teaching and learning process centers on learner transformation rather than meeting curriculum requirements – although curriculum connections do arise organically at the end of the process. It emphasizes flexibility and iteration, enabling students to gain disciplinary insights and develop integrative understanding until they achieve their goals. Teachers navigate this process through careful planning while remaining adaptable, engaging in "planning as learning" to respond effectively to students' evolving needs and interests.

Chapter Nine: Discussions

The overarching research questions of this study are:

RQ1: How do self-identified interdisciplinary elementary teachers in Ontario understand and practice interdisciplinary education?

RQ2: What is the nature and process of interdisciplinary integration in these teachers' practices?

This discussion section is structured in two parts, each dealing with one research question. Within each part, I examine how the findings contribute to answering the corresponding research question. Additionally, I explore where my participants' experiences align or deviate from existing literature. Finally, I discuss possible reasons and provide rationales for such alignment or deviation, as well as propose implications for the field.

Research Question 1

How do self-identified interdisciplinary teachers in Ontario understand and practice interdisciplinary education?

This discussion section will be divided into two parts. The first part will focus on how teachers understand interdisciplinary education, while the second part will delve into their practices, encompassing their pedagogies, the content of what they teach, the mindset they adopt, and the challenges they encounter. Observations are made on how the findings are particular to the grade levels discussed.

How Do Teachers Understand Interdisciplinary Education?

How the participants in this study define interdisciplinary education encompass three points, namely “integrating of different subjects,” “creating more meaningful understanding” and “real-world learning.” This is largely in line with the definition of interdisciplinary scholars in the tradition of Klein and Newell (1997) (see also Mansilla, 2017; Newell, 2013). Accordingly, interdisciplinary study is defined as “a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession . . . IDS draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective” (pp. 393-394). This definition stresses the integration of insights from different disciplines to tackle real-world complex problems through developing meaningful, comprehensive understanding.

The participants’ definitions also align with the perspective of curriculum integration in the tradition of the middle school movement (Beane, 1995), rooted in Dewey’s philosophy of integrating “life” in school learning. John Dewey's argument in "Democracy and Education" (2015) emphasizes bringing life to the classroom, contending that education stems from the imperative to sustain society by transmitting habits, ideals, and standards from older to younger generations (p. 138). Dewey views children as integral members of society rather than passive recipients awaiting preparation for life through schooling, advocating that formal education should be considered a vital aspect of children's lives (p. 168-176). Sociocultural learning theory, as articulated by Vygotsky (1978), highlights the culturally situated nature of all learning, indicating that learning and development are significantly shaped by learners' life situations. In short, life in school and life outside of school cannot be separated. As Beane (1995) explains, in interdisciplinary education, “the source of the curriculum should be life itself” (p. 1).

Participants notably did not mention the curriculum integration spectrum or the degree of integration between subjects, as often articulated by curriculum integration experts (Drake & Reid, 2019; Jacobs, 1989). Instead, their focus was on the outcomes, particularly the knowledge and understanding that were created as well as the transformation of students, rather than on how the curriculum might be structured.

Participants noted that interdisciplinary education offers various benefits, including fostering 21st-century competencies, critical thinking skills, engagement, memory retention, real-world application of knowledge, and improved learning efficacy. Empirical evidence supports these claims, demonstrating interdisciplinary education's role in developing higher-order thinking skills (Antonio & Prudente, 2024; Savage & Drake, 2016; Vidic, 2023; Županec et al., 2023), disciplinary understanding (Mard, 2020; Yeşilkaya et al., 2021), and problem-solving abilities (Kokko et al., 2015; Spintzyk et al., 2016). Moreover, interdisciplinary education enhances achievement, disposition, and character skills such as coping with failure, motivation, and inquiry skills (Goovaerts et al., 2019; Morrison et al., 2021; Savage & Drake, 2016).

In summary, participants' understanding of interdisciplinary education aligns with definitions put forth by interdisciplinary studies scholars (Klein & Newell, 1997; Mansilla, 2017), as well as that of the curriculum integration school rooted in Dewey's philosophy and advocated by Beane (1995). This emphasized integration of disciplinary knowing, elevated understanding, and real-world learning. Deviating from the view of curriculum integration on a typology model, they focus on outcomes rather than curriculum structure. Empirical evidence supports the benefits highlighted.

How Do Teachers Practice Interdisciplinary Education?

Pedagogies. Sociocultural theory indicates that learning is mediated through a set of cultural tools (Vygotsky, 1978). In the participants' experience, interdisciplinary learning is fostered as teachers utilize cultural tools such as teaching approaches and techniques, classroom structures, and disciplinary insights and knowledge. First, the participants utilized a range of teaching methodologies, encompassing inquiry-based learning, project-based learning, STEM, and culturally relevant pedagogies. Research has demonstrated that these methods facilitate interdisciplinary connections (Vidic, 2023).

Furthermore, participants found some pedagogical strategies, like establishing classroom rules and fostering collaboration, as conducive to interdisciplinary education. This is echoed in existing literature. Novice teachers experience stress related to group management, while in-service teachers identify it as a barrier to interdisciplinary education (Richards & Shea, 2006; Walan et al., 2016). Clear rules and routines are crucial for successful outdoor interdisciplinary programs (Beauchamp et al., 2022). Collaborative learning approaches were employed to foster interdisciplinary education (Gillies et al., 2015; Kokko et al., 2015; Županec et al., 2023). It should be noted that while collaborative approaches enhance interdisciplinary learning, they are not mandatory for all interdisciplinary initiatives (Applebee et al., 2007).

In interdisciplinary lessons, participants helped students progress to more integrative activities by deliberate scaffolding and addressing knowledge gaps. This also aligns with findings in the literature, where effective scaffolding and active guidance, along with ongoing support and directing students to relevant sources of information and knowledge, have been shown to enhance students' understanding (Gillies et al., 2015; Kokko et al., 2015; van Umm et al., 2017; Županec et al., 2023).

Another interpretation of this finding is to recognize the essential role of disciplinary knowledge and skills in facilitating interdisciplinary integration. This concept aligns with theories of interdisciplinary studies. Klein and Newell's (1997) definition underscores that interdisciplinary studies "draws on disciplinary perspectives and integrates their insights" (p. 394). Mansilla and Gardner (1997) emphasize grounding interdisciplinary learning in disciplinary insights, highlighting the unique knowledge structures of each discipline which require distinct ways of understanding. This perspective is reinforced in Mansilla's (2017) interdisciplinary learning framework.

Content. Cultural, historical, and social contexts play a significant role in mediating learning (Vygotsky, 1978). Participants enabled interdisciplinary learning by drawing upon students' contexts, addressing real-world issues, and incorporating students' interests. This aligns with literature. In some studies, students apply math and design to build machines, learn biology for physical training, or care for school gardens (Beauchamp et al., 2022; Kokko et al., 2015; Spintzyk et al., 2016). Interdisciplinary projects also mimic real-life situations and teach students to integrate science, math, and technology to solve challenges (Goovaerts et al., 2019; Vidic, 2023). In interdisciplinary lessons, teachers encourage student interests, allowing them to define their own inquiry and co-create projects (Morrison et al., 2021; Parker et al., 2011).

Mindset. Participants in the study showed a commitment to continuous learning, enhancing their interdisciplinary teaching practices through deep curriculum and disciplinary knowledge, embracing trial and error, and being transparent about areas of uncertainty. Literature also shows that greater teaching experience correlates with success in implementing interdisciplinary methods (Margot & Kettler, 2019), and experienced teachers tend to adopt more open-ended teaching approaches (Cassidy & Puttick, 2022). Recommendations emphasize the

importance of teachers familiarizing themselves with standards and possessing strong curriculum-making skills (Greenwood, 2013; Moser et al., 2019). The ability to establish connections between subjects and the real world is valued (Parker et al., 2011), and the significance of teachers' pedagogical content knowledge (PCK) in interdisciplinary teaching and learning is emphasized (Niemelä & Tirri, 2018).

Furthermore, this mindset enables teachers to empower students as active agents within the classroom. It creates an environment where teachers facilitate students' learning while also benefiting from the reciprocal dynamics in which students actively contribute to one another's learning and enhance the teachers' own development (Vygotsky, 1978). In my participants' experiences, such an environment nurtures interdisciplinary education. Empirical studies corroborate this view, indicating that in interdisciplinary classrooms, teachers perceive their relationship with students as a collaborative partnership, thereby promoting student-directed learning (Kokko et al., 2015; Savage & Drake, 2016).

Challenges. A notable point of discussion is the fact that while two challenges to enacting interdisciplinary education are often cited in the literature, my participants did not find them troublesome.

First, while subject integration poses a significant challenge for teachers attempting interdisciplinary teaching in many studies (Braskén & Pörn, 2021; Cassidy & Puttick, 2022; Goovaerts et al., 2019; Johnson et al., 2021; Moser et al., 2019; Ryu et al., 2019; Sevimli & Ünal, 2022), my study's participants did not mention this as a specific challenge. Two reasons account for this. First, the participants in my study have extensive experience, ranging from 10 to 27 years, in interdisciplinary teaching, contrasting with studies involving pre-service or less experienced teachers. Second, as explained in Themes five through seven, in the process

described by my participants, interdisciplinarity becomes an intrinsic characteristic of the teaching and learning process. In their practices, teachers no longer "try" to integrate subjects; rather, the integration of different subjects becomes a necessity for the learning to progress. This issue will be further explored and discussed in detail in the subsequent discussion of RQ2.

Second, the challenge of curriculum coverage, driven by demands such as curriculum requirements and standardized assessments (Gillies & Nichols, 2015; Margot & Kettler, 2019; Weinberg & Sample McMeeking, 2017) did not appear to be a significant issue for the participants in this study. Increasing proficiency and experience have made meeting curriculum requirements "easy" for them. Integration was viewed as necessary by Sara, who emphasized that it provided enough time to cover all aspects of the curriculum, while Allison typically covered all requirements by the end of the school year, allowing for exploration of other topics. Detailed results from Theme 5 further illustrate how rich integrated learning facilitates meeting the demands of the standards more effortlessly.

The Significance of the Elementary Level. A noteworthy aspect is the unique characteristics of the elementary level, specifically Grades 1-6, represented by the participants in this study. First, elementary teachers enjoy considerable freedom and ownership over their classrooms, as they typically teach almost all subjects. Unlike at the secondary level, where interdisciplinary education often requires collaboration with other teachers, elementary teachers do not depend on colleagues to enact interdisciplinary learning. This autonomy partly explains why participants did not view school structure and culture as a challenge, a contrast to literature findings (Margot & Kettler, 2019; Ryu et al., 2019). It should be noted, however, that all participants reported receiving freedom and support from their principals. This also explains why they did not perceive school structure and culture as a constraint.

The second point emphasizes how teachers' practices and expectations are adapted for Grades 1-6 students. They rely on observations and anecdotes for assessment, perhaps due to primary (G1-3) and junior (G4-6) students' limited writing skills. The described integrative understanding, often displayed through conversations or utterances, indicates a developmentally appropriate level of comprehension. For example, Lynn shared a student's insight on "size carries power," suggesting an emerging grasp of the interplay between power and politics. Similarly, Sara mentioned "eavesdropping" on conversations to gauge students' connections. Allison noted a student's observation that water fleas can travel across Ontario because "most bodies of water are connected," indicating a deeper comprehension of habitats. These instances showcase teachers' efforts to cultivate understanding suited to elementary school children. Note that as students progress to higher grades, the expectations and complexity of their learning increase. This emphasizes the relevance of these findings specifically to Grades 1-6.

Research Question 2

What is the nature and the process of interdisciplinary integration in these teachers' practice?

Characteristics of Interdisciplinary Integration

Several notable characteristics define the nature and process of interdisciplinary integration in the practices of my participants. First, interdisciplinarity was described as a natural and organic aspect of the teachers' approaches. Disciplinary knowledge was called upon when it was needed to advance learning. As students worked towards their goal, students integrated these various sorts of disciplinary knowledge – whether through creating a product, solving a complex

problem, or fostering a comprehensive understanding of a phenomenon – thus rendering their endeavors interdisciplinary. Second, the units developed by the participants in this study reflected the core attributes of interdisciplinary learning, as outlined in Mansilla's (2017) framework, which emphasizes purposefulness, disciplinary insights, integration, and critical reflection. Last but not least, the interdisciplinary teaching and learning process centered on learner transformation rather than meeting curriculum requirements.

Alignment and Divergence with Existing Frameworks

In order to make sense of these findings, I will situate these results in the current scholarship of interdisciplinary teaching and learning. First, I will briefly review the theoretical landscape of interdisciplinary studies in K-12 education. Then, I will delve into curriculum integration, a key concept in K-12 education focusing on interdisciplinary subject integration. I will analyze how my study's results align with or diverge from the two dominant perspectives of curriculum integration. I will provide explanations for these alignments or deviations and discuss their implications. Lastly, I will reference recent interdisciplinary studies in K-12 education and suggest avenues for further development.

It should be noted that there has been limited connection between scholars of curriculum integration and those of interdisciplinary studies, both theoretically and empirically. This lack of connection has been a puzzle for me as I undertake this research. The following analysis also aims to clarify and establish connections among these distinct schools of thought.

Interdisciplinary Studies at the K-12 Level. Interdisciplinary studies has emerged as a dynamic field, gathering momentum over the last few decades. Newell's theory, introduced in 2001, marked a significant turning point, spurring growth particularly in areas such as

interdisciplinary collaboration at the professional level, team science, and transdisciplinarity – examining phenomena that transcend disciplinary boundaries (Newell, 2013).

Mansilla's (2017) interdisciplinary learning framework is a crucial contribution to the scholarship of interdisciplinary teaching and learning. Mansilla emphasizes the importance of grounding interdisciplinary learning in disciplinary insights, as each discipline offers unique knowledge structures that require distinct ways of understanding (Mansilla & Gardner, 1997). Mansilla's (2017) interdisciplinary learning framework posits that disciplinary insights are an inseparable component in the learning process. Each discipline offers a unique viewpoint, which, when integrated, contributes to a more comprehensive understanding, enabling a new and advanced state of knowing.

Mansilla (2017) provided two examples in her paper, analyzing interdisciplinary endeavors such as the design of a war monument and understanding a local community's response to an ecological crisis using her framework. These examples, as well as the analysis of the participants' units in Theme 6, illustrate the framework's potential as a tool for comprehending interdisciplinary learning. However, its application in the classroom remains unaddressed by Mansilla. We will revisit this framework in later discussions. Now let me turn to curriculum integration.

Curriculum Integration. In K-12 teaching and learning, when it comes to interdisciplinary studies, the term curriculum integration dominates the literature. To date, there has not been much connection between curriculum integration scholars and the interdisciplinary studies literature described above. As explained in the literature review, there are two different schools of thoughts relating to the term curriculum integration. The first has its roots in curriculum design experts, with popular depiction of integration on a typology model or a

spectrum, ranging from multi-, pluri-, cross-, inter-, to trans-disciplinary education (Brandt, 1991; Fogarty 1991; Drake & Reid, 2019; Jacobs, 1989, 1998; Jantsch (1972, as cited in Newell, 2013; Perkins-Gough, 2003). The second is rooted in the progressive education movement, heavily influenced by the works of John Dewey, with James Beane (1995) being one of its most enthusiastic advocates. Its principles also coincide in large part with the Authentic Education moment discussed in Engaging Minds (Davis et al., 2015). Subsequently, I will analyze how my research findings can be situated within these two perspectives.

Perspective 1: Curriculum integration on a spectrum. One characteristic of this first curriculum integration perspective is a focus on the curriculum as the starting point. This centeredness on the curriculum is related to works that are influential in the sphere of curriculum development: curriculum mapping (Jacobs 2006), lesson planning by backward design (Wiggins & McTighe, 2005), and concept-based curriculum (Erickson et al., 2020). These frameworks have proved very helpful for teachers to plan their lessons and to implement interdisciplinary education with an end in mind, and seem to be popular in many teacher colleges (Dack, 2020; Moser et al., 2019). The process of designing an interdisciplinary unit, according to the curriculum integration spectrum approach, starts with the curriculum, analyzing the standards, creating a concept map, choosing the learning outcome (what students can do, know, and be, as well as the enduring understandings and essential questions[1]), creating the rich performance assessment tasks (RPATs) to assess those learning outcomes, then determine the daily instruction activities/ assessments (Drake & Reid, 2019) (See Appendix B). What is notable here is that the connections between subjects and the connections to the curriculum are made very early on, in

[1] Concepts introduced by Wiggins & McTighe (2005). An enduring understanding is a significant generalization derived from expert experience, highlighting transferable big ideas that hold lasting value beyond a specific topic. Essential questions are open-ended inquiries designed to provoke deep thought, encourage further questions, and foster a deeper understanding beyond simple factual answers.

the “creating a concept map” step. In this step, “the teacher is looking for ways to integrate disciplinary knowledge, interdisciplinary skills, and [dispositions/ characters]” (p. 121).

Interestingly, what I found with my participants is rather opposite. Connections to the curriculum are made after or as students learn, not before. Disciplinary knowledge was invoked as needed to move the inquiry forward, not necessarily pre-planned. Integration was imperative because the learning task/ goal necessitates it (for instance, for Allison’s students, the goal of buying a well demanded a fund-raising project that integrates many disciplinary subjects). Similarly, assessments are often not pre-planned but unfold as learning progresses, with documentation occurring along the way. While there are elements resembling rich performance assessment tasks (RPATs) (they can be very rich indeed, such as determining whether humans could relocate to Mars and build a plan to relocate and sustain life), such tasks took shape and evolved after the inquiry has started, rather than during the planning phase.

My hypothesis is that the planning of interdisciplinary lessons is still very crucial, especially for novice teachers. During the planning phase, teachers establish connections and develop schemas around specific topics or concepts. This preparation allows them to draw from accumulated experiences and connections, enabling them to better support students during class. Collaborative planning with other teachers can enhance this process, as it fosters discussions and dialogues that contribute to building richer understanding (Vygotsky, 1978). However, while planning is crucial, teachers should avoid imposing their own connections on students during the lesson. Instead, they should encourage exploration and be open to the possibility of the lesson going off in a completely different direction than what was planned.

Perspective 2: Progressive curriculum integration. I will now discuss the second perspective of curriculum integration. Curriculum integration, as defined by James Beane (1995), is:

> … a way of thinking about what schools are for, about the sources of curriculum, and about the uses of knowledge. Curriculum integration begins with the idea that the sources of curriculum ought to be problems, issues, and concerns posed by life itself. (p. 1)

In such a setting, students integrate learning experiences into their "schemes of meaning," that is, who they are as a whole. Additionally, students seek knowledge in an "organic – not artificial – way. That is, knowledge is called forth in the context of problems, interests, issues, and concerns at hand" (p. 1). And it just so happens that, because life problems, issues, interests are "real and know no disciplinary boundaries," the learning that happens as a result of examining these constructs will also be interdisciplinary. This is precisely what Dewey (2015) advocates. Dewey (2015) argues in the first chapter of Democracy and Education that education is living – and that learning by living (or learning by doing) should become central to school learning (Dewey, 2015, pp. 138-139; see also Waks, 2017). In the "Aim in Education" chapter, Dewey asserts that the educational aim "must cooperate with the activities of those undergoing instruction," which essentially means that teachers should incorporate the "intrinsic activities and needs" of learners to engender authentic, meaningful learning, because children are already living creatures pursuing ends (Dewey, 2015, p. 198; see also Waks, 2017).

The intersection between Beane's (1995) vision of curriculum integration and the practices of my participants lies in the utilization of disciplinary knowledge. According to Beane, "knowledge from the disciplines is repositioned into the context of the theme, questions, and

activities at hand. Even when teaching and learning move into what looks like discipline-based instruction, the theme continues to provide the context and the motivation" (p. 4). He gives examples to illustrate:

> For example, in constructing surveys, tabulating data, and preparing reports, one would need to draw heavily from the social sciences, language arts, and mathematics. Suppose that some young people did not know how to compute percentages or make graphs. Obviously, the teacher(s) would help them learn how to do these things or, if necessary, find someone else who knew how to do them. In experimenting with the effects of pollutants on plant life, some young people might not know how to carry out controlled tests. In that case, someone would teach them how to do that. (Beane, 1995, p. 4).

This example describes a very similar experience to how disciplinary knowledge is called upon throughout the unit samples described by my participants. What students needed to learn was contextualized by what they were pursuing overall in the unit. For instance, in the middle of a space inquiry, Carol's students needed to understand the distance unit in space called "parsec." Upon discovering that one parsec equals approximately three meters multiplied by ten to the power of 16, they were unsure how to interpret this measurement. To address this challenge, they reached out to a mathematics expert they knew. The following day, Carol delivered a lesson on exponents and distance. In this instance, students did not question why they needed to learn about exponents; rather, they recognized the necessity of comprehending this knowledge to understand and advance their ongoing project.

Problems with Curriculum Integration. There are some concerns that need addressing in Beane's argument. First, while Beane criticizes the fruitless debate between those advocating

for disciplinary integrity and those pushing for curriculum integration, he exacerbates the issue. He argues that multidisciplinary and interdisciplinary approaches are merely "pretenders" to true curriculum integration, which involves transdisciplinary endeavors that transcend subject or disciplinary boundaries. This appears to dismiss the value of other types of cross-disciplinary approaches or "typologies" in favor of transdisciplinarity. Klein (2017) argues that these differing approaches are worth keeping and honoring, because they serve as purposeful "boundary work," reflecting "differing purposes, contexts, degrees of integration and interaction, organizational structures, and epistemological frameworks" chosen by their users (p. 21). In other words, using typologies in integration work can be valuable depending on one's purpose, and it may not be productive to dismiss them in favor of one. This stance detracts from Beane's main arguments on "life as the source of curriculum" and could potentially alienate supporters of this notion who also recognize the benefits of different typologies.

Additionally, Beane's (1995) proposed process for curriculum integration might lead to confusion for those who wish to implement his approach. The process is described as followed:

> Curriculum integration begins with the identification of organizing themes or centers for learning experiences. As previously noted, the themes are drawn from real-life concerns…Planning then proceeds directly to creating activities to address the theme and related issues. There is no intermediate step in which attempts are made to identify which subject areas might contribute to the theme. (p. 4)

The lack of consideration for disciplinary knowledge in planning echoes his vision, where the goal of curriculum integration is "integrative activities that use knowledge without regard for subject or discipline lines" (p.1). This leads to two problems. First, it might not be helpful for

teachers, because they will struggle to support students in integrative activities without prior consideration and preparation for what specific disciplinary knowledge or skills students might need. Second, as demonstrated by many scholars, disciplinary insights are crucial for integration (Mansilla, 2017; Klein & Newell, 1997). In his argument, Beane also contends that disciplines of knowledge are “a useful and necessary ally” (p. 1). However, he does not articulate where teachers would consider disciplinary knowledge, if not in planning.

In summary, Beane's rejection of other integration approaches in favor of transdisciplinarity distracts from his main argument, which emphasizes shifting the focus of curriculum to life itself. Moreover, while he stresses the significance of disciplinary knowledge in integrative efforts, he neglects to include and explain how to incorporate disciplinary knowledge into the integration process. These shortcomings make it difficult for practitioners to put his vision into practice.

Conversely, the multitude of curriculum design frameworks (Erickson et al., 2017; Jacobs, 2006; Wiggins & McTighe, 2005) relating to the curriculum integration spectrum perspective offer a range of tools that could prove useful for educators interested in pursuing interdisciplinary education. While delving deeper into these frameworks is beyond the scope of this study, my argument is centered on the notion that the emphasis on the integration spectrum and curriculum design has diverted both scholars and practitioners from more critical considerations. Educators introduced to curriculum integration in this manner often grapple with the task of identifying themes relevant to students' lives and pinpointing connections between subjects, all while ensuring alignment with curriculum expectations and standards. It is understandable why teachers striving to implement interdisciplinary teaching often cite

integration as one of their most significant challenges (Braskén & Pörn, 2021; Cassidy & Puttick, 2022; Goovaerts et al., 2019; Moser et al., 2019; Sevimli & Ünal, 2022).

Essentially, curriculum integration approaches tend to be curriculum-focused first before being learning-focused. According to this approach, teachers begin with the objective of creating an integrated or interdisciplinary lesson, assuming that this will lead to authentic and enriching learning. However, as evidenced by the participants in my study, the reverse is true: authentic and rich learning naturally leads to interdisciplinarity. While Beane (1995) argues for this latter stance, his dismissal of certain integration approaches or typologies has inadvertently shifted the focus away from it. Also, his failure to incorporate disciplinary knowledge in the integration process has made it challenging for teachers to realize his vision.

The Need for a More Updated K-12 Interdisciplinary Framework. The few authors who bridge K-12 education and interdisciplinary studies (in the tradition of Klein and Newell – where most authors focus on professional work or higher education) such as Lenoir & Hasni (2016), also utilize the integration continuum. Hasni et al. (2015) found that secondary teachers implementing interdisciplinary STEM curriculum in Quebec were not truly integrating subjects but merely "contextualizing learning" or "mobilizing knowledge in one subject to apply in another," noting that "these do not qualify as full interdisciplinary practice" (p. 173-174).

The authors' conclusion regarding "full interdisciplinary practice" may not benefit teachers, as it prompts the question of whether achieving this standard should be the ultimate goal. Again, the choice of employing a specific integration approach or typology should be contextual and purposeful, and understanding this choice should deepen the understanding of the integration efforts (Klein, 2017). Hence, assessing whether teachers' practices meet the criteria for full interdisciplinary practice may not yield productive results. However, many users of

typologies tend to fall into this trap. Viewing integration on a spectrum sometimes leads to a linear perspective of the world – with “full integration” as the proper endpoint. Therefore, careful consideration should be given when utilizing typologies as a framework for analyzing integration.

So far, I have argued that both of the two strands of curriculum integration in the scholarship of K12 interdisciplinary teaching and learning have limitations. Additionally, they have not been updated with more emergent theories of teaching and learning. I have also demonstrated that interdisciplinary scholars in K-12 education, such as Hasni et al. (2015), may tend to use typologies as a linear spectrum where one position is favored over another. This approach might not be beneficial for teachers. Where can K-12 interdisciplinary studies look for direction?

Mansilla’s (2017) interdisciplinary learning theory could be a good start. First, the framework is situated in the constructivist and sociocultural learning worldview, as well as reflective of the critical pedagogy movement, both of which are important progressive approaches to learning and teaching that stem from a coherence-oriented framing of knowing and learning. As McMurtry (Forthcoming, 2024) shows, such coherence-oriented framing of knowing and learning “provide a much better basis for the pluralistic and more tentative approaches of interdisciplinary thinking, research and education” (p. 11). Moreover, given its coherence orientation, this framework could be expanded to include a complexity lens or other contemporary emergent frames (McMurtry, forthcoming 2024).

Second, Mansilla’s (2017) framework could be beneficial on a broad level by providing "criteria" or essential "attributes" for effective interdisciplinary endeavors. For example, the framework emphasizes having clear goals, strong foundations of disciplinary knowledge,

integrated pursuits, and a critical stance. It also suggests the state of interdisciplinary learners: a state of coherence and equilibrium. It underscores characteristics such as being iterative and reflective. However, for this theory to be practical for teachers and students, there needs to be many more concrete frameworks, processes, and tools available.

Chapter Ten: Conclusion

Summary. In this study, I sought to answer two research questions. *How do self-identified interdisciplinary elementary teachers in Ontario understand and practice interdisciplinary education?* and *What is the nature and process of interdisciplinary integration in these teachers' practice?*

To address RQ1, I delved into understanding the experiences of teachers who implemented interdisciplinary education. To reiterate, participants' understanding of interdisciplinary education focused on the transformation of students and their understanding, and placed less emphasis on curriculum structure. This aligns with definitions by interdisciplinary studies scholars like Klein & Newell (1997) and Mansilla (2017), as well as the curriculum integration philosophy of Beane (1995) in the tradition of Dewey (2015). Their practices align with generally effective and progressive teaching methods, which were shown to facilitate interdisciplinary learning both in the case of the participants and in existing literature. Notably, participants did not find challenges such as subject integration and curriculum coverage troublesome. This could be attributed to their extensive experience and the natural emergence of interdisciplinarity in their teaching and learning process. Finally, the teacher's understanding and practices of interdisciplinary education was unique to Grades 1-6 students. The level of complexity of interdisciplinary connections described in the narratives were developmentally appropriate to these grade levels.

To address RQ2, I analyzed in depth the participants' interdisciplinary teaching and learning process, as well as their narrated interdisciplinary units, utilizing Mansilla's (2017) pragmatic-constructionist framework. The practices of my participants reveal several characteristics that define the nature and process of interdisciplinary integration. First,

participants described interdisciplinary learning as natural, highlighting how their lessons effortlessly integrate various disciplinary knowledge and skills while also meeting curriculum standards. Second, the units implemented by participants embody key characteristics of interdisciplinary learning, including serving a purpose, incorporating disciplinary insights, employing integration strategies, and emphasizing criticality. Lastly, the interdisciplinary teaching and learning process prioritizes student transformation over curriculum adherence, emphasizing flexibility and personalization to support students in internalizing disciplinary insights and developing integrative understanding. Teachers navigate this process through careful planning before the lesson, as well as adaptability during the lesson, engaging in "planning as learning" to effectively address students' changing needs and interests.

I attempted to contextualize these findings within the interdisciplinary literature, particularly examining curriculum integration and interdisciplinary studies. My analysis reveals limitations within the two strands of curriculum integration. The curriculum integration typology model, for instance, tends to prioritize curriculum, assuming that integrating subjects will inherently lead to meaningful learning experiences. By contrast, as observed in my study, authentic and enriching learning naturally fosters interdisciplinary connections. Beane (1995) supports this perspective, but his dismissal of specific integration typologies has shifted focus away from it. Moreover, his neglect to consider disciplinary knowledge in the integration process has hindered teachers in achieving his vision. Furthermore, neither strand has been updated to incorporate emerging theories of teaching and learning. On the other hand, within the field of interdisciplinary studies, scholars often view typologies as a linear spectrum favoring one position over another, which may not help teachers. Finally, I suggest Mansilla’s (2017) framework could be a good model to expand on, as it is compatible with more emergent learning

theories. However, further development of processes, tools, and frameworks is necessary to fully support interdisciplinary teaching and learning within this tradition.

Implications. Two main implications emerge. First, educators and administrators embracing curriculum integration frameworks should reflect on their processes to determine when, where, and how integration occurs. They should assess whether a focus on maintaining curriculum connections detracts from creating more meaningful and integrative rich learning experiences. While planning is essential, the ultimate goal should be to foster students' development of integrative thinking, equipping them with the resilience and capacity to address global challenges.

Second, curriculum integration scholars and experts should reassess the practical utility of existing frameworks for educators. In Ontario, official curriculum documents typically do not describe interdisciplinary models or integration levels (Lepone, 2016; Slomka, 2019). Similarly, participants in this study did not discuss curriculum integration types or degrees. Updating existing tools and frameworks within this tradition with more emergent learning theories could be beneficial. Additionally, efforts to bridge curriculum integration with interdisciplinary studies should be explored.

Limitations. The findings of this study are specific to Grades 1-6 and reflect the experience of highly seasoned teachers, and should be understood within the participants' unique contexts, limiting their generalizability to other settings. Several avenues for future research are suggested: replicating similar studies with different participant samples, replicating similar studies in middle school (G7-8) and high school (G9-12) contexts, and conducting research in locations outside of Ontario. Additionally, there is potential for further development of

Mansilla's (2017) framework and leveraging curriculum integration tools and frameworks to create more updated and helpful theories, guidelines, and tools for educators.

References

Adams, P. (2006). Exploring social constructivism: Theories and practicalities. *Education 3-13, 34*(3), 243–257. https://doi.org/10.1080/03004270600898893

Alharbi, L., & Cataldo, K. (2024). Book Review: Cultivating genius: An equity framework for culturally and historically responsive literacy by Muhammad G. *Urban Education*, *59*(4), 1284–1289. SAGE Publications. https://doi.org/10.1177/00420859231162897

Antonio, R.P. & Prudente M.S. (2024). Effects of inquiry-based approaches on students' higher-order thinking skills in science: A meta-analysis. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 12*(1), 251-281. https://doi.org/10.46328/ijemst.3216

Applebee, A. N., Adler, M., & Flihan, S. (2007). Interdisciplinary curricula in middle and high school classrooms: Case studies of approaches to curriculum and instruction. *American Educational Research Journal*, *44*(4), 1002–1039. https://doi.org/10.3102/0002831207308219

Barnard, J., Betteney, M., & Lambirth, A. (2022). Beginner teachers and classroom communities: a thematic analysis of UK beginner teachers' experiences in initial teacher education and beyond. *Teaching and Teacher Education*, *119*, 103871-. https://doi.org/10.1016/j.tate.2022.103871

Beane, J. A. (1995). Curriculum integration and the disciplines of knowledge. *Phi Delta Kappan*, 76(8), 616–622.

Beauchamp, A. A., Lacoste, Y., Kingsbury, C., & Gadais, T. (2022). When are you taking us outside? An exploratory study of the integration of the outdoor learning in preschool and

primary education in Quebec. *Frontiers in Psychology, 13*, 955549–955549. https://doi.org/10.3389/fpsyg.2022.955549

Brandt, R. (1991). On interdisciplinary curriculum: A conversation with Heidi Hayes Jacobs. *Integrating the Curriculum*, 24–26.

Braskén, M., & Pörn, R. (2021). Energy as a multidisciplinary concept in K-12 education – a case study. *LUMAT: International Journal on Math, Science and Technology Education*, *9*(1), 77–99. https://doi.org/10.31129/LUMAT.9.1.1402

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf & K. J. Sher (Eds.), *APA handbook of research methods in psychology, Vol 2: Research designs: Quantitative, qualitative, neuropsychological, and biological* (pp. 57-71, 701 Pages). American Psychological Association, American Psychological Association. https://doi.org/10.1037/13620-004

Braun, V., & Clarke, V. (2019a). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Braun, V., & Clarke, V. (2021). Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches. *Counseling and Psychotherapy Research*, *21*(1), 37–47. https://doi.org/10.1002/capr.12360

Braun, V., Clarke, V., & Rance, N. (2015). How to use thematic analysis with interview data. In *The counselling and psychotherapy research handbook* (pp. 183-). SAGE Publications Ltd. https://doi.org/10.4135/9781473909847.n13

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019b). Thematic analysis. In: Liamputtong, P. (eds) *Handbook of research methods in health social sciences* (pp 843–860). Springer, Singapore. https://doi-org.proxy.bib.uottawa.ca/10.1007/978-981-10-5251-4_103

Bresser, R., & Fargason, S. (2013). Navigating the challenges of inquiry science: Responding to teachers' questions. *In becoming scientists* (1st ed., pp. 129–151). Routledge. https://doi.org/10.4324/9781032680620-7

Bronte Creek Project. (2023, October 16). https://www.brontecreekproject.ca/

Carter, S. M., & Little, M. (2007). Justifying knowledge, justifying method, taking action: Epistemologies, methodologies, and methods in qualitative research. *Qualitative Health Research*, *17*(10), 1316–1328. https://doi.org/10.1177/1049732307306927

Cassidy, M., & Puttick, G. (2022). "Because subjects don't exist in a bubble": Middle school teachers enacting an interdisciplinary curriculum. *Journal of Science Education and Technology*, *31*(2), 233–245. https://doi.org/10.1007/s10956-021-09951-y

Clausen, K. W., & Drake, S. M. (2010). Interdisciplinary practices in Ontario: Past, present, and future. *Issues In Integrative Studies*, *28*(1), 69–108. https://files.eric.ed.gov/fulltext/EJ1101101.pdf

Creswell, J. W. (2014). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). PHI Learning Private Limited.

Dack, H. (2020). “I buy it, but how do we pull it off?”: A structured process for teacher candidates’ interdisciplinary curriculum development. *Middle School Journal*, *51*(5), 4–18. https://doi.org/10.1080/00940771.2020.1814623

Davis, B., Sumara, D., & Luce-Kapler, R. (2015). *Engaging minds: Cultures of education and practices of teaching*. Taylor & Francis Group.

deLusé, S. R. (2009). A critical review of Harvard’s Project Zero. *Issue of Integrative Studies*, *27*, 86–112.

Deniz, H., Kaya, E., Yesilyurt, E., Newley, A., & Lin, E. (2019). Integrating engineering, science, reading, and robotics across grades 3-8 in a STEM education era. *Journal of Learning and Teaching in Digital Age*, *6*(1), 40–45. https://dergipark.org.tr/en/pub/joltida

Dewey, J. (2015). *Democracy and education*. (Original work published 1916).

Drake, S. M., & Reid, J. L. (2019). Integrated curriculum for the twenty-first century. In *International handbook of holistic education* (1st ed., pp. 118–128). Routledge. https://doi.org/10.4324/9781315112398-15

Drake, S. M., & Reid, J. L. (2020). 21st century competencies in light of the history of integrated curriculum. *Frontiers in Education (Lausanne)*, *5*. https://doi.org/10.3389/feduc.2020.00122

Erickson, H. L., Lanning, L. A., & French, R. (2017). *Concept-based curriculum and instruction for the thinking classroom*. Corwin.

Gero, A. (2017). Students’ attitudes towards interdisciplinary education: A course on interdisciplinary aspects of science and engineering education. *European Journal of Engineering Education*, *42*(3), 260–270. https://doi.org/10.1080/03043797.2016.1158789

Gillies, R. M., & Nichols, K. (2015). How to support primary teachers' implementation of inquiry: Teachers' reflections on teaching cooperative inquiry-based science. *Research in science education (Australasian Science Education Research Association), 45*(2), 171–191. https://doi.org/10.1007/s11165-014-9418-x

Goovaerts, L., De Cock, M., Struyven, K., & Dehaene, W. (2019). Developing a module to teach thermodynamics in an integrated way to 16-year-old pupils. *European Journal of STEM Education*, *4*(1). https://doi.org/10.20897/ejsteme/3964

Government of Ontario. (2024). *Integrated learning*. https://www.dcp.edu.gov.on.ca/en/program-planning/cross-curricular-and-integrated-learning/integrated-learning

Greenwood, R. (2013). Subject-based and cross-curricular approaches within the revised primary curriculum in Northern Ireland: teachers' concerns and preferred approaches. *Education 3-13*, *41*(4), 443–458. https://doi.org/10.1080/03004279.2013.819618

Gürkan, B. (2018). Examination of secondary school teachers' opinions regarding interdisciplinary teaching. *Pegem Egitim ve Ogretim Dergisi*, *9*(1), 91–124. https://doi.org/10.14527/PEGEGOG.2019.004

Hardman, J., & Borges Corte, V. (2023). The "golden key": A novel approach to teaching/learning biology in a secondary school in Brazil: A cultural historical activity theory approach. *South African Journal of Higher Education, 37*(3), 1–19. https://doi.org/10.20853/37-3-4313

Hardré, P. L., Ling, C., Shehab, R. L., Nanny, M. A., Nollert, M. U., Refai, H., Ramseyer, C., Herron, J., & Wollega, E. D. (2013). Teachers in an interdisciplinary learning

community: Engaging, integrating, and strengthening K-12 education. *Journal of Teacher Education*, *64*(5), 409–425. https://doi.org/10.1177/0022487113496640

Harrison, L. M., Hurd, E., & Brinegar, K. (2020). *Integrative and interdisciplinary curriculum in the middle school - Integrative approaches in teacher preparation and practice*. Routledge.

Hasni, A., Lenoir, Y., & Froelich, A. (2015). Mandated interdisciplinarity in secondary school: The case of science, technology, and mathematics teachers in Quebec. *Issues in Interdisciplinary Studies*, *33*, 144–180. https://files.eric.ed.gov/fulltext/EJ1117890.pdf

Gardner, H., & Mansilla, V. B. (1994). Teaching for understanding – Within and across disciplines. *Educational Leadership, 51*(5), 14-. Association for Supervision and Curriculum Development.

Jacobs, H. H. (1989). Interdisciplinary curriculum options: A case for multiple configurations. *Educational Horizons*, *68*(1), 25–35.

Jacobs, H. H. (1998). The teacher as designer: integrating the curriculum. *International Schools Journal*, *18*(1), 22–33.

Johnson, T. M., Byrd, K. O., & Allison, E. R. (2021). The impact of integrated STEM modeling on elementary preservice teachers' self-efficacy for integrated STEM instruction: A co-teaching approach. *School Science and Mathematics*, *121*(1), 25–35. https://doi.org/10.1111/ssm.12443

King N. (2004). Using templates in the thematic analysis of text. In Cassell C., Symon G. (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 257–270). London, UK: Sage. Crossref.

Klein, J. T. (2017). Typologies of interdisciplinarity: The boundary work of definition. In *The Oxford handbook of interdisciplinarity*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198733522.013.3

Klein, J. T. (2018). "Advancing" interdisciplinary studies: The boundary work of integrating, complexifying, and professionalizing. *Issue of Integrative Studies*, *36*(2), 45–67.

Klein, J., and Newell, W. (1997). Advancing interdisciplinary studies. In J. Gaff and J. Ratcliffe (Eds.), *Handbook of the undergraduate curriculum: A comprehensive guide to purposes, structures, practices, and changes* (pp. 393-415). San Francisco: Jossey-Bass.

Kodkanon, K., Pinit, P., & Murphy, E. (2018). High-school teachers' experiences of interdisciplinary team teaching. In *Issues in Educational Research* (Vol. 28, Issue 4). https://ocul-uo.primo.exlibrisgroup.com/permalink/01OCUL_UO/17kkpb9/cdi_eric_primary_EJ1196087

Kokko, S., Eronen, L., & Sormunen, K. (2015). Crafting maths: Exploring mathematics learning through crafts. *Design and Technology Education: An International Journal*, *20*(2), 22–31. https://files.eric.ed.gov/fulltext/EJ1119545.pdf

Lattuca, L. R. (2002). Learning interdisciplinarity: Sociocultural perspectives on academic work. *The Journal of Higher Education (Columbus), 73*(6), 711–739. https://doi.org/10.1080/00221546.2002.11777178

Le, H. C., Nguyen, V. H., & Nguyen, T. L. (2023). Integrated STEM approaches and associated outcomes of K-12 student learning: A systematic review. *Education Sciences 13*(3), 297. https://doi.org/10.3390/educsci13030297

Le, T., Duong, X., & Hoang, X. (2023). Comparing labor productivity of Vietnam to some Asian countries. *Journal of Asian Research 7*(1). 10.22158/jar.v7n2p1.

Leonard, J. B. (2012). Integrative learning: A grounded theory. *Issues in Integrative Studies, 30*(1), 48-74. https://interdisciplinarystudies.org/wp-content/issues/vol30_2012/05_Vol_31_pp_48_74.pdf

Lenoir, Y., & Hasni, A. (2016). Interdisciplinarity in primary and secondary school: Issues and perspectives. *Creative Education*, *07*(16), 2433–2458. https://doi.org/10.4236/ce.2016.716233

Mansilla, V. B. (2006). Interdisciplinary work at the frontier: An empirical examination of expert interdisciplinary epistemologies. *Issues In Integrative Studies*, *24*, 1–31.

Mansilla, V. B. (2017). Interdisciplinary learning: A cognitive-epistemological foundation. *The Oxford handbook of interdisciplinarity*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198733522.013.22

Mansilla, V. B., & Gardner, H. (1997). Of kinds of disciplines and kinds of understanding. *Phi Delta Kappan*, *78*(5), 381–386.

Mansilla, V. B., & Lenoir, Y. (2010). Interdisciplinarity in United States schools: Past, present, and future. *Issues In Integrative Studies*, *28*(1), 1–27.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 1–16. https://doi.org/10.1186/s40594-018-0151-2

Mård, N. (2021). History in multidisciplinary education: A case study in a Finnish primary school. *Education 3-13*, *49*(5), 513–528. https://doi.org/10.1080/03004279.2020.1737172

McKillop, J. (n.d.). The Bronte Creek Project: Outdoor environmental education in a high school. In *Outdoor environmental education in the contemporary world* (pp. 267–281). Springer International Publishing. https://doi.org/10.1007/978-3-031-29257-6_17

McKim, C. (2023). Meaningful member-checking: A structured approach to member-checking. *American Journal of Qualitative Research, 7*(2), 41-52.

McMurtry, A. (forthcoming). Learning theory and interdisciplinarity: Reframing learning in terms of evolving coherences rather than 'true' representations or correspondences. In (R. Szostak, ed.), *Handbook of interdisciplinary teaching and administration*. Edward Elgar.

McMurtry, A., & McMurtry, R. Y. (2016). More productive ways to think about learning, knowledge, and education. *Medical Education*, *50*(11), 1091–1093. https://doi.org/10.1111/medu.13070

McMurtry, A., Rohse, S., & Kilgour, K. N. (2016). Socio-material perspectives on interprofessional team and collaborative learning. *Medical Education*, *50*(2), 169–180. https://doi.org/10.1111/medu.12833

Merriam, S. B. (2009). *Qualitative research: a guide to design and implementation*. Jossey-Bass.

Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2021). Teachers' role in students' learning at a project-based STEM high school: Implications for teacher education. *International Journal of Science and Mathematics Education*, *19*(6), 1103–1123. https://doi.org/10.1007/s10763-020-10108-3

Moser, K. M., Ivy, J., & Hopper, P. F. (2019). Rethinking content teaching at the middle level: An interdisciplinary approach. *Middle School Journal*, *50*(2), 17–27. https://doi.org/10.1080/00940771.2019.1576579

Newell, W. H. (2001). A theory of interdisciplinary studies. *Issue of Integrative Studies*, *19*, 1–25.

Niemelä, M. (2022). Subject matter-specific curriculum integration: a quantitative study of Finnish student teachers' integrative content knowledge. *Journal of Education for Teaching*, *48*(2), 228–240. https://doi.org/10.1080/02607476.2021.1989288

Niemelä, M. A., & Tirri, K. (2018). Teachers' knowledge of curriculum integration: A current challenge for Finnish subject teachers. *Contemporary Pedagogies in Teacher Education and Development*. InTech. https://doi.org/10.5772/intechopen.75870

Nikitina, S. (2006). Three strategies for interdisciplinary teaching: Contextualizing, conceptualizing, and problem-centring. *Journal of Curriculum Studies, 38*(3), 251–271. https://doi.org/10.1080/00220270500422632

Nikitina, S. & Mansilla, V. B. (2003). Three strategies for interdisciplinary math and science teaching: A case of the Illinois Mathematics and Science Academy. *GoodWork® Project Series Report, 21*.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177/1609406917733847

OECD. (2020). *Curriculum overload: A way forward*. OECD Publishing, Paris, https://doi.org/10.1787/3081ceca-en.

Parker, J., Heywood, D., & Jolley, N. (2012). Developing pre-service primary teachers' perceptions of cross-curricular teaching through reflection on learning. *Teachers and Teaching, Theory and Practice*, *18*(6), 693–716. https://doi.org/10.1080/13540602.2012.746504

Perkins-Gough, D. (2003). Creating a timely curriculum: A conversation with Heidi Hayes Jacobs. *Educational Leadership, 61*(4), 12. Association for Supervision and Curriculum Development.

Repko, A. (2007). Integrating interdisciplinarity: How the theories of common ground and cognitive interdisciplinarity are informing the debate on interdisciplinary integration. *Issues in Integrative Studies, 25*(1), 1-31. https://interdisciplinarystudies.org/wp-content/issues/vol25_2007/03_Vol_25_pp_1_31.pdf

Richards, J., & Shea, K. (2015). Moving from separate subject to interdisciplinary teaching: The complexity of change in a preservice teacher K-1 early field experience. *Qualitative Report*. https://doi.org/10.46743/2160-3715/2006.1681

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International Journal of Technology and Design Education*, *29*(3), 493–512. https://doi.org/10.1007/s10798-018-9440-9

Savage, M. J., & Drake, S. M. (2016). Living transdisciplinary curriculum: Teachers' experiences with the International Baccalaureate's Primary Years Programme. *International Electronic Journal of Elementary Education*, *9*(1), 1–20.

Sevimli, E., & Ünal, E. (2022). Is the STEM approach useful in teaching mathematics? Evaluating the views of mathematics teachers. *European Journal of STEM Education*, *7*(1). https://doi.org/10.20897/ejsteme/11775

Slomka, J. M. (2019). Analyzing the nature of Ministry guidelines for developing interdisciplinary science courses (Grades 11–12) in Ontario (Canada). *Canadian Journal*

of Science, Mathematics and Technology Education, *19*(4), 367–386. https://doi.org/10.1007/s42330-019-00062-w

Spintzyk, K., Strehlke, F., Ohlberger, S., Gröben, B., & Wegner, C. (2016). An empirical study investigating interdisciplinary teaching of biology and physical education. *Science Educator*, *25*(1), 35–42.

van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2017). Inquiry-based science education: Scaffolding pupils' self-directed learning in open inquiry. *International Journal of Science Education*, *39*(18), 2461–2481. https://doi.org/10.1080/09500693.2017.1388940

Vidic, A. (2023). Comparison of interdisciplinary connections between Mathematics and other subjects through student-centered approaches. *REDIMAT, 12*(1), 29–55. https://doi.org/10.17583/redimat.10178

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Massachusetts: Harvard University Press.

Walan, S., Mc Ewen, B., & Gericke, N. (2016). Enhancing primary science: An exploration of teachers' own ideas of solutions to challenges in inquiry- and context-based teaching. *Education 3-13*, *44*(1), 81–92. https://doi.org/10.1080/03004279.2015.1092456

Weinberg, A. E., & Sample McMeeking, L. B. (2017). Toward meaningful interdisciplinary education: High school teachers' views of mathematics and science integration. *School Science and Mathematics*, *117*(5), 204–213. https://doi.org/10.1111/ssm.12224

Wertsch, J. V. (2008). From social interaction to higher psychological processes: A clarification and application of Vygotsky's theory. *Human Development, 51*(1), 66–79. https://doi.org/10.1159/000112532

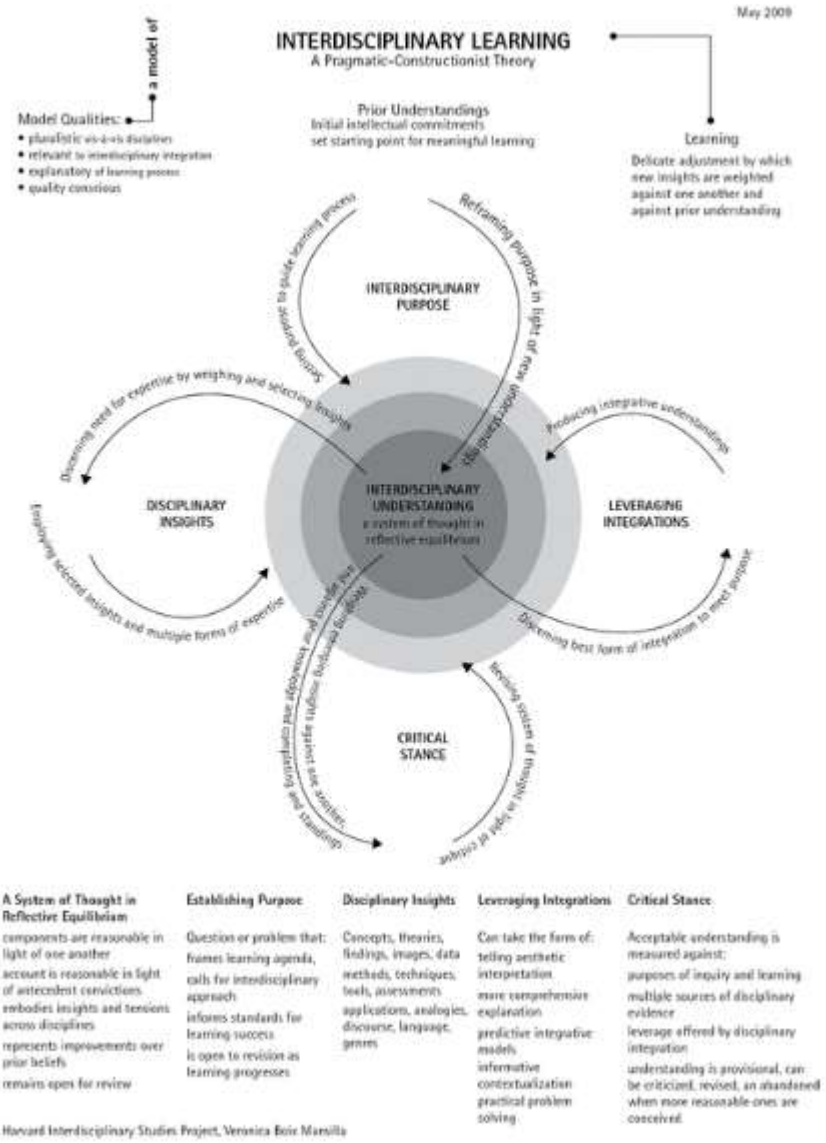
Wiggins, G. P., & McTighe, J. (2005). *Understanding by design* (Expanded 2nd ed.). Association for Supervision and Curriculum Development.

Yeşilkaya, Ö., Çongur, E., Yeşilkaya, Ö. Ç., Jelen, B., & Eskioğlu, I. (2021). Music and mathematics: The effect of matching musical meters with geometric shapes on 6th Graders' learning outcomes. *The Asian Institute of Research Education Quarterly Reviews*, *4*, 264–279. https://doi.org/10.31014/aior.1993.04.02.245

Županec, V., Lazarević, T., Sekulić, V., & Pribićević, T. (2023). The effectiveness of an interdisciplinary approach in biology teaching in primary school: A comparison with monodisciplinary approach. *International Journal of Educational Methodology*, *9*(1), 169–182. https://doi.org/10.12973/ijem.9.1.169

Appendix A

Mansilla's (2017) Interdisciplinary Learning Framework



A System of Thought in Reflective Equilibrium	Establishing Purpose	Disciplinary Insights	Leveraging Integrations	Critical Stance
components are reasonable in light of one another	Question or problem that:	Concepts, theories, findings, images, data	Can take the form of:	Acceptable understanding is measured against:
account is reasonable in light of antecedent convictions	frames learning agenda,	methods, techniques, tools, assessments	telling aesthetic interpretation	purposes of inquiry and learning
embodies insights and tensions across disciplines	calls for interdisciplinary approach	applications, analogies, discourse, language, genres	more comprehensive explanation	multiple sources of disciplinary evidence
represents improvements over prior beliefs	informs standards for learning success		predictive integrative models	leverage offered by disciplinary integration
remains open for review	is open to revision as learning progresses		informative contextualization	understanding is provisional, can be criticized, revised, an abandoned when more reasonable ones are conceived
			practical problem solving	

Harvard Interdisciplinary Studies Project, Veronica Boix Mansilla

Appendix B

Drake & Reid's (2019) Process and Tools for Curriculum Integration

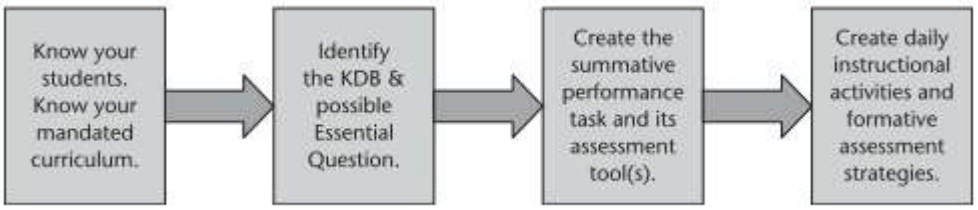


Figure B1. Designing a Holistic Integrated Curriculum

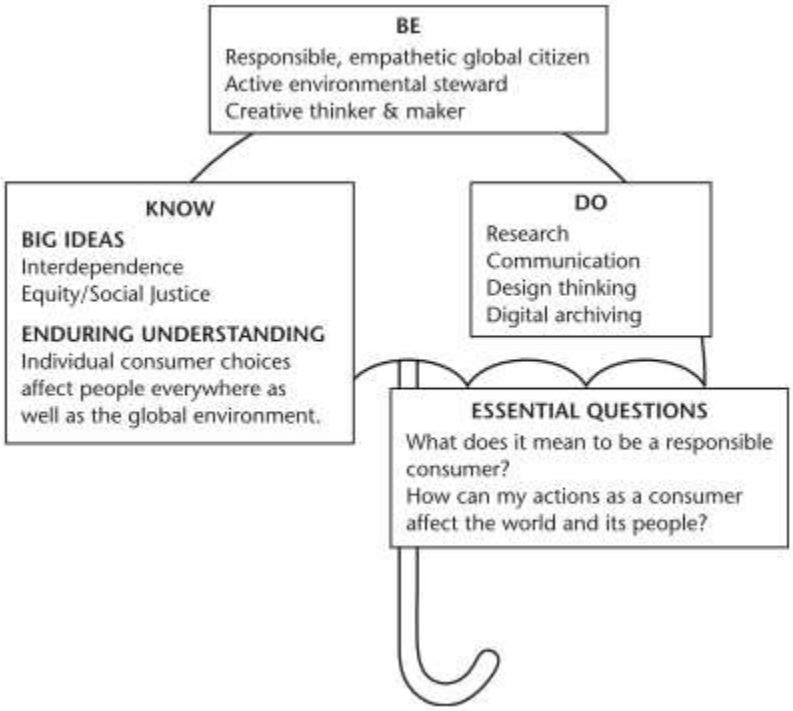


Figure B2. The Know-Do-Be (KDB) Umbrella for a Unit